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The Impact of Ice Compression and Massage Techniques on Lactate Removal and Interleukin-6 Concentrations During Halftime Recovery in Intermittent Sports

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Abstract

Background. High-intensity intermittent sports increase blood lactate levels and inflammatory markers such as interleukin-6 (IL-6), which may hinder recovery and performance. Effective recovery strategies are crucial for enhancing lactate clearance and regulating inflammation.

Objectives. This study aimed to evaluate the effects of 15-minute ice compression and sport massage interventions during halftime on athletes' lactate clearance and IL-6 levels.

Materials and Methods. Thirty-six male soccer players, aged 18 to 24 years, were randomly assigned to one of three groups for this experimental study: ice compression (IC, n = 12), sport massage (SM, n = 12), and passive recovery (PR, n = 12). Each participant completed a standardized exercise regimen designed to induce fatigue. The PR group rested passively after the workout, while the intervention groups received a massage or ice compression for 15 minutes. Blood lactate and IL-6 levels were assessed before exercise (T0), immediately after (T1), and fifteen minutes post-exercise (T2). To analyse the differences observed, a mixed-model ANOVA and post-hoc tests (Bonferroni/Games-Howell) were performed.

Results. According to the results obtained, the lactate levels (IC: $\Delta T1-T2 = -2.34 \pm 0.96$ mmol/L, $d = 2.209$; SM: $\Delta T1-T2 = -1.39 \pm 0.79$ mmol/L, $d = 0.829$) and IL-6 levels (IC: $\Delta T1-T2 = -1.44 \pm 0.93$ pg/mL, $d = 1.206$; SM: $\Delta T1-T2 = -1.58 \pm 0.63$ pg/mL, $d = 1.645$) were both significantly lower than PR ($p < 0.05$). Although IC and SM exhibited similar anti-inflammatory effects ($p = 0.898$), IC demonstrated superior lactate clearance compared to SM ($p = 0.023$, $d = -1.081$). PR showed only minimal decreases in both biomarkers.

Conclusions. Massage and ice compression effectively enhance lactate clearance after high-intensity exercise, with massage offering additional benefits in reducing IL-6-mediated inflammation. These findings support massage as an excellent recovery method for athletes requiring immediate physiological repair following exertion.

Keywords: ice compression, sport massage, lactate clearance, interleukin-6, inflammatory response.

Introduction

In fast-paced sports like soccer, basketball, or futsal, the increase in lactic acid and elevated levels of inflammatory substances, particularly Interleukin-6 (IL-6), during the first half can hinder athletes' performance in the second half due to fatigue (Marqués-Jiménez et al., 2017; Reilly et al., 2008). Fatigue encompasses perceptual-motor, cognitive, and physiological aspects and represents a physiological breakdown that leads to exhaustion. The primary causes of this condition include the depletion of energy stores, thermal strain, and muscle failure, which occur due to prolonged overload during intense physical activity. The nervous system is crucial in maintaining muscle function by regulating metabolic activity to prevent catastrophic system failure (Reilly et al., 2008).

The buildup of inflammatory markers, such as IL-6, and metabolic byproducts like lactate can weaken neuromuscular function and endurance (Chen et al., 2025; Wan et al., 2017). Although lactate is produced to assist in removing H^+ ions, which can lower pH and hinder muscle contraction, it does not directly cause muscle fatigue (Vavříčka et al., 2024). According to the lactic acid hypothesis, the accumulation of lactate or acid in working muscles slows muscle contractions and impairs exercise performance. This concept is analogous to how products of chemical reactions can inhibit enzymes. Furthermore, studies on heart muscle demonstrate that during periods of diminished blood flow, lactate and H^+ can lead to weaker heart contractions and irregular heartbeats (Cairns, 2006). Meanwhile, skeletal muscle cells produce the pro-inflammatory cytokine interleukin-6 (IL-6), which is released during prolonged or intense muscle contractions (Lin et al., 2023). It can increase significantly during heavy or prolonged exercise due to physiological muscle stress, microstructural damage, and depleted energy stores, particularly muscle glycogen. IL-6 regulates energy metabolism by enhancing the mobilization of glucose and fatty acids, which indicates metabolic stress (Covarrubias & Horng, 2014). Additionally, it indicates local and systemic inflammatory processes that occur with muscle fatigue, especially following heavy exercise or competition. Research has shown that IL-6 levels rise significantly after completing a marathon, correlating with symptoms of fatigue and diminished physical performance (Nash et al., 2023). Therefore, IL-6 can serve as a biological indicator of muscle fatigue.

On this basis, recovery strategies during match intervals become crucial (Fajar et al., 2025; Romagnoli et al., 2016). Efficient recovery strategies during short match intervals (e.g., halftime) are critical for maintaining athletic performance. Ice compression and massage are two popular methods to accelerate recovery (Fajar et al., 2025; Kafrawi et al., 2024). Ice compression, a cold therapy method, has decreased tissue temperature and inflammation and promoted metabolic waste clearance, facilitating vasoconstriction (White & Wells, 2013; Yao et al., 2024). Cold application reduces blood vessel narrowing, blood flow, and cellular metabolic activity, slowing lactic acid production due to post-exercise tissue damage. It also inhibits the release of pro-inflammatory cytokines like IL-6, modulating the inflammatory response (Peake et al., 2016). This suppression occurs through cryotherapy's anti-inflammatory effects, which reduce capillary permeability and neutrophil activity,

triggering IL-6 release during post-exercise oxidative stress (Peake et al., 2015). This reduces systemic inflammation, facilitating metabolic recovery and buffering of lactic acid by non-muscle organs (Mila-Kierzenkowska et al., 2013).

Likewise, massage treatment neutralises lactic acids and IL-6. Massage is widely employed in sports recovery; it enhances circulation and may modulate inflammatory responses (Crane et al., 2012). Massage techniques like effleurage and petrissage increase blood and lymph flow, promoting the redistribution of lactic acid from muscles to the liver (Ogai et al., 2008). Rhythmic pressure movements stimulate lactate dehydrogenase, reducing local accumulation (Wiltshire et al., 2010a). Massage reduces post-exercise micro-muscle damage, suppressing IL-6 release from muscle and immune cells. Applying pressure helps activate the parasympathetic pathway, which lowers oxidative stress and pro-inflammatory cytokines, leading to a healing environment for recovery after exercise (Waters-Banker et al., 2014; Wiltshire et al., 2010b).

This research aims to address the issue of fatigue in high-intensity intermittent sports like futsal, soccer, and basketball. The accumulation of lactic acid and pro-inflammatory cytokines, such as IL-6, during the first half of a match can reduce athlete performance in the second half. This fatigue affects cognitive and neuromuscular aspects and is caused by metabolic products like lactate and IL-6. The study also focuses on the effectiveness of recovery strategies during match breaks, such as halftime. Interventions like ice and massage have been widely used in post-exercise recovery, but their benefits in intra-competitive contexts are still under-researched. The findings of this study are expected to contribute to improving endurance, optimising performance, and reducing injury risk among athletes involved in high-intensity sports.

Materials and Methods

This research used a randomised, controlled, parallel-group design to evaluate the impacts of ice compression and massage therapies during halftime on lactate clearance and interleukin-6 (IL-6) concentrations in athletes participating in high-intensity intermittent sports. Participants were categorised by football and randomly allocated to one of three groups: (1) ice compression (IC), (2) sports massage (SM), or (3) passive recovery (control/PR). Outcomes were assessed at three intervals: pre-intermittent exercise (T0), immediately post-intermittent exercise (T1), and post-intervention (T2). The study procedure complied with CONSORT's recommendations for randomised trials (Sut et al., 2022).

Study Participants

We recruited 36 male soccer athletes (ages 18–24) from UNESA FC. Inclusion criteria required ≥ 4 years of competitive experience, regular training (≥ 4 sessions/week), and no injuries or anti-inflammatory drug use in the preceding month. Exclusion criteria included cardiovascular or metabolic disorders. Sample size was determined via G*Power (v3.1.9.7) with an effect size of 0.4, $\alpha = 0.05$, and power = 0.8, yielding 12 participants per group.

The Institutional Review Board at Semarang State University (068/KEPK/FK/KLE/2024) approved the study

and ensured adherence to the Declaration of Helsinki. Participants received clear instructions and signed an informed consent form. Health insurance was provided throughout the research process. Participants were free to withdraw without penalty and kept their data secure for research purposes.

Study Organization

As mentioned earlier, this study involved three groups: Ice Compression (IC), Sport massage (SM), and Passive recovery as a control group (PR). The night before the pretest, the participants were asked to fast but were allowed to drink water as needed. Participants were asked to undergo a health check at the Surabaya State University soccer field at 06:00 am. After the health check, we gave each group a pretest by collecting data on lactic acid and IL-6 levels. After the pretest, they did intermittent physiological exercise similar to playing soccer. For more details, intermittent exercise will be explained in Table 1.

We developed the intermittent training in this study to replicate the physiological demands typically encountered in soccer. The exercise involved repeated cycles of sprinting, jogging, and walking at prescribed intensities, determined by the percentage of each participant's maximum heart rate (HR max). Each cycle, as shown in Table 1, lasted 4 minutes and comprised 15 seconds of sprinting at 90–95% HR max, 30 seconds jogging at 60–70% HR max, and 15 seconds of walking at 30–40% HR max. Seven cycles were completed, resulting in an aggregate exercise duration of 42 minutes. Organized intervals facilitated the preservation of a work-to-rest ratio of 2:1, hence promoting physiological stress akin to that observed in actual match conditions.

Participants made the simulation more realistic by making three 180° turns during sprinting every two cycles, mimicking the usual speed changes and turns found in competitive situations. The participants' heart rate was monitored using the H10 Polar to ensure the intensity remained on target. We allowed participants to drink water

(3–5 mL/kg BW) every two intervals to prevent dehydration (Li et al., 2024) participants crossed over to the second arm for: NOR+PHS, NOR+CON, HYP+PHS, or HYP+CON. The PHS was prescribed according to the participants' fluid and sweat sodium losses. CON drank ad libitum of commercially-available electrolyte solution. Exercise trials consisted of two phases: (1. This exercise model was designed to induce significant lactate buildup and elevate IL-6 levels, creating a realistic scenario to evaluate the effectiveness of halftime recovery methods.

Immediately after the intermittent exercise, posttest 1 (T1) was conducted by re-measuring lactic acid and IL-6 levels. After the test, participants were immediately given treatment according to their respective groups (IC, SM, and PR). Table 2 explains the details of the intervention.

Participants were given three recovery interventions after completing an intermittent exercise protocol and post-exercise measurements. The interventions were passive recovery (PR), sports massage (SM), and ice compression (IC). Cold gel ice packs were applied to the IC group's quadriceps, hamstrings, and calves because earlier studies indicated they effectively reduce blood flow, lower metabolic activity, and alter inflammation following exercise. To enhance blood and lymphatic circulation, alleviate muscle stiffness, and facilitate the removal of metabolic wastes such as lactate, the SM group underwent a sports massage employing established techniques. For a continuous fifteen minutes, the PR group received no assistance and remained in a comfortable position. The interventions were executed in a standardized, controlled environment to guarantee consistency and comparability. A further post-exercise assessment was performed to evaluate the immediate impact of each intervention on lactate concentration and IL-6 levels (T2).

Measurement

The outcome measure of this research was lactic acid and IL-6 levels. Lactic acid and IL-6 levels were measured

Table 1. Intermittent exercise program

Activity	Intensity (HR max)	Duration	Interval per cycle	Total cycle	Total Duration
Sprint (15 seconds)	90-95%	4 minutes in 1 activity cycle	2 minutes (work rest ratio 2:1)	7 cycle	42 minutes
Jogging (30 seconds)	60-70%				
Walking (15 seconds)	30-40%				

Note: During the sprint, participants perform three 180° direction changes every two cycles (similar to intermittent exercise).

Table 2. Program interventions in each group (IC, SM, PR group)

Treatment	Procedure
Ice compression (IC group)	Participants received 15-minute localized ice compression using gel packs at 12–15°C (Lateef, 2010) on the major muscle groups of the lower limbs (quadriceps, hamstrings, and calves), facilitated by adjustable compression wraps.
Sports Massage (SM group)	Sports massage is conducted by a certified therapist, concentrating on the primary lower-limb muscle groups (quadriceps, hamstrings, and calves). The massage techniques employed include effleurage, petrissage, shaking, tapotement, and walking, all applying moderate pressure (2–3 kgf/cm ²). We perform each technique six times, using effleurage for both the opening and closing phases, resulting in a total duration of 15 minutes.
Passive recovery (PR group)	Participants rested by sitting passively for 15 minutes.

at three intervals: pre-exercise (T0), immediately post-intermittent exercise (T1), and post-intervention (T2). We assessed lactic acid levels using the Roche Cobas Accutrend Plus GCTL Meter for blood lactate testing. We obtained lactic acid measurements by drawing blood from the participant's fingertip and applying it to the device. To quantify IL-6 levels, we performed an ELISA test using a specific kit (Human IL-6 Immunoassay Quantikine ELISA Kit, catalog No. D6050). We analyzed the data with an ELISA Reader (iMark Microplate Absorbance Reader). The study's ELISA test necessitated the collection of blood samples from participants using a sterile 3 ml syringe, which were subsequently placed into a specialized 5 ml tube (Veroject Plain). We centrifuged the blood sample at 3000 rpm for 15 minutes to isolate the serum from the cellular debris.

Preserve the resultant serum at -20°C if immediate analysis is not conducted.

Statistical Analysis

The research data were analyzed using Microsoft Office Excel 2016 and SPSS Series 23. We conducted descriptive tests by displaying each group's mean $\pm$ SD of the variables. We also checked if the data followed a normal distribution using Shapiro-Wilk tests. A mixed-model ANOVA was conducted to compare differences between groups and time points, followed by Bonferroni post-hoc tests. Effect sizes, Cohen's d for ANOVA and Cohen's d for pairwise comparisons, and 95% confidence intervals, were reported. Significance was set at $p < 0.05$.

Table 3. The effect of ice compression, sport massage, and passive recovery intervention on variables

Group	Variable	Mean ± SD	Min	Max	Shapiro-Wilk test	Paired t-test	ES Cohen's d	
IC	IL-6	T0	4.14 ± 0.85	2.69	5.59	0.993		
		T1	7.04 ± 1.28	4.35	8.73	0.322		
		T2	5.60 ± 1.10	3.54	7.88	0.842		
		ΔT0-T1	2.90 ± 1.00	1.41	4.14	0.195	0.00*	2.669
		ΔT0-T2	1.46 ± 0.84	0.44	3.60	0.069	0.00*	1.485
		ΔT1-T2	-1.44 ± 0.93	-3.16	-0.44	0.199	0.00*	1.206
	Lactic acid	T0	5.09 ± 0.87	3.4	6.3	0.237		
		T1	12.29 ± 1.45	10.3	13.9	0.730		
		T2	9.59 ± 0.94	8.5	11.7	0.716		
		ΔT0-T1	6.84 ± 1.70	4.5	9.2	0.237	0.00*	6.021
		ΔT0-T2	4.50 ± 1.49	3.0	7.2	0.073	0.00*	4.961
		ΔT1-T2	-2.34 ± 0.96	-4.5	-0.8	0.716	0.00*	2.209
SM	IL-6	T0	3.93 ± 1.02	2.25	5.79	0.863		
		T1	6.98 ± 0.98	4.62	8.03	0.081		
		T2	5.40 ± 0.94	3.92	6.73	0.653		
		ΔT0-T1	3.05 ± 0.67	2.24	4.35	0.335	0.00*	3.049
		ΔT0-T2	1.47 ± 0.80	0.38	3.64	0.068	0.00*	1.498
		ΔT1-T2	-1.58 ± 0.63	-2.41	-0.39	0.161	0.00*	1.645
	Lactic acid	T0	4.74 ± 0.72	3.6	5.9	0.962		
		T1	11.82 ± 1.86	8.0	15.6	0.999		
		T2	10.40 ± 1.55	7.8	13.3	0.452		
		ΔT0-T1	7.08 ± 2.01	2.9	10.0	0.962	0.00*	5.020
		ΔT0-T2	5.68 ± 1.72	2.7	8.9	0.999	0.00*	4.683
		ΔT1-T2	-1.39 ± 0.79	-2.7	-0.23	0.452	0.00*	0.829
PR	IL-6	T0	4.04 ± 0.99	2.78	5.79	0.193		
		T1	7.15 ± 0.75	5.38	8.12	0.186		
		T2	7.00 ± 0.70	5.4	8.03	0.553		
		ΔT0-T1	3.11 ± 0.58	2.05	4.15	0.990	0.00*	3.541
		ΔT0-T2	2.96 ± 0.69	1.8	3.86	0.357	0.00*	3.452
		ΔT1-T2	-0.15 ± 0.28	-0.65	0.22	0.271	0.08	0.206
	Lactic acid	T0	4.33 ± 1.16	2.8	6.4	0.230		
		T1	11.45 ± 1.40	9.7	14.3	0.066		
		T2	11.36 ± 1.74	8.3	14.8	0.268		
		ΔT0-T1	7.12 ± 0.85	5.7	8.1	0.230	0.00*	5.538
		ΔT0-T2	7.03 ± 1.26	4.2	8.4	0.066	0.00*	4.754
		ΔT1-T2	-0.09 ± 0.66	-1.5	0.7	0.268	0.64	0.056

Δ represents the difference; T0 refers to pre-intermittent exercise; T1 indicates immediately post-intermittent exercise; T2 denotes post-intervention (T2). The Shapiro-Wilk test shows a normal distribution with $p > 0.05$; * indicates a significant difference with $p < 0.05$; ES stands for effect size.

Results

This section examines the efficacy of ice compression and sports massage interventions lasting 15 minutes after intermittent exercise to neutralize lactic acid and interleukin-6 (IL-6). This study involved 36 soccer players from UNESA FC, with the following means and standard deviations of their physical attributes: age 20.72 ± 1.49 years, body weight 66.47 ± 2.68 kg, body height 173.31 ± 2.59 cm, training experience 10.83 ± 1.48 years, and competitive experience 5.08 ± 0.73 years. Table 2 presents the outcomes of the descriptive statistics.

The study examined the effects of three different halftime recovery interventions: ice compression (IC), sports massage (SM), and passive recovery (PR) on serum interleukin-6 (IL-6) and blood lactate levels. Table 3 shows that both IL-6 and lactate levels went up a lot after exercise, which means that exercise successfully causes metabolic and inflammatory stress. In the IC group, IL-6 levels rose from 4.14 ± 0.85 pg/mL (T0) to 7.04 ± 1.28 pg/mL (T1), followed by a significant reduction to 5.60 ± 1.10 pg/mL at T2. Similarly, lactate levels increased from 5.09 ± 0.87 mmol/L (T0) to 12.29 ± 1.45 mmol/L (T1), before decreasing significantly to 9.59 ± 0.94 mmol/L post-intervention (T2). These findings suggest ice compression may facilitate both inflammatory and metabolic recovery during halftime. The SM group also demonstrated a significant post-exercise elevation in IL-6 and lactate, with post-intervention measurements showing significant reductions in both IL-6 and lactate. However, the PR group exhibited only marginal decreases in IL-6 and lactate. Overall, both active recovery methods were better than passive recovery at reducing the increases in IL-6 and lactate levels caused by exercise.

Next, a mixed-model ANOVA test was done to see how three different treatments (ice compression, sports massage, and passive recovery) affected lactic acid and IL-6 levels. The results indicated that both variables had a p-value (significance) of 0.000, indicating a significant difference. We also performed a difference test to determine which groups differed. To determine which difference test to employ, we examine the results of the Test of Homogeneity of Variances. If the test results indicate equal variances, the subsequent test used is the Bonferroni test. Conversely, if the test results show unequal variances, the next test applied is the Games-Howell test.

Table 4. Pairwise Comparisons of Intervention Effects on lactic acid and IL-6 levels

Variable	Group	p (sig.)	ES Cohen's d
IL-6	IC	SM	0.898
	IC	PR	0.001*
	SM	PR	0.000*
Lactic acid	IC	SM	0.023*
	IC	PR	0.000*
	SM	PR	0.001*

*Significant difference at $p < 0.05$; IL-6 was analysed using the Games-Howell test; lactic acid was analysed using the Bonferroni test; ES refers to Effect Size

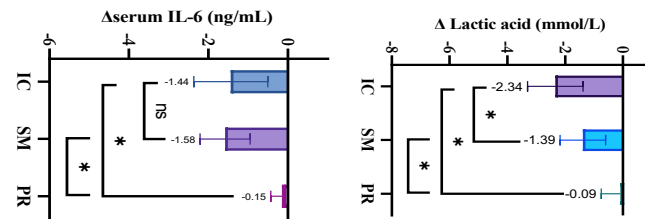


Fig. 1. The changes in serum IL-6 and lactic acid levels were compared among the IC, SM, and PR groups; *significant difference was found at $p < 0.05$, ns indicates no significant difference; Δ is changed after intervention

The results of post-intervention comparisons between groups on lactic acid and IL-6 levels are shown in Table 4. The Bonferroni test was used for lactic acid because the homogeneity assumption was met, and the Games-Howell test was used for IL-6 because of the inhomogeneity of variance. The ice compression (IC) and sports massage (SM) groups did not significantly differ in their IL-6 levels ($p = 0.898$; $d = -0.057$), suggesting that they were equally effective at lowering inflammatory responses following exercise. When comparing the active recovery and passive recovery groups, there were significant differences in lactic acid and IL-6 levels, with ice compression and sports massage showing better results than passive recovery. It's interesting to note that while both significantly accelerated lactate clearance, sports massage was less successful than ice compression ($p = 0.023$, $d = -1.081$). These findings demonstrate that active intervention significantly outperforms passive recovery in lowering fatigue biomarkers during a brief rest interval (halftime), with ice compression providing the benefit of speeding up metabolic recovery.

Discussion

The study investigated the effects of 15-minute ice compression and sports massage on lactate clearance and IL-6 levels in male soccer athletes. The results indicated that both active recovery strategies significantly reduced post-exercise lactate and IL-6 levels, with ice compression demonstrating greater efficacy in accelerating lactate clearance. These findings underscore the differences in their mechanisms and outcomes.

Both IC and SM demonstrated significant reductions in IL-6 levels from T1 to T2 ($p < 0.05$), with effect sizes of $d = 1.206$ and $d = 1.645$, respectively, indicating substantial anti-inflammatory benefits. Interestingly, IC and SM did not significantly differ in their ability to lower IL-6 ($p = 0.898$; $d = -0.057$), suggesting that they are equally effective at regulating the acute inflammatory response. These findings corroborate previous research showing that cryotherapy dampens inflammatory signals by reducing neutrophil activation and capillary leakage, which in turn suppresses IL-6 release (Peake et al., 2015). The downregulation of nuclear factor kappa B (NF- κ B), a transcription factor that regulates pro-inflammatory cytokines under oxidative stress, may be partly responsible for the decrease in IL-6 (VanderVeen et al., 2019). Peake et al., (2017) reported that cryotherapy had anti-inflammatory effects, which they attributed to decreased capillary permeability and

suppressed neutrophil activity. This assertion is supported by the observed decrease in IL-6 levels after IC. The significant decrease in IL-6 ($\Delta T1-T2 = -1.44 \pm 0.93$ pg/mL) in the IC group is corroborated by He et al., (2025), who found that cold therapy reduces overall inflammation by diminishing oxidative stress. The parasympathetic nervous system, which regulates inflammatory responses, is activated by massage, likely explaining why the SM group showed a smaller yet still significant decrease in IL-6 ($\Delta T1-T2 = -1.58 \pm 0.63$ pg/mL) (Waters-Banker et al., 2014).

Similar to this, massage reduces oxidative stress and muscle microtrauma by mechanically stimulating the muscles and activating the parasympathetic nervous system (Crane et al., 2012; Waters-Banker et al., 2014). Together, these physiological mechanisms lessen the release of IL-6 from immune and muscle cells. Conversely, the PR group did not exhibit a statistically significant decrease in IL-6 from T1 to T2 ($\Delta = -0.15 \pm 0.28$ pg/mL; $p = 0.08$), confirming earlier findings that passive recovery is insufficiently stimulating to promote inflammatory resolution after intense exercise (Romagnoli et al., 2016).

The IC group showed a greater post-intervention decrease in lactate clearance ($\Delta T1-T2 = -2.34 \pm 0.96$ mmol/L; $p < 0.05$; $d = 2.209$) compared to SM ($\Delta T1-T2 = -1.39 \pm 0.79$ mmol/L) indicating an effective clearance of lactate within a 15-minute halftime intervention. This finding aligns with White & Wells, (2013), who noted that cold application induces vasoconstriction, subsequently reducing metabolic activity and lactic acid production. Conversely, Ogai et al., (2008) propose that enhanced circulation and lactate redistribution through lymphatic drainage may account for SM's moderate effectiveness. Cold therapy can enhance lactate clearance by inducing vasoconstriction, followed by reactive vasodilation. This process improves blood flow and facilitates the removal of metabolic waste during recovery (Khoshnevis et al., 2014). Additionally, cold therapy can reduce muscle activity, helping to conserve energy in the muscles and slowing the lactate production process (Hylldahl & Peake, 2020).

However, to a lesser degree, massage also significantly decreased lactate levels ($\Delta = -1.39 \pm 0.79$ mmol/L; $p < 0.05$; $d = 0.829$). It has been shown that massage helps improve blood flow in small blood vessels and boosts lymphatic flow, which helps move lactate from muscles to the liver, making it easier to remove. While the role of massage in enhancing metabolic recovery is confirmed by this evidence, its mechanisms may require a longer time to reveal their full benefits compared to the more immediate physiological effects of cold application. However, conflicting results exist, Crane et al., (2012) reported no significant decrease in lactate following massage, which may be attributed to variations in the duration or pressure levels of the massage. The discrepancy in results could stem from the study employing a 15-minute moderate-pressure ($2-3$ kgf/cm²) technique, underscoring the necessity for clear treatment guidelines.

Its two main effects, (1) vasoconstriction, which slows down local metabolism and lactate production, and (2) anti-inflammatory modulation, which lowers IL-6 release by reducing oxidative stress, might explain why IC is more effective for recovery. On the other hand, SM mainly helps remove lactate from the body by increasing blood and lymph flow and reducing muscle stiffness, which helps get rid of waste and provide nutrients. On the other hand, SM mainly helps clear lactate from the body by boosting blood and lymph

flow and reducing muscle stiffness, which aids in removing waste and delivering nutrients. On the other hand, SM mainly improves the mechanical clearance of lactate by increasing blood and lymph flow and reducing muscle stiffness, which improves waste removal and nutrient delivery (Weerapong et al., 2005). Under time-constrained recovery periods, such as halftime, mechanical clearance alone may be less effective than metabolic suppression, as indicated by the smaller effect size of SM on lactate (Cohen's $d = -1.081$ vs IC's $d = -2.731$).

Although this study backs up the effectiveness of IC and SM, other research shows contradictory results. For example, despite shorter intervention durations (10 minutes), Romagnoli et al., (2016) found no significant difference in IL-6 levels between basketball players' active and passive recovery. Furthermore, the fact that only male athletes ($n = 36$) were included restricts its generalisability to female populations, which might have different inflammatory reactions (Aragón-Vela et al., 2021). Despite being statistically powered, the small sample size means that results should not be extrapolated to larger athletic cohorts.

Given its quick metabolic and anti-inflammatory effects, these results support the inclusion of IC in high-intensity intermittent sports halftime recovery regimens. SM is still a useful substitute, especially in situations where cryotherapy is not an option. Future studies should look at: (1) gender-specific responses; (2) combined interventions (e.g., IC followed by SM) to maximise their effects; and (3) long-term results on performance sustainability and injury prevention.

Conclusions

Ice compression and sports massage are more effective than passive recovery in reducing lactate and IL-6 levels after high-intensity intermittent exercise. Ice compression accelerates lactate clearance and diminishes inflammatory responses. These findings indicate that incorporating active recovery strategies during short rest periods, such as halftime in a match, can significantly enhance athlete performance. The study recommends that coaches and sports practitioners integrate these methods into their match rest routines to mitigate muscle fatigue, expedite metabolic recovery, and lower the risk of fatigue-related injuries. Future studies should assess the long-term impact of these methods on performance, investigate their effects on female athletes and various age groups, and explore additional therapies with synergistic effects.

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Conflict of Interest

All researchers declare that there is no conflict of interest in this research

References

- Marqués-Jiménez, D., Calleja-González, J., Arratibel, I., Delextrat, A., & Terrados, N. (2017). Fatigue and

- Recovery in Soccer: Evidence and Challenges. *The Open Sports Sciences Journal*, 10(1), 52-70.
<https://doi.org/10.2174/1875399X01710010052>
- Reilly, T., Drust, B., & Clarke, N. (2008). Muscle fatigue during football match-play. *Sports Medicine*, 38(5), 357-367.
<https://doi.org/10.2165/00007256-200838050-00001>
- Chen, G., Liu, J., Guo, Y., & Sun, P. (2025). Mechanisms for Regulatory Effects of Exercise on Metabolic Diseases from the Lactate-Lactylation Perspective. *International Journal of Molecular Sciences*, 26(8), 3469.
<https://doi.org/10.3390/IJMS26083469>
- Wan, J. J., Qin, Z., Wang, P. Y., Sun, Y., & Liu, X. (2017). Muscle fatigue: general understanding and treatment. *Experimental & Molecular Medicine*, 49(10), e384.
<https://doi.org/10.1038/EMM.2017.194>
- Vavříčka, J., Brož, P., Follprecht, D., Novák, J., & Kroužeký, A. (2024). Modern Perspective of Lactate Metabolism. *Physiological Research*, 73(4), 499-514.
<https://doi.org/10.33549/physiolres.935331>
- Cairns, S. P. (2006). Lactic acid and exercise performance: Culprit or friend? *Sports Medicine*, 36(4), 279-291.
<https://doi.org/10.2165/00007256-200636040-00001>
- Lin, W., Song, H., Shen, J., Wang, J., Yang, Y., Yang, Y., Cao, J., Xue, L., Zhao, F., Xiao, T., & Lin, R. (2023). Functional role of skeletal muscle-derived interleukin-6 and its effects on lipid metabolism. *Frontiers in Physiology*, 14, 1110926. <https://doi.org/10.3389/FPHYS.2023.1110926>
- Covarrubias, A. J., & Horng, T. (2014). IL-6 strikes a balance in metabolic inflammation. *Cell Metabolism*, 19(6), 898.
<https://doi.org/10.1016/J.CMET.2014.05.009>
- Nash, D., Hughes, M. G., Butcher, L., Aicheler, R., Smith, P., Cullen, T., & Webb, R. (2023). IL-6 signaling in acute exercise and chronic training: Potential consequences for health and athletic performance. *Scandinavian Journal of Medicine and Science in Sports*, 33(1), 4-19.
<https://doi.org/10.1111/sms.14241>
- Fajar, M. K., Hariyanto, A., Wahjuni, E. S., Kartiko, D. C., Siantoro, G., Phanpheng, Y., Kusuma, I. D. M. A. W., Pramono, B. A., Rusdiawan, A., & Pranoto, A. (2025). Determining the Efficacy of Providing Ice Compression for Fitness Enhancement After Speed Endurance Exercise on Reducing Heart Rate, IL-6, and Fatigue Index in Football Athletes. *Physical Education Theory and Methodology*, 25(1), 58-65.
<https://doi.org/10.17309/tmfv.2025.1.07>
- Romagnoli, M., Sanchis-Gomar, F., Alis, R., Risso-Ballester, J., Bosio, A., Graziani, R. L., & Rampinini, E. (2016). Changes in muscle damage, inflammation, and fatigue-related parameters in young elite soccer players after a match. *The Journal of Sports Medicine and Physical Fitness*, 56(10), 1198-1205.
- Kafrawi, F. R., Nurhasan, Wahjuni, E. S., Rusdiawan, A., Bektı, A. P., & Ayubi, N. (2024). Sports massage has the potential to reduce ischemic muscle pain and increase range of motion after exercise. *Fizjoterapia Polska*, 2024(1), 60-65. <https://doi.org/10.56984/8ZG2EF85A3>
- White, G. E., & Wells, G. D. (2013). Cold-water immersion and other forms of cryotherapy: physiological changes potentially affecting recovery from high-intensity exercise. *Extreme Physiology & Medicine*, 2(1), 26.
<https://doi.org/10.1186/2046-7648-2-26>
- Yao, Y., Xie, W., Opoku, M., Vithran, D. T. A., Li, Z., & Li, Y. (2024). Cryotherapy and thermotherapy in the management of osteoarthritis and rheumatoid arthritis: A comprehensive review. *Fundamental Research*.
<https://doi.org/10.1016/J.FMRE.2024.07.008>
- Peake, J. M., Roberts, L. A., Figueiredo, V. C., Egner, I., Krog, S., Aas, S. N., Suzuki, K., Markworth, J. F., Coombes, J. S., Cameron-Smith, D., & Raastad, T. (2016). The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. *The Journal of Physiology*, 595(3), 695. <https://doi.org/10.1113/JP272881>
- Peake, J. M., Markworth, J. F., Nosaka, K., Raastad, T., Wadley, G. D., & Coffey, V. G. (2015). Modulating exercise-induced hormesis: Does less equal more? *Journal of Applied Physiology*, 119(3), 172-189.
<https://doi.org/10.1152/jappphysiol.01055.2014>
- Mila-Kierzenkowska, C., Jurecka, A., Woźniak, A., Szpinda, M., Augustyńska, B., & Woźniak, B. (2013). The effect of submaximal exercise preceded by single whole-body cryotherapy on the markers of oxidative stress and inflammation in blood of volleyball players. *Oxidative Medicine and Cellular Longevity*.
<https://doi.org/10.1155/2013/409567>
- Crane, J. D., Ogborn, D. I., Cupido, C., Melov, S., Hubbard, A., Bourgeois, J. M., & Tarnopolsky, M. A. (2012). Massage therapy attenuates inflammatory signaling after exercise-induced muscle damage. *Science Translational Medicine*, 4(119).
<https://doi.org/10.1126/SCITRANSLMED.3002882>
- Ogai, R., Yamane, M., Matsumoto, T., & Kosaka, M. (2008). Effects of petrissage massage on fatigue and exercise performance following intensive cycle pedalling. *British Journal of Sports Medicine*, 42(10), 534-538.
<https://doi.org/10.1136/BJSM.2007.044396>
- Wiltshire, E. V., Poitras, V., Pak, M., Hong, T., Rayner, J., & Tschakovsky, M. E. (2010a). Massage impairs postexercise muscle blood flow and "lactic acid" removal. *Medicine and Science in Sports and Exercise*, 42(6), 1062-1071.
<https://doi.org/10.1249/MSS.0B013E3181C9214F>
- Waters-Banker, C., Dupont-Versteegden, E. E., Kitzman, P. H., & Butterfield, T. A. (2014). Investigating the Mechanisms of Massage Efficacy: The Role of Mechanical Immunomodulation. *Journal of Athletic Training*, 49(2), 266. <https://doi.org/10.4085/1062-6050-49.2.25>
- Wiltshire, E. V., Poitras, V., Pak, M., Hong, T., Rayner, J., & Tschakovsky, M. E. (2010b). Massage impairs postexercise muscle blood flow and "lactic Acid" removal. *Medicine and Science in Sports and Exercise*, 42(6), 1062-1071.
<https://doi.org/10.1249/MSS.0B013E3181C9214F>
- Sut, N., Kocak, Z., Korkmaz, S., & Uzun, C. (2022). Compliance of abstracts of randomized control trials with CONSORT guidelines: A case study of Balkan journals. *European Science Editing*, 48(July 2021), 1-10.
<https://doi.org/10.3897/ese.2022.e71240>
- Li, H., Early, K. S., Zhang, G., Ma, P., & Wang, H. (2024). Personalized Hydration Strategy to Improve Fluid Balance and Intermittent Exercise Performance in the Heat. *Nutrients*, 16(9), 1341.
<https://doi.org/10.3390/NU16091341>
- Lateef, F. (2010). Post exercise ice water immersion: Is it a form of active recovery? *Journal of Emergencies, Trauma and Shock*, 3(3), 302. <https://doi.org/10.4103/0974-2700.66570>

- VanderVeen, B. N., Fix, D. K., Montalvo, R. N., Counts, B. R., Smuder, A. J., Murphy, E. A., Koh, H. jin, & Carson, J. A. (2019). The Regulation of Skeletal Muscle Fatigability and Mitochondrial Function by Chronically Elevated IL-6. *Experimental Physiology*, 104(3), 385. <https://doi.org/10.1113/EP087429>
- He, J., Zhang, X., Ge, Z., Shi, J., Guo, S., & Chen, J. (2025). Whole-body cryotherapy can reduce the inflammatory response in humans: a meta-analysis based on 11 randomized controlled trials. *Scientific Reports*, 15(1). <https://doi.org/10.1038/S41598-025-90396-3>
- Khoshnevis, S., Craik, N. K., & Diller, K. R. (2014). Cold-induced vasoconstriction may persist long after cooling ends: an evaluation of multiple cryotherapy units. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*, 23(9), 2475. <https://doi.org/10.1007/S00167-014-2911-Y>
- Hyldahl, R. D., & Peake, J. M. (2020). Combining cooling or heating applications with exercise training to enhance performance and muscle adaptations. *Journal of Applied Physiology*, 129(2), 353-365. <https://doi.org/10.1152/JAPPLPHYSIOL.00322.2020>
- Weerapong, P., Hume, P. A., & Kolt, G. S. (2005). The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sports Medicine*, 35(3), 235-256. <https://doi.org/10.2165/00007256-200535030-00004>
- Aragón-Vela, J., Fontana, L., Casuso, R. A., Plaza-Díaz, J., & R. Huertas, J. (2021). Differential inflammatory response of men and women subjected to an acute resistance exercise. *Biomedical Journal*, 44(3), 338. <https://doi.org/10.1016/J.BJ.2020.02.005>

Вплив льодової компресії та масажних технік на виведення лактату та концентрацій інтерлейкіну-6 під час відновлювальної перерви в інтервальних видах спорту

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Історія питання. Високоінтенсивні інтервальні види спорту підвищують рівні лактату в крові та маркери запалення, як-от інтерлейкін-6 (IL-6), що може перешкоджати відновленню та знижувати результативність. Ефективні стратегії відновлення мають вирішальне значення для покращення кліренсу лактату та регулювання запалення.

Мета дослідження. Метою цього дослідження було оцінити вплив 15-хвилинних інтервенцій із застосування льодової компресії та спортивного масажу під час перерви на кліренс лактату та рівні IL-6 у спортсменів.

Матеріали та методи. Для проведення цього експериментального дослідження тридцять шість футболістів-чоловіків віком від 18 до 24 років було розподілено за методом рандомізації на три групи: льодова компресія (ЛК, n = 12), спортивний масаж (СМ, n = 12) та пасивне відновлення (ПВ, n = 12). Кожен учасник виконав стандартизовану програму вправ, розроблену з метою індукції втоми. Група ПВ після тренування проходила період пасивного відпочинку, тоді як учасники інтервенційних груп протягом 15 хвилин отримували масаж або льодову компресію. Вимірювання рівнів лактату та IL-6 у крові проведено перед тренуванням (T0), безпосередньо після тренування (T1) та через п'ятнадцять хвилин після завершення тренування (T2). Для аналізу виявлених відмінностей проведено дисперсійний аналіз за змішаною моделлю та post-hoc тести (Бонферроні/Геймса-Хауелла).

Результати. Згідно з отриманими результатами, рівні лактату (ЛК: $\Delta T1-T2 = -2.34 \pm 0.96$ ммоль/л, d = 2.209; СМ: $\Delta T1-T2 = -1.39 \pm 0.79$ ммоль/л, d = 0.829) та рівні IL-6 (ЛК: $\Delta T1-T2 = -1.44 \pm 0.93$ пг/мл, d = 1.206; СМ: $\Delta T1-T2 = -1.58 \pm 0.63$ пг/мл, d = 1.645) були значно нижчими, ніж у ПВ (p < 0.05). Незважаючи на подібні протизапальні ефекти щодо застосування ЛК та СМ (p = 0.898), ЛК продемонструвала вищу ефективність кліренсу лактату порівняно із СМ (p = 0.023, d = -1.081). ПВ показало лише мінімальне зниження обох біомаркерів.

Висновки. Масаж і льодова компресія ефективно сприяють виведенню лактату після високоінтенсивних фізичних вправ, причому масаж має додаткові переваги, зменшуючи запалення, опосередковане інтерлейкіном-6. Представлені результати підтверджують, що масаж є відмінним методом регенерації для спортсменів, які потребують негайного фізіологічного відновлення після фізичних навантажень.

Ключові слова: льодова компресія, спортивний масаж, кліренс лактату, інтерлейкін-6, запальна реакція.

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Identifying the Effects of Unilateral and Bilateral Complex Training on the Maximum Strength, Explosive Power, and Changing Direction Ability of Volleyball Players

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Abstract

Background. Unilateral and bilateral complex trainings are techniques that combine various exercises focused on developing different muscle groups and physical qualities, such as strength, power, speed, and balance. Understanding the most effective training strategy is essential for optimizing volleyball-specific physical performance.

Objectives. This study aimed to compare the effects of unilateral and bilateral complex training on lower-limb performance, specifically maximum strength, explosive power, and change-of-direction ability, in male collegiate volleyball players, and to evaluate these effects within this specific group.

Materials and Methods. A total of 68 male volleyball players aged 18-26 years from four universities in Shanghai were randomly assigned to unilateral (n = 34) or bilateral (n = 34) training groups. Both groups underwent 8 weeks of complex training programs designed based on expert input. Performance outcomes included 1RM squat, isometric mid-thigh pull (IMTP), countermovement jump (CMJ), drop jump (DJ), 5m and 10m sprints, and agility tests. Data were analyzed using paired and independent sample t-tests and Cohen's d for effect sizes.

Results. Both training protocols significantly improved all performance indicators ($p < 0.05$ or $p < 0.01$). The unilateral group showed substantially greater enhancements in unilateral IMTP, single-leg CMJ and DJ, and short-distance sprint times. The bilateral group had better bilateral CMJ gains and slightly higher ball speed, though only bilateral CMJ reached statistical significance. No marked difference was found in change-of-direction ability, though unilateral training yielded slightly greater progress.

Conclusions. The findings indicate that both unilateral and bilateral complex training are effective for enhancing lower-limb performance. However, unilateral training may be more beneficial for improving single-leg power and sprinting, while bilateral training better supports bilateral explosive strength and volleyball-specific skills.

Keywords: unilateral training, bilateral training, lower-limb performance, explosive power, sprint speed, collegiate volleyball players.

Introduction

Volleyball, as a high-intensity intermittent sport, places high demands on athletes' maximum strength, explosive power, and ability to change direction, all of which are crucial to performance. The "Outline for Building a Sports Strong Country" (State Council Bulletin of the People's Republic of China, 2019) and the "Notice on Further Strengthening Basic Physical Training" (General Administration of Sport

of China, 2020), highlight the importance of developing scientific, systematic training systems and improving athletes' physical fitness as a foundation for overall competitive ability. Physical fitness significantly influences technical, psychological, and cognitive performance, with strength and agility being core components. Explosive power defined as a rapid accumulation of force and directional mobility referring to the athlete's ability to decelerate, change direction, and accelerate again are essential in volleyball due to its fast-paced, reactive nature. Players often execute powerful and quick actions such as passing, spiking, and blocking within seconds. The modern evolution of volleyball, emphasizing

strength-based techniques and rapid movement patterns, further underscores the importance of leg explosive power and agility. As noted by Sheppard (2006), explosive leg power enhances directional changes, a view supported by Ben Abdelkrim (2010) and Çakır, Mehmet, and Esin Ergin (2022), who emphasize that fast, multi-directional movements are foundational to effective performance in both offensive and defensive actions. Therefore, developing explosive strength and change-of-direction ability is critical for improving volleyball athletes' competitive level and overall game performance.

Current volleyball agility training mainly emphasizes multi-directional movement (Chuang, 2022; Born, 2016), this study found that drop jump training from a height of 60 cm was the most effective for improving lower limb explosive power and change of direction performance in collegiate Sanda athletes. However, the researchers noted that further studies are necessary to confirm the optimal drop height for this type of training (Li et al., 2023). Research indicates that enhanced lower limb explosiveness improves the body's ability to overcome resistance during rapid directional changes, thereby boosting agility (Kovaleski, 2001; Peterson, 2006; Barnes, 2007). As a result, improving lower limb strength, explosive power, and agility in volleyball athletes has become a key training objective. Traditional methods such as reinforcement and resistance training have shown limited effectiveness due to various constraints. In contrast, complex training originating in the 1970s and combining resistance with biomechanically similar plyometric exercises has emerged as a more scientific and efficient method (Fukunaga, 1997; Weber, 2006; Hao, 2019). By leveraging post-activation potentiation, complex training has proven beneficial in enhancing explosive strength, initially in long jumpers and now in a wide range of sports (Liu, 2021). Compared to standalone resistance training, it offers greater improvements in rapid strength development, performance enhancement, reduced training time, and lower injury risk. However, inconsistencies in experimental results highlight the ongoing need to refine complex training protocols to maximize their effectiveness.

Previous studies on complex training have explored both unilateral and bilateral approaches, where unilateral complex training involves single-leg exercises (e.g., lunge squats, single-leg jumps) and bilateral complex training uses both legs simultaneously (e.g., squats, frog jumps). Research by Young (2006) indicated that bilateral vertical training exercises produce weaker effects in elite athletes, with low transfer to actual athletic performance despite improving maximum strength. Similarly, Cronin et al. (2007) found that back squat strength transfers poorly to sprint performance, especially in high-level athletes. In contrast, unilateral resistance training has been shown to enhance strength and physical stability, with studies suggesting it aligns better with sport-specific movement patterns and reduces injury risk (Jones et al., 2012). Unilateral training has also been associated with improved agility, sprinting, and jumping abilities (Speirs et al., 2016; McCurdy et al., 2010; Bogdanis et al., 2019). One explanation for its effectiveness is the bilateral force deficit phenomenon, where the total force generated unilaterally can exceed that of bilateral training. Despite these findings, there is still limited research on the effects of unilateral complex training, especially in volleyball,

and existing studies often lack in-depth comparisons of unilateral and bilateral approaches in complex training settings. Therefore, further research is needed to determine the most effective method for improving maximum strength and explosive power in volleyball players.

Based on the above, this study aims to systematically compare the effects of unilateral and bilateral complex training on the maximum strength, explosive power, and change-of-direction ability of volleyball players, with the goal of clarifying the mechanisms and differences in training outcomes between these two modes. Through scientifically designed training programs, the research seeks to evaluate the effectiveness of each approach in enhancing lower limb performance and provide empirical evidence to support coaches in creating individualized training plans. The study not only contributes to the theoretical framework of complex training and fosters innovation in training methodologies but also offers practical, evidence-based guidance for improving volleyball athletes' performance. Additionally, the findings may serve as a reference for training practices in other team ball sports. The main objectives are: (1) to compare the effects of unilateral and bilateral complex training on volleyball players' maximum strength, explosive power, and change-of-direction ability, and (2) to evaluate these effects within a specific group of volleyball players.

Material and Methods

This study was experimental research, aiming to compare the effects of unilateral and bilateral complex training of the lower limbs on developing the maximum strength, explosive power, and changing direction ability of volleyball players' lower limbs. During the experiment, two different training programs, namely unilateral complex training and bilateral complex training, were adopted. The training effects of the two training programs were measured by comparing the pre-test and post-test results of various indicators of the maximum strength, explosive power, and changing direction ability of the lower limbs.

Participants

This study employed an experimental design and involved male college volleyball players aged 18 to 26 years. A total of 68 athletes from two universities in Shanghai. The mean age of participants in the EG was 20.88 ± 1.43 years, with an average height of 184.71 ± 7.44 cm, weight of 80.20 ± 12.19 kg, and body fat percentage (BFP) of 15.76 ± 3.48 %. For the CG, the mean age was 20.76 ± 1.30 years, with an average height of 185.53 ± 7.77 cm, weight of 80.93 ± 10.96 kg, and BFP of 15.01 ± 3.96 %. These results indicate that the two groups were comparable in terms of basic physical characteristics at baseline, with no significant differences observed between the groups. The basic characteristics of volleyball players are shown in Table 1.

Participants were included in the study if they met the following criteria: (1) voluntarily provided informed consent, (2) had a minimum of 2 years of volleyball training experience, (3) were between 18 and 26 years old, (4) had no major sports injuries in the past 3 months, and (5) were available to attend all training sessions throughout the intervention period. Exclusion criteria included: (1) any

Table 1. Basic Characteristics of Volleyball Players in the EG and CG Groups

Group	Characteristics	Mean	SD
Experimental Group (EG)	Age	20.88	1.43
	Height (cm)	184.71	7.44
	Weight (kg)	80.20	12.19
	BFP (%)	15.76	3.48
Control Group (CG)	Age	20.76	1.30
	Height (cm)	185.53	7.77
	Weight (kg)	80.93	10.96
	BFP (%)	15.01	3.96

recent injury without full recovery, (2) current use of medication due to illness, (3) scheduling conflicts that would prevent full participation, or (4) a lack of commitment to completing the study.

All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments. Ethical approval for this study was obtained from Mahasarakham University (Certificate No. 655-533/2024) and Shanghai University (Certificate No. ECSHU 2024-076).

Data Collection Procedure

Participants were selected using stratified purposive sampling to include both high-level and ordinary collegiate volleyball athletes. The sampling process included the following steps:

1. Identification of eligible players based on inclusion/exclusion criteria.
2. Use of G*Power 3.1.9.7 software to determine the required sample size ($\alpha = 0.05$, power = 0.80, effect size = 0.8), resulting in 27 per group.

3. Adjusting for a 20% dropout rate, the final sample size was increased to 34 per group, totaling 68 participants.
4. Random group assignment was performed using the lottery method by school for practical convenience.
5. Final consent was obtained via face-to-face communication and written clarification documents.

Instruments

The training interventions were designed using expert interviews and a questionnaire survey. Interviews involved 9 sports training professionals, while an additional 12 experts completed structured questionnaires. Performance measurements included:

- Maximum Strength of the lower limbs.
- Explosive Power (e.g., vertical jump).
- Changing Direction Ability (e.g., agility tests).

The precise measurement protocols and tools (e.g., dynamometers, timing gates, force plates) will be described in the subsequent section of the article.

Statistical Analysis

Data were analyzed using SPSS (Version 24). Descriptive statistics (mean, SD) were calculated for all variables. Inferential analyses included:

1. Independent sample t-tests for between-group comparisons.
2. Paired t-tests for within-group pre- and post-test comparisons.
3. Effect sizes (Cohen's d) to interpret the magnitude of the training effects.

Statistical significance was set at $p < 0.05$.

Results

After the experiment, both the control group and the experimental group showed statistically significant

Table 2. Comparison of the data before and after the experiment in CG (n = 34)

Variable		Pre	Post	t	p - value
		Mean (SD)	Mean (SD)		
Maximum strength	1RM Squat	115.18 ± 18.58	138.29 ± 23.85	-5.211	0.000**
	Isometric Mid-Thigh Pull (Bilateral)	2235.84 ± 328.93	2559.44 ± 308.11	-4.844	0.000**
	Isometric Mid-Thigh Pull (Left side)	1977.80 ± 285.94	2134.09 ± 223.99	-3.405	0.002**
	Isometric Mid-Thigh Pull (Right-side)	1958.86 ± 241.95	2124.65 ± 170.66	-3.812	0.001**
Explosive power	CMJ, (cm) (Left side)	20.70 ± 4.25	21.92 ± 3.87	-3.496	0.001**
	CMJ, (cm) (Right-side)	20.20 ± 3.94	21.28 ± 3.41	-4.037	0.000**
	CMJ, (cm) (Bilateral)	43.01 ± 6.02	47.62 ± 4.65	-6.241	0.000**
	DJ, (m/s) (Left-side)	0.72 ± 0.17	0.75 ± 0.14	-2.245	0.032*
	DJ, (m/s) (Right-side)	0.70 ± 0.16	0.74 ± 0.12	-2.460	0.019*
	DJ, (m/s) (Bilateral)	1.72 ± 0.27	1.82 ± 0.35	-3.349	0.002**
	5-meter sprint, (s)	1.02 ± 0.06	0.99 ± 0.08	3.238	0.003**
	10-meter sprint, (s)	1.74 ± 0.09	1.68 ± 0.09	5.630	0.000**
	Jump-spiked ball speed, (m/s)	18.55 ± 3.35	20.60 ± 3.00	-4.558	0.000**
Changing direction ability	Jump-served ball speed, (m/s)	19.68 ± 3.34	21.42 ± 2.59	-3.326	0.001**
	180° Change of Direction Speed(s)	1.15 ± 0.11	1.13 ± 0.14	2.286	0.029*

Note: CG: Control group (Bilateral Complex Training Group); * $p < 0.05$ ** $p < 0.01$

Table 3. Comparison of the data before and after the experiment in EG (n = 34)

	Variable	Pre	Post	t	p - value
		Mean (SD)	Mean (SD)		
Maximum strength	1RM Squat	110.62 ± 20.22	128.59 ± 23.42	-4.185	0.000**
	Isometric Mid-Thigh Pull (Bilateral)	2144.11 ± 295.76	2421.26 ± 346.36	-3.899	0.000**
	Isometric Mid-Thigh Pull (Left - side)	1911.81 ± 244.76	2178.79 ± 221.77	-5.103	0.000**
	Isometric Mid-Thigh Pull (Right - side)	1893.08 ± 232.25	2177.44 ± 251.07	-6.657	0.000**
Explosive power	CMJ, (cm) (Left - side)	20.71 ± 4.45	23.43 ± 4.93	-6.618	0.000**
	CMJ, (cm) (Right - side)	20.04 ± 3.83	23.05 ± 3.49	-7.366	0.000**
	CMJ, (cm) (Bilateral)	43.71 ± 5.47	45.44 ± 6.22	-3.366	0.002**
	DJ, (m/s) (Left - side)	0.71 ± 0.18	0.79 ± 0.15	-5.473	0.000**
	DJ, (m/s) (Right - side)	0.70 ± 0.18	0.78 ± 0.15	-4.929	0.000**
	DJ, (m/s) (Bilateral)	1.69 ± 0.37	1.75 ± 0.36	-3.133	0.004**
	5-meter sprint, (s)	0.99 ± 0.06	0.95 ± 0.09	3.625	0.001**
	10-meter sprint, (s)	1.72 ± 0.07	1.62 ± 0.10	8.324	0.000**
	Jump-spiked ball speed, (m/s)	18.20 ± 2.54	18.76 ± 2.57	-3.733	0.001**
	Jump-served ball speed, (m/s)	18.76 ± 2.93	19.34 ± 2.79	-3.201	0.003**
Changing direction ability	180° Change of Direction Speed(s)	1.13 ± 0.12	1.10 ± 0.14	3.755	0.001**

Note: EG: Experimental group (Unilateral Complex Training Group); * p<0.05 ** p<0.01

Table 4. Comparison of the differences in pre and post-test Variable between groups (n = 34)

	Variable	EG	CG	t	p - value
		Mean (SD)	Mean (SD)		
Maximum strength	1RM Squat	17.97 ± 25.04	23.12 ± 25.87	-1.049	0.294
	Isometric Mid-Thigh Pull (Bilateral)	277.15 ± 414.48	323.61 ± 389.56	-1.595	0.111
	Isometric Mid-Thigh Pull (Left - side)	266.98 ± 305.07	156.29 ± 267.66	-2.245	0.025*
	Isometric Mid-Thigh Pull (Right - side)	284.37 ± 249.07	165.78 ± 253.58	-2.257	0.024*
Explosive power	CMJ, (cm) (Left - side)	2.72 ± 2.40	1.21 ± 2.02	-2.097	0.036*
	CMJ, (cm) (Right - side)	3.01 ± 2.39	1.08 ± 1.56	-4.232	0.000**
	CMJ, (cm) (Bilateral)	1.73 ± 3.00	4.62 ± 4.31	-3.802	0.000**
	DJ, (m/s) (Left - side)	0.08 ± 0.08	0.03 ± 0.08	-3.011	0.003**
	DJ, (m/s) (Right - side)	0.07 ± 0.07	0.04 ± 0.08	-2.490	0.013*
	DJ, (m/s) (Bilateral)	0.06 ± 0.11	0.10 ± 0.18	-0.613	0.540
	5-meter sprint, (s)	0.04 ± 0.07	0.02 ± 0.04	-2.087	0.037*
	10-meter sprint, (s)	0.09 ± 0.10	0.05 ± 0.06	-2.622	0.009**
	Jump-spiked ball speed, (m/s)	0.56 ± 0.87	0.86 ± 1.05	-1.897	0.058
	Jump-served ball speed, (m/s)	0.59 ± 1.07	0.92 ± 1.08	-1.050	0.294
Changing direction ability	180° Change of Direction Speed, (s)	0.08 ± 0.13	0.04 ± 0.06	-0.908	0.364

Note: CG: Control group (Bilateral Complex Training Group); EG: Experimental group (Unilateral Complex Training Group)* p<0.05 ** p<0.01

improvements in all 15 variables of maximum strength, explosive power, and changing direction ability, with all P-values less than 0.05 (see Tables 2 and 3).

Comparison of differences in changes between the experimental group and the control group before and after the experiment. Results show that in terms of maximum strength, there are significant differences in Isometric Mid-Thigh Pull (Left) and Isometric Mid-Thigh Pull (Right) (p <0.05). In terms of explosive power, there are significant differences in the indicators CMJ (Left), CMJ (Right), CMJ (Bilateral), DJ (Left), DJ (Right), 5m sprint, and 10m sprint

(p < 0.05). The p - values of other indicators are all greater than 0.05, indicating no significant differences. (see Table 4).

Discussion

Based on the T-test results in Table 2 and Table 3, After 8 weeks of intervention training, both unilateral and bilateral complex training significantly improved the maximum strength, explosive power, and change-of-direction ability of male university volleyball players. In terms of maximum strength, both groups showed very significant gains in 1RM

Squat and Isometric Mid-Thigh Pull, with slightly higher bilateral improvements in overall strength and slightly higher unilateral gains in single-leg force. In terms of explosive power, the unilateral group exhibited greater percentage improvements in single-leg vertical jumps (CMJ and DJ) and short sprints (5m and 10m), while the bilateral group achieved better gains in bilateral CMJ and ball speed performance. Both groups also showed very significant improvements in all explosive power indicators ($p < 0.01$). Regarding change-of-direction ability, both groups improved significantly ($p < 0.05$), with the unilateral group showing slightly greater progress. These findings align with previous research by Appleby et al. (2019), Häkkinen et al. (1996), and Cormier et al., (2020), supporting that both training modes are effective, though unilateral complex training may provide greater benefits for unilateral strength, speed, and agility-related tasks.

Based on the T-test results in Table 4, both unilateral and bilateral complex training significantly improved performance indicators, but with different strengths. In terms of maximum strength, there was no significant difference between the groups in 1RM Squat and Bilateral Isometric Mid-Thigh Pull, indicating similar effectiveness. However, the unilateral group showed significantly greater improvements in unilateral Isometric Mid-Thigh Pull (Left and Right), suggesting superior effectiveness in enhancing single-leg strength. This supports findings from Yang Jiaqun (2016), Appleby et al. (2019), and Zhang et al. (2023), who emphasized the distinct advantages of unilateral and bilateral training. In terms of explosive power, the unilateral group showed significantly greater improvements in unilateral CMJ and DJ, as well as in 5- and 10-meter sprints, while the bilateral group showed better performance gains in bilateral CMJ and volleyball-specific skills like jump-spiked and jump-served ball speed though the latter showed no statistically significant difference. These results align with studies by Drouzas et al. (2020), and Zhang et al. (2025), who demonstrated that unilateral training is more effective for improving single-leg power and short-distance sprinting, while bilateral training better supports tasks involving two-foot takeoffs. Regarding change-of-direction ability, no significant difference was found between groups, though the unilateral group showed a slightly greater improvement. This supports the idea that while both training types are effective, unilateral training may be more beneficial for movements requiring single-leg force production. Overall, each method has unique advantages unilateral training excels in enhancing unilateral power and speed, whereas bilateral training is more effective for bilateral explosive tasks and volleyball-specific performance.

Conclusions

In summary, the findings of this study indicate that both unilateral and bilateral complex training significantly enhance maximum strength, explosive power, and change of direction ability in male university volleyball players over an 8-week period. While both groups showed significant within-group improvements, the unilateral complex training group demonstrated greater performance gains across eight key indicators, particularly in unilateral strength and speed-related measures such as isometric mid-thigh pull, countermovement jump (CMJ), drop jump (DJ), and short-distance sprints. Conversely, the bilateral training group showed superior outcomes in bilateral CMJ and demonstrated slight advantages in bilateral

force output and ball velocity during spike and serve actions. These results suggest that unilateral complex training is more effective for improving lower-limb functional performance related to unilateral power and sprinting, whereas bilateral training is more beneficial for enhancing bilateral explosive movements. Overall, unilateral complex training appears to offer broader performance benefits for volleyball athletes.

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Conflict of Interest

The authors have no conflicts of interest to declare.

References

- The State Council of the People's Republic of China (2019, September 10). Approval of the plan for the economic and social development of the Tibet Autonomous Region. *State Council Bulletin*, 2019(25). Retrieved from https://www.gov.cn/gongbao/content/2019/content_5430499.htm
- General Administration of Sport of China (2020). *Notice on Further Strengthening Basic Physical Training*. Retrieved from <https://www.sport.gov.cn/n315/n20001395/c20010625/content.html>
- Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, 24(9), 919-932. <https://doi.org/10.1080/02640410500457109>
- Abdelkrim, N. B., Castagna, C., El Fazaa, S., & El Ati, J. (2010). The effect of players' standard and tactical strategy on game demands in men's basketball. *Journal of Strength & Conditioning Research*, 24(10), 2652-2662. <https://doi.org/10.1519/JSC.0b013e3181e2e0a3>
- Çakır, M., & Ergin, E. (2022). The effect of core training on agility, explosive strength and balance in young female volleyball players. *Spor Bilimleri Araştırmaları Dergisi*, 7(2), 525-535. <https://doi.org/10.25307/jssr.1171779>
- Chuang, C. H., Hung, M. H., Chang, C. Y., Wang, Y. Y., & Lin, K. C. (2022). Effects of agility training on skill-related physical capabilities in young volleyball players. *Applied sciences*, 12(4), 1904. <https://doi.org/10.3390/app12041904>
- Born, D. P., Zinner, C., Düking, P., & Sperlich, B. (2016). Multi-directional sprint training improves change-of-direction speed and reactive agility in young highly trained soccer players. *Journal of Sports Science &*

- Medicine*, 15(2), 314.
<https://pmc.ncbi.nlm.nih.gov/articles/PMC4879446/>
- Li, G., Wu, W., Zhen, K., Zhang, S., Chen, Z., Lv, Y., Hou, X., & Yu, L. (2023). Effects of different drop height training on lower limb explosive and change of direction performance in collegiate Sanda athletes. *iScience*, 26(10).
<https://doi.org/10.1016/j.isci.2023.107972>
- Kovaleski, J. E., Heitman, R. J., Andrew, D. P., Gurchiek, L. R., & Pearsall IV, A. W. (2001). Relationship Between Closed-Linear-Kinetic-and Open-Kinetic-Chain Isokinetic Strength and Lower Extremity Functional Performance. *Journal of Sport Rehabilitation*, 10(3).
<https://doi.org/10.1123/jsr.10.3.196>
- Peterson, M. D., Alvar, B. A., & Rhea, M. R. (2006). The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of strength and conditioning research*, 20(4), 867-873.
<https://doi.org/10.1519/R-18695.1>
- Barnes, J. L., Schilling, B. K., Falvo, M. J., Weiss, L. W., Creasy, A. K., & Fry, A. C. (2007). Relationship of jumping and agility performance in female volleyball athletes. *Journal of strength and conditioning research*, 21(4), 1192-1196.
<https://doi.org/10.1519/R-22416.1>
- Fukunaga, T., Ichinose, Y., Ito, M., Kawakami, Y., & Fukashiro, S. (1997). Determination of fascicle length and pennation in a contracting human muscle in vivo. *Journal of applied physiology*, 82(1), 354-358.
<https://doi.org/10.1152/jappl.1997.82.1.354>
- Weber, K. R. (2006). *Complex training for enhanced performance in power athletes*. California State University, Fullerton. Retrieved from <https://www.proquest.com/dissertations-theses/complex-training-enhanced-performance-power/docview/304909428/se-2>
- Hao Lei, Nie Yudi, Han Xiaowei, & Zhong Bingshu (2019). Experimental study on the effect of composite training on the explosive power of lower limbs in competitive diving athletes. *Journal of Capital Sports University*, 31(02), 175-181. <https://doi.org/10.14036/j.cnki.cn11-4513.2019.02.016>
- Liu Yang (2021). Research on the Influence of Composite Training on Lower Limb Explosive Power of College Basketball Secondary Athletes. *Shandong Institute of Physical Education*, 2021.
- Young, W. B. (2006). Transfer of strength and power training to sports performance. *International journal of sports physiology and performance*, 1(2), 74-83.
<https://doi.org/10.1123/ijsspp.1.2.74>
- Cronin, J., Ogden, T., Lawton, T., & Brughelli, M. (2007). Does increasing maximal strength improve sprint running performance? *Strength & Conditioning Journal*, 29(3), 86-95. https://journals.lww.com/nsca-scj/Abstract/2007/06000/Does_Increasing_Maximal_Strength_Improve_Sprint.14.aspx
- Jones, M. T., Ambegaonkar, J. P., Nindl, B. C., Smith, J. A., & Headley, S. A. (2012). Effects of unilateral and bilateral lower-body heavy resistance exercise on muscle activity and testosterone responses. *Journal of Strength & Conditioning Research*, 26(4), 1094-1100.
<https://doi.org/10.1519/JSC.0b013e318248ab3b>
- Speirs, D. E., Bennett, M. A., Finn, C. V., & Turner, A. P. (2016). Unilateral vs. bilateral squat training for strength, sprints, and agility in academy rugby players. *Journal of Strength & Conditioning Research*, 30(2), 386-392.
<https://doi.org/10.1519/JSC.0000000000001096>
- McCurdy, K., O'Kelley, E., Kutz, M., Langford, G., Ernest, J., & Torres, M. (2010). Comparison of lower extremity EMG between the 2-leg squat and modified single-leg squat in female athletes. *Journal of sport rehabilitation*, 19(1), 57-70. <https://doi.org/10.1123/jsr.19.1.57>
- Bogdanis, G. C., Tsoukos, A., Kaloheri, O., Terzis, G., Veligekas, P., & Brown, L. E. (2019). Comparison between unilateral and bilateral plyometric training on single-and double-leg jumping performance and strength. *Journal of Strength & Conditioning Research*, 33(3), 633-640.
<https://doi.org/10.1519/JSC.0000000000001962>
- Appleby, B. B., Cormack, S. J., & Newton, R. U. (2019). Specificity and transfer of lower-body strength: influence of bilateral or unilateral lower-body resistance training. *Journal of Strength & Conditioning Research*, 33(2), 318-326. <https://doi.org/10.1519/JSC.0000000000002923>
- Häkkinen, K., Kallinen, M., Linnamo, V., Pastinen, U. M., Newton, R. U., & Kraemer, W. J. (1996). Neuromuscular adaptations during bilateral versus unilateral strength training in middle-aged and elderly men and women. *Acta Physiologica Scandinavica*, 158(1), 77-88.
<https://doi.org/10.1046/j.1365-201X.1996.523293000.x>
- Cormier, P., Freitas, T. T., Rubio-Arias, J. Á., & Alcaraz, P. E. (2020). Complex and contrast training: does strength and power training sequence affect performance-based adaptations in team sports? A systematic review and meta-analysis. *Journal of Strength & Conditioning Research*, 34(5), 1461-1479.
<https://doi.org/10.1519/JSC.0000000000003493>
- Yang Jiaqun (2016). *The Influence of Bulgarian Split Squat and Squat Training on the Athletic Qualities of Male College Students*. Beijing Sport University, 2016.
- Zhang, W., Chen, X., Xu, K., Xie, H., Li, D., Ding, S., & Sun, J. (2023). Effect of unilateral training and bilateral training on physical performance: A meta-analysis. *Frontiers in physiology*, 14, 1128250. <https://doi.org/10.3389/fphys.2023.1128250>
- Drouzas, V., Katsikas, C., Zafeiridis, A., Jamurtas, A. Z., & Bogdanis, G. C. (2020). Unilateral Plyometric Training is Superior to Volume-Matched Bilateral Training for Improving Strength, Speed and Power of Lower Limbs in Preadolescent Soccer Athletes. *Journal of Human Kinetics*, 74(1), 161-176. <https://doi.org/10.2478/hukin-2020-0022>
- Zhang, Z., Qu, W., Peng, W., Sun, J., Yue, J., Guan, L., ... & Li, D. (2025). Effect of unilateral and bilateral plyometric training on jumping, sprinting, and change of direction abilities: a meta-analysis. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 97.
<https://doi.org/10.1186/s13102-025-01113-6>

Визначення впливу унілатерального та білатерального комплексного тренування на максимальну силу, вибухову потужність та здатність до зміни напрямку руху волейболістів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. Унілатеральні та білатеральні комплексні тренування — це методики, які поєднують в собі виконання різних вправ, спрямованих на розвиток різних груп м'язів та фізичних якостей, як-от сила, потужність, швидкість та рівновага. Розуміння найефективнішої стратегії тренувань є надзвичайно важливим для оптимізації фізичної результативності, специфічної для волейболу.

Мета дослідження. Це дослідження мало на меті порівняти вплив унілатерального та білатерального комплексного тренування на працездатність нижніх кінцівок, зокрема максимальну силу, вибухову потужність та здатність до зміни напрямку руху, в університетських волейболістів чоловічої статі, а також оцінити цей вплив у межах цієї конкретної групи.

Матеріали та методи. Загалом 68 чоловіків-волейболістів віком 18-26 років з чотирьох університетів Шанхаю було розподілено за методом рандомізації на групи унілатерального ($n = 34$) та білатерального ($n = 34$) тренування. Обидві групи провели восьмижуровні програми з комплексного тренування, розроблені на основі рекомендацій експертів. До показників результативності належали: присідання з одним повторенням максимальної ваги (1ПМ), ізометричне підтягування середини стегна (ІПСС), стрибок із контррухом (СКР), стрибок у глибину (СГ), спринти на 5 і 10 метрів та тести на швидкість. Дані було проаналізовано за допомогою t-критеріїв для парних і незалежних вибірок та коефіцієнта d Коена з метою оцінки розмірів ефектів.

Результати. Обидва протоколи тренувань значно поліпшили усі показники результативності ($p < 0.05$ або $p < 0.01$). Група, яка займалася унілатеральним тренуванням, продемонструвала істотно вищі показники у виконанні одностороннього ІПСС, СКР і СГ на одній нозі, а також у спринті на короткі дистанції. Група, в якій застосовувалася методика білатерального тренування, мала кращі результати у двосторонньому СКР і дещо вищу швидкість польоту м'яча, однак виконання лише білатерального СКР досягло статистичної значущості. Істотної різниці в здатності змінювати напрямок руху встановлено не було, проте використання методики унілатерального тренування забезпечило дещо більший прогрес.

Висновки. Результати дослідження показують, що як унілатеральне, так і білатеральне комплексне тренування є ефективними для підвищення працездатності нижніх кінцівок. Однак унілатеральне тренування може бути кориснішим щодо поліпшення показників потужності однієї ноги та спринту, тоді як білатеральне тренування сприяє кращому розвитку білатеральної вибухової сили та навичок, специфічних для волейболу.

Ключові слова: унілатеральне тренування, білатеральне тренування, працездатність нижніх кінцівок, вибухова потужність, швидкість спринту, університетські волейболісти.

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Assessing Responses of Functional Resistance Training on Selected Body Composition Variables Among Female Students

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Abstract

Objectives. This study aimed to examine the responses of incorporating functional resistance training program and to ascertain the impact of this structured program on body composition variables among female students.

Materials and Methods. For this study, 20 interested female students (age: 22.15 ± 1.95 years) from the SRM IST in Kattankulathur, Chennai, were selected as participants. After baseline measurements, participants were randomized into training ($n = 10$) and control ($n = 10$) groups. The experimental group engaged in an 8-week training program comprising 40–60 minutes of low-to-moderate intensity functional resistance training. Body composition variables such as weight, BMI, and waist-hip ratio were chosen as dependent variables for the study. To assess the baseline group differences, independent sample t-tests were used. Intervention effects were examined by paired sample t-tests to determine within-group effect of college students, including body weight, BMI and WHR. The significance level was set at 0.05.

Results. The paired sample t-test showed a significant difference ($p < 0.05$) in body composition among the experimental group. The pre and post-test values were considerably different ($p < 0.05$) in the training group. According to the findings, it was revealed that functional resistance program led to marked decreases ($p < 0.05$) in weight, BMI and WHR. However, no substantial differences were found in the control group.

Conclusions. The study concluded that after eight weeks of engaging in FRT programme, significant improved responses were observed in body composition variables such as weight, BMI, and waist-hip ratio among female students.

Keywords: functional resistance training, body composition, female students.

Introduction

Physical fitness and healthy body composition are vital signs of total wellbeing, especially among young women (Kochman et al., 2022; Fernández-García et al., 2020). In today's modern lifestyle, lack of physical activity and unhealthy eating habits are more common, particularly in young adults, leading to rise in obesity, metabolic syndrome, and life style diseases (Alexander et al., 2017; Chomiuk et al., 2024; Godala et al., 2022). Particularly in college women students, stress in the academic life, decreased physical activity, and rise in

sedentary behaviour have led to negative trends in health and fitness (Celestine et al., 2017; Arya et al., 2024). And also regular physical activity has been shown to improve overall health, yet finding the time to exercise is still a big obstacle for many people (Warburton et al., 2006; O'Dougherty et al., 2012). As a result, there is an important need to adopt sustained and effective training program that not only to enhance fitness but also positively affect body composition, an important indicator of physical health and diseases risk.

Body composition variables serve as vital indicators for measuring the effectiveness of fitness regimen (Godoy-Cumillaf et al., 2025). An unfavourable body composition, especially high fat mass or abdominal fat, is closely associated with a greater risk of musculoskeletal problems, coronary diseases, and diabetes problems (Dutta et al., 2006; Kim et al., 2019). For young adult women, keeping a healthy body com-

position is also crucial for balancing hormone, reproductive health, and mental health, including enhanced self-esteem and body image (Segarra I et al., 2023; Moncur, 2011).

With the increasing popularity of functional and time efficient workout programs, FRT (Functional Resistance Training) has risen as popular and effective workout (Brogno B, 2025). Unlike traditional resistance training, which frequently uses free weights and machines to isolate muscle, FRT include multi-planar and compound movements that imitate daily activities (Zuo et al., 2022; Khazaei et al., 2023). These movements engage more than one muscle groups concurrently, developing strength, stability, balance, neuromuscular coordination and overall performance (Liao et al., 2019; Akbar et al., 2022). Exercises such as squats, lunges, push-pull, and rotational lifts are the keystone of FRT, providing a practical and holistic approach to fitness (Kompf et al., 2022; Faro et al., 2019; Feito et al., 2018).

In previous studies have shown that resistance training can significantly effects body composition by increasing body mass and reducing fat mass (Lopez et al., 2022; Liu et al., 2022; Wewege et al., 2019). However, the majority of the studies have mostly focused on male populations or traditional resistance methods. Only few studies are concentrated on FRT. There remains a research gap in the previous studies concerning the effect of functional resistance training on body composition among female college students, they are in a unique demographic with particular lifestyle, physiological traits and motivational characteristics. In this context, our study aims to investigate effect of functional resistance training program on selected body composition variables among women students. By focusing on this demographic, the study seeks to insight on how FRT can serve as a useful intervention not only for enhancing fitness and health, and also for avoiding metabolic disorders and obesity at early stage. The findings may inform physical trainers, health educators, and physical education teachers in creating effective and safe training program tailored to the young women.

Materials and Methods

Participants

There were 20 interested women students (age: 22.15 ± 1.95 years) selected from the SRM IST, Kattankulathur, Chennai for this study. Most of the subjects were actively engaged in recreational activities and had prior resistance training experience, but none of the participants frequently performed resistance training. Clinical history and physical examinations were used to determine eligibility. A history of chronic illnesses (diabetes, cardiorespiratory issues or metabolic abnormalities) or any other condition that would have made it difficult to follow exercise regimens was one of the study's exclusion criteria. All the participants received a detail explanation about the training program and purpose of this study, and their oral consent was also collected.

Experimental Design

The participants were divided in to two groups at random, including FRT group and control group. The FRT group participated 8 weeks training period and control

group not involved in specific training. Pre and post-test are conducted before and after the training programme. Below given flow chart detailing study's procedure.

Training Protocol

The participants were trained in eight consecutive weeks which includes five sessions per week, each training sessions lasts nearly 40-60 minutes. Before and after the main exercise, the training protocols comprised static and dynamic stretching as part of the conventional warm-up and cool-down.

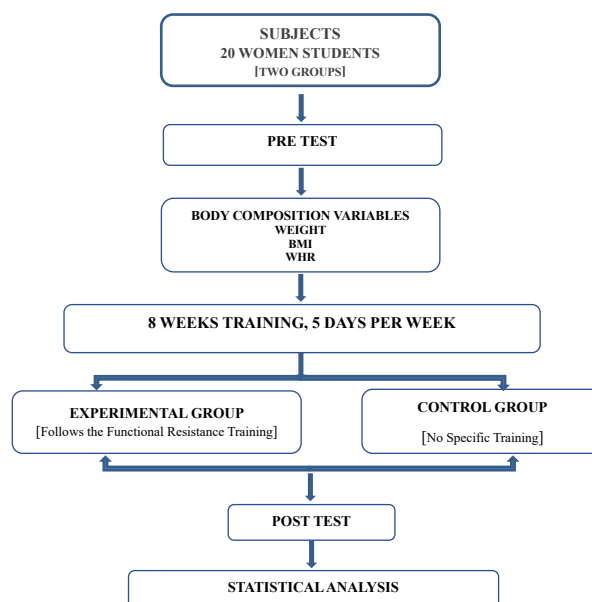


Fig. 1. Shows Flow chart of experimental design

The warm- up lasts nearly 10 minutes, it includes stretching exercises and jumping exercises like jumping jacks, high knee, back kicks. The whole body FRT performed different exercises lasts 25 to 30 minutes, Exercises included squats, push ups, lunges, crunches, plank, rowing, presses, swings and lifts. In a session participants were performed eight exercises with two sets of 8 to 10 repetition and gradually the repetition increased 10 to 12 in after two weeks. In the beginning of fifth weeks number of sets were increased in to 3 sets and repetition at 8 to 10 and gradually increased in to 10-12. Warm down includes loosening exercises and stretching.

Criterion Measures

Body composition variable such as Weight, BMI, and WHR were measured with the help of 'Inbody 770 Body Composition Analyser'.

Statistical Analysis

For assess the baseline group differences, Independent sample t-test were used. Intervention effects were examined by paired sample t-tests to determine within group effect such as Body weight, BMI and WHR of college students. 0.05 level was set for significance level.

Results

Table 1. Output of independent t test for identifying Base line group difference of experimental and control group on selected variables

Body Composition Variables	Group	Mean (SD)	t	p
WEIGHT	EG	49.70 (4.61)	0.506	0.619
	CG	50.56 (2.76)		
BMI	EG	20.98 (1.75)	0.533	0.601
	CG	20.55 (1.86)		
WHR	EG	0.750 (0.032)	0.535	0.600
	CG	0.742 (0.034)		

Note: EG = Experimental group, CG = Control group, Data are presented as Mean $\pm$ SD, BMI-body mass index, WHR-waist hip ratio, df = 9, Level of significance = 0.05.

There were no significant variations in terms of the Body Weight, BMI and WHR of college students between trained and control group before training (Table 1). Average Body Weight of Experimental group and Control group is 49.70 & 50.56, Average BMI level of Experimental group and Control group is 20.98 & 20.55 and the WHR of Experimental group and Control group is .750 & .742, respectively. All the p value is greater than 0.05 ($p = .619, .601, \& .600 > 0.05$). The output of independent t test result shows that there is no significance different between these two groups. The body weight, BMI and WHR of experimental group ($n = 10$) and control group ($n = 10$) were similar before training.

Table 2. Output of paired t test for analysing before and after the intervention of experimental and control Groups

Variables	Group	Pre-test mean (SD)	Post-test mean (SD)	t	p
WEIGHT	EG	49.70 (4.61)	48.82(4.51)	8.63	0.000
	CG	50.56 (2.76)	50.43(2.78)	1.22	0.253
BMI	EG	20.98(1.75)	20.27(1.71)	6.91	0.000
	CG	20.55(1.86)	20.47(1.86)	0.784	0.453
WHR	EG	0.750(0.032)	0.731(0.024)	4.67	0.001.
	CG	0.742(0.035)	0.738(0.032)	1.81	0.104

EG = Experimental group, CG = Control group, Data are presented as Mean $\pm$ SD, BMI-body mass index, WHR-waist hip ratio, df = 9, Level of significance = 0.05.

Table 2 (output of paired sample t test) presents the mean of pre- and post-training values for the Body Weight, Body Mass Index (BMI) and Waist Hip Ratio (WHR) of experimental and control groups. There were statistically no significant differences pre- and post-training values in the control group ($p = .253, .453, .104 > 0.05$). There were statistically significant differences pre- and post-training values of the variables such as Body Weight, BMI and WHR only in the training group ($p = .00, .000, .001 < 0.05$). In the Experimental/ Training group, Body Weight (before intervention = 49.70, after intervention = 48.82), BMI (before intervention = 20.98, after intervention = 20.27), and WHR (before intervention = .750, after intervention = .731) decreased with functional resistance training.

Discussion

The study objective was to investigate the impact of a structured functional resistance training program on body composition variables such as weight, BMI and waist Hip Ratio among women students. After the statistical analysis, the result findings show that there were significant differences in pre- and post-training values of chosen variables only in the training group. But, there were statistically no significant differences in pre- and post-training values of the control group. The study results indicate that the FRT group, compared to the control group, was more effective in differences in body composition.

Our findings are confirm with previous studies state that functional resistance training has positive on body composition, a study found that Functional Strength Training was more successful than Traditional Strength Training at reducing fat mass, when comparing the impact of 8 weeks of FST and TST on the body composition of older women (de Resende-Neto et al., 2019). In another study, the results were similar to our study, pointed that training group was more effective than control group in improving body composition and specifically, training group significantly improved body mass, body fat percentage and BMI (Wang et al., 2024). A study conducted on elderly women, it was shown that six month of FST might also effectively enhance BMI (Liao, et al., 2019). Moreover, there have so many previous studies related to resistance training on body compositions that shows RT with outdoor fitness equipment's twice a week for 8 weeks can significantly improve body composition (Marcos-Pardo, P. J. et al., 2024). Moreover, a study conducted on obese college students shows that RT with load can help improve the body composition and noticed significant changes in body weight, BMI and waist hip ratio (Liu, W. J., & Ma, H. T., 2023). Previous study on untrained male adults shows that RT had a better effect in significantly improve in body composition (Kashiani et al., 2020). Thus, in these studies indicate that the positive effect of functional resistance training on body composition. So, this study finding suggests that Functional resistance training is a safe, effective, and practical intervention for enhancing body composition among women students. Considering time constraints and academic stress of the students, FRT offers time efficient training program that combines cardiovascular and muscular benefits. These advantages that make FRT an attractive for physical education professionals, health educators, and trainers to improve fitness participation of female and combat sedentary life. FRT also has psychological advantages, as developments in physical appearance and can enhance motivation and self-esteem among young women.

The study produced positive results, but there has several limitations. The sample size was small, that can restrict generalizability of the findings. Proper diet and lifestyle factors were not controlled, which could have influenced outcomes. Moreover, the study focused on basic body composition variables, Future research could use more variables and different technique for measurements. It is recommended that future studies should advised to use loner training periods, and include nutritional control, investigating physical and psychological variables.

Conclusions

Considering the results of this investigation, the study shows that functional resistance training favours body

composition variables among college women students. The study concluded that after the eight weeks of FRT programme shows there were significant responses in the body composition variables such as Weight, BMI, and Waist hip ratio among women students.

Conflict of Interest

The author states that there are no conflicts of interest regarding the publication of this manuscript

References

- Kochman, M., Kasperek, W., Guzik, A., & Druzbicki, M. (2022). Body composition and physical fitness: Does this relationship change in 4 years in young adults? *International Journal of Environmental Research and Public Health*, 19(3), 1579. <https://doi.org/10.3390/ijerph19031579>
- Fernández-García, J. C., Gálvez-Fernández, I., Mercadé-Melé, P., & Gavalá-González, J. (2020). Longitudinal study of body composition and energy expenditure in overweight or obese young adults. *Scientific Reports*, 10(1), 5305. <https://doi.org/10.1038/s41598-020-62249-8>
- Alexander, G. L., Lindberg, N., Firemark, A. L., Rukstalis, M. R., & McMullen, C. (2017). Motivations of young adults for improving dietary choices: Focus group findings prior to the MENU GenY dietary change trial. *Health Education & Behavior*, 45(4), 492-500. <https://doi.org/10.1177/1090198117736347>
- Chomiuk, T., Niezgoda, N., Mamcarz, A., & Śliż, D. (2024). Physical activity in metabolic syndrome. *Frontiers in Physiology*, 15, 1365761. <https://doi.org/10.3389/fphys.2024.1365761>
- Godala, M., Krzyżak, M., Maślach, D., & Gaszyńska, E. (2022). Relationship between dietary behaviors and physical activity and the components of metabolic syndrome: A case-control study. *International Journal of Environmental Research and Public Health*, 19(11), 6562. <https://doi.org/10.3390/ijerph19116562>
- Calestine, J., Bopp, M., Bopp, C. M., & Papalia, Z. (2017). College student work habits are related to physical activity and fitness. *International Journal of Exercise Science*, 10(7), 1009-1017. <https://doi.org/10.70252/XL0M8139>
- Arya, S., Madhavan, N., & Jith, J. (2024). Empowering the mind and body: The impact of exercise on college women's stress resilience and self-esteem. *International Journal of Physical Education, Sports and Health*, 11(5), 88-90. <https://doi.org/10.22271/kheljournal.2024.v11.i5b.3493>
- Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: The evidence. *CMAJ*, 174(6), 801-809. <https://doi.org/10.1503/cmaj.051351>
- O'Dougherty, M., Hearst, M. O., Arikawa, A. Y., Stovitz, S. D., Kurzer, M. S., & Schmitz, K. H. (2012). Young women's physical activity from one year to the next: What changes? What stays the same? *Translational Behavioral Medicine*, 2(2), 129-136. <https://doi.org/10.1007/s13142-011-0108-1>
- Godoy-Cumillaf, A., Fuentes-Merino, P., Giakoni-Ramírez, F., Maldonado-Sandoval, M., Bruneau-Chávez, J., & Merellano-Navarro, E. (2025). Impact on body composition and physical fitness of an exercise program based on immersive virtual reality: A case report. *Journal of Functional Morphology and Kinesiology*, 10(1), 56. <https://doi.org/10.3390/jfmk10010056>
- Dutta, P. S., Ramdas Nayak, V. K., & Punja, D. (2021). Body composition analysis components as markers for coronary artery diseases in type 2 diabetic patients. *Journal of Taibah University Medical Sciences*, 17(3), 369-375. <https://doi.org/10.1016/j.jtumed.2021.10.002>
- Kim, H. Y., Kim, J. K., Shin, G. G., Han, J. A., & Kim, J. W. (2019). Association between abdominal obesity and cardiovascular risk factors in adults with normal body mass index: Based on the Sixth Korea National Health and Nutrition Examination Survey. *Journal of Obesity & Metabolic Syndrome*, 28(4), 262-270. <https://doi.org/10.7570/jomes.2019.28.4.262>
- Segarra, I., Menárguez, M., & Roqué, M. V. (2023). Women's health, hormonal balance, and personal autonomy. *Frontiers in Medicine*, 10, 1167504. <https://doi.org/10.3389/fmed.2023.1167504>
- Moncur, B. F. (2011). *The relationship between source of self-esteem and body composition in college women* (Master's thesis, Brigham Young University).
- Brogno, B. (2025). Aging with strength: Functional training to support independence and quality of life. *Inquiry*, 62, 469580251348133. <https://doi.org/10.1177/00469580251348133>
- Zuo, C., Bo, S., Wang, T., & Zhang, W. (2022). Functional and traditional resistance training are equally effective in increasing upper and lower limb muscular endurance and performance variables in untrained young men. *Frontiers in Physiology*, 13, 868195. <https://doi.org/10.3389/fphys.2022.868195>
- Khazaei, L., Parnow, A., & Amani-Shalamzari, S. (2023). Comparing the effects of traditional resistance training and functional training on the bio-motor capacities of female elite taekwondo athletes. *BMC Sports Science, Medicine and Rehabilitation*, 15(1), 139. <https://doi.org/10.1186/s13102-023-00754-9>
- Liao, T., Li, L., & Wang, Y. T. (2019). Effects of functional strength training program on movement quality and fitness performance among girls aged 12–13 years. *Journal of Strength and Conditioning Research*, 33(6), 1534-1541. <https://doi.org/10.1519/JSC.0000000000002190>
- Akbar, S., Soh, K. G., Nasiruddin, N. J. M., Bashir, M., Cao, S., & Soh, K. L. (2022). Effects of neuromuscular training on athletes' physical fitness in sports: A systematic review. *Frontiers in Physiology*, 13, 939042. <https://doi.org/10.3389/fphys.2022.939042>
- Kompf, J. M., Rhodes, R. E., & Lee, S. (2022). Selecting resistance training exercises for novices: A Delphi study with expert consensus. *American Journal of Lifestyle Medicine*, 19(3), 437-449. <https://doi.org/10.1177/15598276221115662>
- Faro, J., Wright, J. A., Hayman, L. L., Hastie, M., Gona, P. N., & Whiteley, J. A. (2019). Functional resistance training and affective response in female college-age students. *Medicine and Science in Sports and Exercise*, 51(6), 1186-1194. <https://doi.org/10.1249/MSS.0000000000001895>
- Feito, Y., Heinrich, K. M., Butcher, S. J., & Poston, W. S. C. (2018). High-intensity functional training (HIFT):

- Definition and research implications for improved fitness. *Sports*, 6(3), 76. <https://doi.org/10.3390/sports6030076>
- Lopez, P., Taaffe, D. R., Galvão, D. A., Newton, R. U., Nonemacher, E. R., Wendt, V. M., ... & Rech, A. (2022). Resistance training effectiveness on body composition and body weight outcomes in individuals with overweight and obesity across the lifespan: A systematic review and meta-analysis. *Obesity Reviews*, 23(5), e13428. <https://doi.org/10.1111/obr.13428>
- Liu, X., Gao, Y., Lu, J., Ma, Q., Shi, Y., Liu, J., ... & Su, H. (2022). Effects of different resistance exercise forms on body composition and muscle strength in overweight and/or obese individuals: A systematic review and meta-analysis. *Frontiers in Physiology*, 12, 791999. <https://doi.org/10.3389/fphys.2022.791999>
- Wewege, M. A., Desai, I., Honey, C., Coorie, B., Jones, M. D., Clifford, B. K., Leake, H. B., & Hagstrom, A. D. (2022). The effect of resistance training in healthy adults on body fat percentage, fat mass and visceral fat: A systematic review and meta-analysis. *Sports Medicine*, 52(2), 287-300. <https://doi.org/10.1007/s40279-021-01562-2>
- de Resende-Neto, A. G., Oliveira Andrade, B. C., Cyrino, E. S., Behm, D. G., De-Santana, J. M., & Da Silva-Grigoletto, M. E. (2019). Effects of functional and traditional training in body composition and muscle strength components in older women: A randomized controlled trial. *Archives of Gerontology and Geriatrics*, 84, 103902. <https://doi.org/10.1016/j.archger.2019.103902>
- Wang, Z., Ma, H., Zhang, W., Zhang, Y., Youssef, L., Carneiro, M. A., ... & Wang, D. (2024). Effects of functional strength training combined with aerobic training on body composition, physical fitness, and movement quality in obese adolescents. *Nutrients*, 16(10), 1434. <https://doi.org/10.3390/nu16101434>
- Marcos-Pardo, P. J., Espeso-García, A., Vaquero-Cristóbal, R., Abelleira-Lamela, T., & González-Gálvez, N. (2024). The effect of resistance training with outdoor fitness equipment on the body composition, physical fitness, and physical health of middle-aged and older adults: A randomized controlled trial. *Healthcare*, 12(7), 726. <https://doi.org/10.3390/healthcare12070726>
- Liu, W., & Ma, H. (2023). Effects of resistance training on weight in college students. *Revista Brasileira de Medicina do Esporte*. https://doi.org/10.1590/1517-8692202329012023_0020
- Kashiani, A. B., Soh, K. G., Soh, K. L., Ong, S. L., & Kittichottipannich, B. (2020). Comparison between two methods of variable resistance training on body composition, muscular strength and functional capacity among untrained males. *Malaysian Journal of Movement, Health & Exercise*, 9(1), 45-66.

Оцінка реакцій щодо проведення функціонального силового тренування на певні показники композиції тіла серед студентів жіночої статі

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 2 табл., 1 рис., 30 джерел.

Мета дослідження. Мета цього дослідження полягала у вивченні реакцій щодо впровадження програми функціональних силових тренувань та визначенні впливу зазначеної структурованої програми на показники композиції тіла серед студенток.

Матеріали та методи. Для проведення цього дослідження було відібрано 20 зацікавлених студентів жіночої статі (вік: 22.15 ± 1.95 роки), які навчалися в Інституті науки і технологій імені Шрі Рамасвами у місті Каттанкулатур, Ченнай. Після вимірювання вихідних показників, учасниць було рандомізовано на тренувальну ($n = 10$) та контрольну ($n = 10$) групи. Експериментальна група брала участь у 8-тижневій програмі тренувань, що складалася з 40–60 хвилин функціональних силових тренувань низької та помірної інтенсивності. В якості залежних змінних для дослідження було обрано такі показники складу тіла, як вага, ІМТ та співвідношення талії і стегон. З метою оцінки базових групових відмінностей використовувались t-критерії для незалежних вибірок. Інтервенційні ефекти досліджувались за допомогою t-критеріїв для парних вибірок задля визначення внутрішньогрупового впливу університетських студентів, включаючи масу тіла, ІМТ та СТС. Рівень значущості було встановлено на позначці 0.05.

Результати. Т-критерій для парних вибірок показав значну різницю ($p < 0.05$) у показниках композиції тіла серед учасниць експериментальної групи. У тренувальній групі значення показників перед початком і після завершення ви-

пробування суттєво відрізнялися ($p < 0.05$). Згідно з отриманими результатами, встановлено, що виконання програми з функціонального силового тренування призвело до вираженого зниження ($p < 0.05$) ваги, ІМТ та СТС. Однак у контрольній групі суттєвих відмінностей виявлено не було.

Висновки. У дослідженні зроблено висновки, що після восьми тижнів участі в програмі функціональних силових тренувань у студенток спостерігалися значні покращення реакцій щодо показників складу тіла, як-от вага, ІМТ й співвідношення талії та стегон.

Ключові слова: функціональне силове тренування, композиція тіла, студенти жіночої статі.

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Comparing the Effectiveness of Various Recovery Method Combinations on Improving Leg Muscle Power and Blood Lactic Acid Level

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Abstract

Objectives. This study aimed to investigate the impact of various recovery methods on improving lower extremity muscle power and decreasing lactic acid levels among student-athletes.

Materials and Methods. This study employed a randomized control group with a pretest and posttest design. The participants of this study were selected using simple random sampling, consisted of forty students who were divided into four groups: the sports massage and hot water group (MHW), sports massage and cold water (MCW), hot water immersion (HWI), cold water immersion (CWI). Data were collected using a force plate to measure lower extremity muscle power (watt), while a lactate meter was used to determine lactic acid level (mmol/l). Data were analyzed using the Wilcoxon signed-rank test to examine the difference of measured variables before and after treatment. Subsequently, the Kruskal-Wallis test was performed to investigate between-groups differences, followed by post-hoc testing using the Mann-Whitney test.

Results. The results indicated that all groups (MHW, MCW, HWI, and CWI) experienced an increase in lower extremity muscle power, and reduced lactic acid levels. MHW was most effective in increasing lower extremity muscle power by 11.63 watt, while HWI had the most positive influence on reducing lactic acid levels by 7.16 mmol/l.

Conclusions. These findings demonstrate the value of combining sports massage with hot and cold-water therapies as a rehabilitation strategy. The researchers emphasize the significance of these therapies in improving lower extremity muscle power and reducing lactic acid accumulation, which contributes to optimal physical conditioning and performance during sports competitions.

Keywords: lactate, power, recovery, sports massage, students, water immersion.

Introduction

Fatigue is a state resulting from both physically and mentally exertion that leads to a reduced in performance (Pageaux & Lepers, 2016). Muscular fatigue often results from intense physical activity or excessive exercise, diminishing muscle power due to accumulation of metabolic byproducts (Lucertini et al., 2017). Two of the most significant processes causing exercise-induced fatigue are ATP depletion and fibers acidosis, resulting in significant changes in the level

of metabolites such as lactate (Finsterer, 2012). Lactate is no longer assumed to promote fiber acidosis, but rather to protect against this process (Robergs et al., 2004). However, it remains a good indirect indicator for the onset of fatigue since its exercise-induced blood rise corresponds with fiber acidosis (Finsterer, 2012; Robergs et al., 2004). The build-up of lactic acid in the muscle inhibits the function of enzymes essential for chemical reactions, ultimately weaken muscle contractions and reducing muscle power (Wan et al., 2017). This accumulation occurs when lactic acid is produced faster than it can be removed during recovery. If this condition were not effectively resolved, excessive exercise—often referred to as overtraining—can lead to significant lactic acid build-up, which may contribute to sports-related injuries in athlete (Kreher & Schwartz, 2012; Rusdiawan et

al., 2020; Wan et al., 2017). Thus, rapid recovery is important for athletes performing high-intensity loads in many type of sports (Budak, 2023).

Several methods of therapy are used by athletes to prevent injury and speed up the recovery process, including active and passive recovery (Kellmann et al., 2018). Active recovery involves low-intensity exercise such as walking, jogging, and stretching designed to prevent muscle spasms, cramps, and muscle stiffness (Fares et al., 2022; Li et al., 2024). Meanwhile, passive recovery relies on external stimulation rather than engaging in physical action. Common technique includes temperature-based therapies, compression garments, nutrient supplements, and massage (Li et al., 2024). Massage—which is the application of pressure to muscles, tendons, or ligaments (Hermoko & Sulastri, 2023)—is widely used by many people to reduce pain (Poppendieck et al., 2016), as well as relaxing muscles and improving blood circulation (Yuniana et al., 2022). When athletes receiving massage treatment, the hand pressure helps to break down lactic acid that has accumulated in the muscles, facilitating its transport into the bloodstream for removal (Wiltshire et al., 2009). To summarize, massage treatment aids recovery by stimulating blood flow, which accelerates the removal of lactic acid from the muscles (Prasetya et al., 2023; Weerapong et al., 2005).

In addition to massage, Thorpe (2021) reported the benefit of thermal water-based therapy to improve body recovery. Warm water immersion is known to induce many benefits such as reduce fatigue and muscle tension (Cullen et al., 2024; Ghadicolaei et al., 2019). Conversely, immersing in cold water can help to minimize inflammation and muscle soreness following intense exercise while providing a refreshing sensation (An et al., 2019; Leeder et al., 2011). The physiological response triggered by the immersion method can lead to improved nutrient distribution and byproduct removal from muscle tissue. Furthermore, the psychological benefits of water immersion should not be overlooked; warm water's soothing effects can improve mood, reduce stress and anxiety levels, contributing to a general sense of well-being during the recuperation process (Cullen et al., 2024). As a result, adding different immersion techniques into recovery methods can provide athletes with a more holistic approach in improving their physical and mental recovery after excessive exercise (Cochrane, 2004).

Given that competitive athletes may have limited time for recovery strategies and that speedy performance restoration is the most important factor, scientific clarification is required to determine whether and under what conditions massage may be a useful tool for enhancing post-exercise recovery (Poppendieck et al., 2016). In recent years, a large number of review articles have been published that analyze the findings of studies aimed at improving post-exercise recovery with massage therapies (Dakić et al., 2023; Karadavut & Acar, 2024). Despite being a common and widely used recovery technique among athletes (Nédélec et al., 2013; Poppendieck et al., 2016), massage alone is generally thought to have mild and inconclusive effects on performance recovery. Therefore, coaches and athletes often tried to combine sport massage with various recovery method to seek the most effective method to speed up the recovery. In addition to that, the order of the recovery is thought to affect the recovery process itself. Therefore, researchers are searching for the

most effective strategies to restore performance and speed up post-exercise recovery. This study aims to investigate the effect of various combination of recovery methods in lowering extremities power and blood lactic acid among student-athletes.

Materials and Methods

Research Design and Participant

This study was experimental research using pre-test and post-test control group design. Forty healthy male student-athletes who were selected from population using systematic random sampling with inclusion criteria as follows: (1) age between 18-24 years old; (2) actively participated in any endurance sport competition during the last three years; (3) did not suffer from orthopedic injuries in lower extremities within a year of the study; (4) did not experienced any other condition that could significantly impact the result of power muscle and lactic acid measurements; (5) did not have history of disease related to the nervous or musculoskeletal system, and (6) did not take ergogenic aids or dietary supplements during the study period. All subjects meeting the criteria received information about the research protocols, including its risks and benefits, which adhered to the ethical guidelines of the Declaration of Helsinki prior to their participation in the study. After that, a written informed consent was obtained from each student as an agreement to participate as a research subject in this study. All research procedures were approved by the ethic committee of Universitas Airlangga.

Procedure

Forty subjects were randomly assigned into four equal groups which was tested by same researchers, same treatment, and same measurement tools. The first group received sports massage followed by hot water immersion group (MHW), second group received sports massage followed by cold-water immersion (MCW), third group underwent hot water immersion (HWI), and the last group received cold-water immersion only (CWI). The experimental design is illustrated in Figure 1.

Each subject began the activity with a standardized warm up consisting of five minutes of static stretching targeting the hamstring, quadricep, and calf, followed by another five minutes of an alternating repetition of extension and flexion of lower limb. After ten minutes of warming up, subjects performed a high intensity bout of exercise on a cycle ergometer for 30 minutes on 85% of their repetition maximum (RM). Heart rate and blood pressure were thoroughly monitored during exercise using polar heart rate (polar H10 Bluetooth Heart Rate Sensor & Fitness Tracker, Kempele, Finland) and digital sphygmomanometer (Omron Deluxe HEM-8712, Osaka, Japan). Temperature was assessed using 3-in-1 Infrared Thermometer (Omron MC720, Osaka, Japan).

Afterward, subjects were asked to do countermovement jump (CMJ) on a portable force plate (PACO PS-2142, Roseville, USA) to measure leg muscle power. Subjects were asked to stand in a stationary position with bodyweight evenly distributed between both feet, positioned shoulder-width apart, with hips and knees extended. They were

instructed to put both hands on the hips, bend their knees, then jump as high as possible and land simultaneously on both feet. They were given three attempts, and the average score was recorded for data analysis. CMJ was measured twice, before (pre-test) and after (post-test) the treatment was given. The concentration of lactic acid was also examined during pre-test and post-test using ROCHE Accutrend Plus (Roche Diagnostic, McKesson, Germany). A trained nurse collected fingertip blood samples using a lancet which immediately place into the test strip. After a few seconds, the device displayed the results.

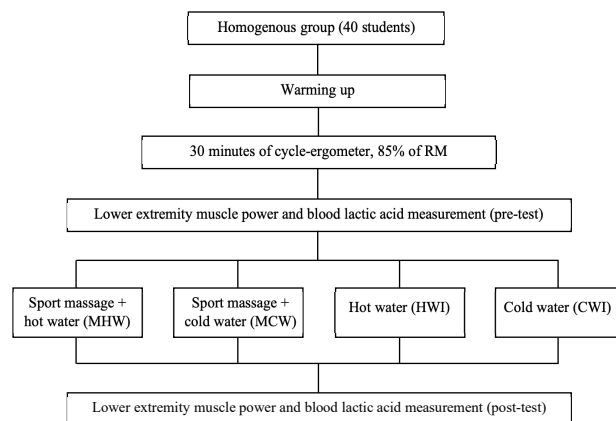


Fig. 1. Experimental Design

In addition to power and lactic acid, anthropometric measurements were assessed prior the research period, including age (years), bodyweight (kg), height (m), and body mass index (kg/m²). Bodyweight was measured using digital scale at the nearest 0.1 kg and height was measured using portable stadiometer at the nearest 0.1 cm.

The interventions were given according to the respected group. Subjects in MHW received twenty minutes of sport massage, followed by indoor hot bath for ten minutes. MCW received sport massage for twenty minutes and cold-water immersion for ten minutes. HWI received indoor hot bath for ten minutes. And last group was CWI who received cold-water immersion for ten minutes. Sport massage was performed by national certified masseurs, consisting of

effleurage, petrissage, friction, and effleurage applied on the lower extremities for five minutes each. Hot bath was done in sauna room, with water temperature was set on 35oC ± 1oC and relative humidity was 90%. Meanwhile, cold water immersion was done individually in cold-water bathtub which temperature was set on 9oC ± 1oC. Cold water immersion was started from the moment subject placed in seated position in the bathtub. The temperature was continuously adjusted to 9oC by adding ice cubes.

Statistical Analysis

Leg muscle power and blood lactic acid level were analyzed using SPSS 30 for Mac and GraphPad Prism for Mac. Saphiro-Wilk test was performed to analyze the normal distribution. Wilcoxon Signed Rank test was done to investigate the difference of measured variables before and after treatment. Afterward, Kruskal-Wallis test were performed to investigate between groups differences, followed by post-hoc test using Mann-Whitney to seek which pairs showed significant different. All data were presented as mean and standard deviation. All statistical analyses were done at a = 0.05.

Results

All subjects were male student athletes with average age of 20.26 ± 1.45 years. The average bodyweight, height, and body mass index were 61.80 ± 3.75 kg, 165.50 ± 4.33 cm, and 22.67 ± 0.95 kg/m². No report of injuries to the spine of lower extremities during the experimental period. Kruskal-Wallis test showed that all baseline characteristics were similar between groups (p > 0.05) (Table 1).

The result of Wilcoxon Sign Rank test in Table 2 indicated that all groups showed significant different in muscle leg power between pre-test and post-test measurements (p < 0.05). Students in MHW, MCW, HWI, and CWI groups all demonstrated a substantial increase in leg power, with greatest increase was found in MHW group which rise from 63.01 ± 3.85 watt to 74.64 ± 5.19 watt, representing an increase of 18.46%. The similar result was also observed in lactic acid level, where students in all group experienced significant improvement. The greatest decrease was reported in MHW group again, with lactic acid level dropping from

Table 1. Baseline Characteristic of Subjects (Mean ± SD)

Characteristic	Groups (n=40)				sig.
	MHW	MCW	HWI	CWI	
Age (year)	19.90 ± 1.22	20.20 ± 1.79	20.40 ± 1.52	19.85 ± 1.22	0.080
Weight (kg)	61.55 ± 3.06	60.32 ± 6.96	59.90 ± 4.45	60.11 ± 3.85	0.066
Height (cm)	165.80 ± 5.74	167.25 ± 9.53	166.10 ± 6.52	166.10 ± 5.20	0.320
Body mass index (kg/m ²)	22.67 ± 0.95	21.63 ± 0.65	21.78 ± 0.80	21.81 ± 0.80	0.212
Temperature (oC)	35.85 ± 0.64	34.22 ± 0.51	35.18 ± 0.50	34.95 ± 0.72	0.180
Heart rate (bpm)	79.45 ± 4.56	78.02 ± 6.00	78.77 ± 5.92	78.69 ± 7.05	0.100
Diastole (mmHg)	109.20 ± 6.82	104.56 ± 5.75	108.15 ± 5.86	107.55 ± 6.20	0.062
Systole (mmHg)	74.35 ± 5.43	74.87 ± 6.24	77.82 ± 4.29	76.76 ± 4.25	0.070
Training volume (hours/week)	7.26 ± 0.56	6.52 ± 0.88	7.50 ± 0.72	7.13 ± 0.56	0.100
Training experience (years)	6.20 ± 2.35	7.24 ± 2.02	7.67 ± 2.78	6.85 ± 3.12	0.752

11.12 ± 2.32 mmol/l before treatment to 4.27 ± 1.82 mmol/l after treatment was given, which corresponds to a reduction of 61.60%. Meanwhile, the smallest improvement in muscle leg and lactic acid level were found in group receiving passive rest and cold-water immersion or CWI, with the improvements were 11.12% and 51.95%, respectively (Table 3). These results, analyzed using the Wilcoxon Sign Rank Test, indicate that the interventions applied were effective in improving leg muscle power and reducing fatigue-related lactic acid buildup in all groups of participants.

Table 2. The Result of Leg Muscle Power and Lactic Acid Concentration Measurements

Group		Leg Power (watt)	Sig.	Lactic Acid (mmol/l)	Sig.
MHW	Pre-test	63.01 ± 3.85	0.001*	11.12 ± 2.32	0.001*
	Post-test	74.64 ± 5.19		4.27 ± 1.82	
MCW	Pre-test	60.93 ± 4.98	0.000*	10.60 ± 1.72	0.000*
	Post-test	72.11 ± 6.24		4.31 ± 0.92	
HWI	Pre-test	63.21 ± 4.20	0.000*	12.40 ± 2.46	0.000*
	Post-test	72.29 ± 5.28		5.24 ± 1.78	
CWI	Pre-test	59.60 ± 3.68	0.000*	11.30 ± 2.67	0.000*
	Post-test	66.23 ± 3.55		5.43 ± 1.49	

*significant at $\alpha = 0.05$ using Wilcoxon Sign Rank test

Table 3 presents the differences between groups in delta (change) in leg muscle power and lactic acid concentration, analyzed using the Kruskal-Wallis test. The change in leg muscle power was statistically significant in all groups ($p = 0.001$), with the MHW and MCW groups showing the highest increase ($\Delta = 11.63 \pm 4.11$ watts and 11.18 ± 4.29 watts, respectively), corresponding to an increase of ~18%. The HWI and CWI groups were followed by lower increases, especially CWI with the smallest increase ($\Delta = 6.63 \pm 2.37$ watts, 11.12%).

Table 3. Between-Group Differences in Delta of Leg Muscle Power and Lactic Acid Level

Group	Δ Leg Power (watt)		Sig.	Δ Lactic Acid (mmol/l)		Sig.
	Mean ± SD	%		Mean ± SD	%	
MHW	11.63 ± 4.11	18.46	0.001*	6.85 ± 2.66	61.60	0.020*
MCW	11.18 ± 4.29	18.35		6.29 ± 2.29	59.34	
HWI	9.08 ± 3.26	14.36		7.16 ± 2.65	57.74	
CWI	6.63 ± 2.37	11.12		5.87 ± 2.95	51.95	

*significant at $\alpha = 0.05$ using Kruskal-Wallis

For lactic acid, the decrease was also shown to be significantly different between groups ($p = 0.020$), with the HWI group showing the largest mean decrease ($\Delta = 7.16 \pm 2.65$ mmol/l), while the CWI group again showed the smallest reduction ($\Delta = 5.87 \pm 2.95$ mmol/l). Overall, this table highlights those different interventions resulted in varying degrees of improvement, with MHW and MCW appearing to be most effective in increasing leg muscle power, while HWI achieved the greatest reduction in lactic acid concentrations (Table 3).

Discussion

The findings of this study prove that recovery methods that combine sports massage and water immersion—both hot and cold—have proven to be more effective than immersion in water alone in accelerating post-exercise recovery. One of the underlying factors that could explain the mechanism is due to the synergistic physiological and neurological effects provided by each method (Duñabeitia et al., 2022; Romadhona et al., 2019; Stella et al., 2024). While water immersion primarily targets systemic recovery through hydrostatic stress and temperature-induced vascular responses (Matsui & Onodera, 2013), sport massage acts locally to improve circulation, reduce muscle stiffness, and promote lymphatic drainage (Davis et al., 2020). Cold water immersion (CWI) causes vasoconstriction, which reduces inflammation, edema, and perceived muscle pain (White & Wells, 2013), while hot water immersion (HWI) improves vasodilation, improving blood flow and tissue elasticity (Jackman et al., 2023). When preceded by sport massage, this effect is even stronger: cold-water immersion and massage will support reperfusion and helps to restore mobility by increasing circulation in previously narrowed vessels (Romadhona et al., 2019), while post-hot water immersion and sport massage benefits muscles that are already warm and relaxed, allowing for deeper and more effective tissue manipulation.

This sequential treatment that combines sports massage with water immersion has been shown to maximize the removal of metabolic waste—especially lactic acid (Wismanadi et al., 2024)—and accelerate the delivery of oxygen and nutrients to damaged muscle tissue (Moovenhan & Nivethitha, 2014). This process directly supports muscle cell regeneration and recovery of physical performance after intense exercise. Physiologically, water immersion utilizes the principle of hydrostatic pressure that increases venous blood flow back to the heart, as well as accelerates the removal of waste products such as hydrogen ions and lactic acid from the muscles (B. E. Kauffman & Kauffman, 2014). When combined with massage, this effect is amplified through mechanical stimulation of soft tissues that facilitate circulation, improve lymphatic drainage, and reduce muscle tension. A study by Afandi et al. (2023) showed that the combination of CWI and massage was more effective in reducing delayed muscle pain (DOMS) than CWI alone, while Angelopoulos et al. (2022) found that the combination of these interventions resulted in more optimal recovery in a shorter time.

In addition to the physiological aspect, the psychological benefits are also significant; massage is able to lower stress hormones such as cortisol and activate the parasympathetic nervous system (Baek et al., 2022; Lindgren et al., 2010), thereby helping athletes feel more relaxed and mentally recovered. This is especially important in the context of high-frequency sports training, where mental and physical endurance are equally crucial (Dakić et al., 2023). Therefore, this multimodal recovery approach not only provides immediate benefits in accelerating muscle strength recovery and lactic acid clearance, but also creates holistically optimal conditions for readiness for the next workout. The effectiveness of this approach is evident in the results of increased muscle strength and significant reduction in lactic

acid levels in the MHW and MCW groups in Tables 2 and 3 of this study.

The finding of this study showed that the combination of sport massage with hot-water bath was more effective in increasing leg muscle power and reducing lactic acid level after high-intensity exercise. Recovery using the combination of sports massage and hot water method has almost the same effect as recovery in contrast water (hot-cold), where there will be alternating vasodilation and vasoconstriction phases (Romadhona et al., 2019). The combination between sport massage followed by hot water bath is known to provide better effects than the other combinations, because alternating vasoconstriction and vasodilation are thought to work in a manner comparable to muscle pumping (vaso-pumping), increasing blood flow and removing metabolites so that it can improve recovery (Cochrane, 2004). Increased circulation will increase oxygen supply which eventually help to recycle lactic acid into an energy source (Setiawan et al., 2023).

Conclusion

The findings in this study highlight that various combination recovery strategies contribute to increasing leg muscle power and reducing lactic acid levels better than a single recovery method. When applied appropriately, this method can speed up post-workout recovery, restore muscle function more efficiently, and support overall athletic performance. Its effectiveness lies in the synergistic physiological and neurological effects provided by each method. Therefore, integrating this recovery approach into training routines can provide significant benefits for student-athletes who want to optimize recovery and maintain excellent physical condition.

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Conflict of Interest

The authors declare no conflict of interest.

References

- Pageaux, B., & Lepers, R. (2016). Fatigue Induced by Physical and Mental Exertion Increases Perception of Effort and Impairs Subsequent Endurance Performance. *Frontiers in Physiology*, 7, 587. <https://doi.org/10.3389/fphys.2016.00587>
- Lucertini, F., Gervasi, M., D'Amen, G., Sisti, D., Rocchi, M. B. L., Stocchi, V., & Benelli, P. (2017). Effect of water-based recovery on blood lactate removal after high-intensity exercise. *PLoS ONE*, 12(9), e0184240. <https://doi.org/10.1371/journal.pone.0184240>
- Finsterer, J. (2012). Biomarkers of peripheral muscle fatigue during exercise. *BMC Musculoskeletal Disorders*, 13(1), 218. <https://doi.org/10.1186/1471-2474-13-218>
- Robergs, R. A., Ghiasvand, F., & Parker, D. (2004). Biochemistry of exercise-induced metabolic acidosis. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology*, 287(3), R502-516. <https://doi.org/10.1152/ajpregu.00114.2004>
- Wan, J., Qin, Z., Wang, P., Sun, Y., & Liu, X. (2017). Muscle fatigue: General understanding and treatment. *Experimental & Molecular Medicine*, 49(10), e384. <https://doi.org/10.1038/emm.2017.194>
- Kreher, J. B., & Schwartz, J. B. (2012). Overtraining Syndrome. *Sports Health*, 4(2), 128-138. <https://doi.org/10.1177/1941738111434406>
- Rusdiawan, A., Sholikhah, A. M., & Prihatiningsih, S. (2020). The Changes in pH Levels, Blood Lactic Acid and Fatigue Index to Anaerobic Exercise on Athlete After NaHCO₃ Administration. *Malaysian Journal of Medicine and Health Sciences*, 16(Supp 16), 50-56.
- Budak, H. (2023). The Effect of Passive Rest and Sports Massage Recovery Methods on Blood Lactate Clearance After High-Intensity Exercise. *Akdeniz Spor Bilimleri Dergisi*, 6(2), 406-418. <https://doi.org/10.38021/asbid.1230326>
- Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts, A. J., Duffield, R., Erlacher, D., Halson, S. L., Hecksteden, A., Heidari, J., Kallus, K. W., Meeusen, R., Mujika, I., Robazza, C., Skorski, S., Venter, R., & Beckmann, J. (2018). Recovery and Performance in Sport: Consensus Statement. *International Journal of Sports Physiology and Performance*, 13(2), 240-245. <https://doi.org/10.1123/ijsp.2017-0759>
- Fares, R., Vicente-Rodríguez, G., & Olmedillas, H. (2022). Effect of Active Recovery Protocols on the Management of Symptoms Related to Exercise-Induced Muscle Damage: A Systematic Review. *Strength & Conditioning Journal*, 44(1), 57. <https://doi.org/10.1519/SSC.0000000000000654>
- Li, S., Kempe, M., Brink, M., & Lemmink, K. (2024). Effectiveness of Recovery Strategies After Training and Competition in Endurance Athletes: An Umbrella Review. *Sports Medicine - Open*, 10(1), 55. <https://doi.org/10.1186/s40798-024-00724-6>
- Hermoko, A. I., & Sulastri, S. (2023). Effects of Effleurage Massage in Reducing Pain in Intranatal Patients. *Contagion: Scientific Periodical Journal of Public Health and Coastal Health*, 5(4), Article 4. <https://doi.org/10.30829/contagion.v5i4.18394>
- Poppendieck, W., Wegmann, M., Ferrauti, A., Kellmann, M., Pfeiffer, M., & Meyer, T. (2016). Massage and Performance Recovery: A Meta-Analytical Review. *Sports Medicine*, 46(2), 183-204. <https://doi.org/10.1007/s40279-015-0420-x>
- Yuniana, R., Tomoliyus, Kushartanti, B. W., Arovah, N. I., & Nasrullo, A. (2022). Effectiveness of massage therapy continued exercise therapy against pain healing, ROM, and pelvic function in people with chronic pelvic injuries. *Journal of Physical Education and Sport*, 23(12), 1433-1441.
- Wiltshire, E., Belcourt, V., Pak, M., Hong, T., Rayner, J., & Tschakovsky, M. (2009). Massage Impairs Post Exercise Muscle Blood Flow and 'Lactic Acid' Removal. *Medicine and Science in Sports and Exercise*, 42, 1062-1071. <https://doi.org/10.1249/MSS.0b013e318c9214f>
- Prasetya, F. I., Hartono, S., Wahyuni, E. S., Muhammad, H. N., Tyas, E. S., & Sasmito, P. (2023). The Effect of Sports Massage and Acupressure on Lactic Acid Levels, Physical and Psychological Fatigue, and the Effect on Nurse Performance. *International Journal of Public Health Excellence (IJPHE)*, 3(1), Article 1. <https://doi.org/10.55299/ijphe.v3i1.732>

- Weerapong, P., Hume, P. A., & Kolt, G. S. (2005). The Mechanisms of Massage and Effects on Performance, Muscle Recovery and Injury Prevention. *Sports Medicine*, 35(3), 235-256. <https://doi.org/10.2165/00007256-200535030-00004>
- Thorpe, R. T. (2021). Post-exercise Recovery: Cooling and Heating, a Periodized Approach. *Frontiers in Sports and Active Living*, 3, 707503. <https://doi.org/10.3389/fspor.2021.707503>
- Cullen, T., Steward, C. J., Menzies, C., Pugh, C. J. A., & Douglas Thake, C. (2024). The effect of underwater massage during hot water immersion on acute cardiovascular and mood responses. *Journal of Thermal Biology*, 121, 103858. <https://doi.org/10.1016/j.jtherbio.2024.103858>
- Ghadicolaei, H. T., Gorji, M. A. H., Bagheri, B., Charati, J. Y., & Hadinejad, Z. (2019). The Effect of Warm Footbath on the Quality of Sleep on Patients with Acute Coronary Syndrome in Cardiac Care Unit. *Journal of Caring Sciences*, 8(3), 137-142. <https://doi.org/10.15171/jcs.2019.020>
- An, J., Lee, I., & Yi, Y. (2019). The Thermal Effects of Water Immersion on Health Outcomes: An Integrative Review. *International Journal of Environmental Research and Public Health*, 16(7), 1280. <https://doi.org/10.3390/ijerph16071280>
- Leeder, J., Gissane, C., van Someren, K., Gregson, W., & Howatson, G. (2011). Cold water immersion and recovery from strenuous exercise: A meta-analysis. *British Journal of Sports Medicine*, 46, 233-240. <https://doi.org/10.1136/bjsports-2011-090061>
- Cochrane, D. J. (2004). Alternating hot and cold water immersion for athlete recovery: A review. *Physical Therapy in Sport*, 5(1), 26-32. <https://doi.org/10.1016/j.ptsp.2003.10.002>
- Dakić, M., Toskić, L., Ilić, V., Đurić, S., Dopsaj, M., & Šimenko, J. (2023). The Effects of Massage Therapy on Sport and Exercise Performance: A Systematic Review. *Sports*, 11(6), 110. <https://doi.org/10.3390/sports11060110>
- Karadavut, Ö., & Acar, G. (2024). Effects of Sports Massage on Post-Workout Fatigue. *Uluslararası Türk Spor ve Egzersiz Psikolojisi Dergisi*, 4(1), 15-29. <https://doi.org/10.55376/ijtsep.1486062>
- Nédélec, M., McCall, A., Carling, C., Legall, F., Berthoin, S., & Dupont, G. (2013). Recovery in Soccer: Part II—Recovery Strategies. *Sports Medicine*, 43(1), 9-22. <https://doi.org/10.1007/s40279-012-0002-0>
- Duñabeitia, I., Arrieta, H., Rodriguez-Larrad, A., Gil, J., Esain, I., Gil, S. M., Irazusta, J., & Bidaurreazaga-Letona, I. (2022). Effects of Massage and Cold Water Immersion After an Exhaustive Run on Running Economy and Biomechanics: A Randomized Controlled Trial. *Journal of Strength and Conditioning Research*, 36(1), 149-155. <https://doi.org/10.1519/JSC.00000000000003395>
- Romadhona, N. F., Sari, G. M., & Utomo, D. N. (2019). Comparison of sport massage and combination of cold water immersion with sport massage on decrease of blood lactic acid level. *Journal of Physics: Conference Series*, 1146, 012012. <https://doi.org/10.1088/1742-6596/1146/1/012012>
- Stella, A. B., Dragonetti, A. M., Fontanot, S., Sabot, R., Martini, M., Galmonte, A., Canton, G., Deodato, M., & Murena, L. (2024). The Acute Effects of Cold Water Immersion and Percussive Massage Therapy on Neuromuscular Properties and Muscle Soreness after Exercise in Young Male Soccer Players. *Sports*, 12(6), 167. <https://doi.org/10.3390/sports12060167>
- Matsui, T., & Onodera, S. (2013). Cardiovascular responses in rest, exercise, and recovery phases in water immersion. *Journal of Physical Fitness and Sports Medicine*, 2(4), 475-480. <https://doi.org/10.7600/jpfsm.2.475>
- Davis, H. L., Alabed, S., & Chico, T. J. A. (2020). Effect of sports massage on performance and recovery: A systematic review and meta-analysis. *BMJ Open Sport — Exercise Medicine*, 6(1), e000614. <https://doi.org/10.1136/bmjsem-2019-000614>
- White, G. E., & Wells, G. D. (2013). Cold-water immersion and other forms of cryotherapy: Physiological changes potentially affecting recovery from high-intensity exercise. *Extreme Physiology & Medicine*, 2(1), 26. <https://doi.org/10.1186/2046-7648-2-26>
- Jackman, J. S., Bell, P. G., Van Someren, K., Gondek, M. B., Hills, F. A., Wilson, L. J., & Cockburn, E. (2023). Effect of hot water immersion on acute physiological responses following resistance exercise. *Frontiers in Physiology*, 14, 1213733. <https://doi.org/10.3389/fphys.2023.1213733>
- Wismanadi, H., Utama, D. K. A., & Wahyudi, H. (2024). Recovery of cold Water immersion as A reduction of Lactic levels In Persebaya U-19 football athletes context review. *Altius: Jurnal Ilmu Olahraga Dan Kesehatan*, 13(1), Article 1. <https://doi.org/10.36706/altius.v13i1.41>
- Mooventhan, A., & Nivethitha, L. (2014). Scientific Evidence-Based Effects of Hydrotherapy on Various Systems of the Body. *North American Journal of Medical Sciences*, 6(5), 199-209. <https://doi.org/10.4103/1947-2714.132935>
- Kauffman, B. E., & Kauffman, B. W. (2014). *Chapter 73—Aquatic therapy*. In T. L. Kauffman, R. Scott, J. O. Barr, & M. L. Moran (Eds.), *A Comprehensive Guide to Geriatric Rehabilitation* (Third Edition) (pp. 517–519). Churchill Livingstone. <https://doi.org/10.1016/B978-0-7020-4588-2.00073-5>
- Afandi, N. R., Kushartanti, B. W., Hafidz, A., & Chen, H. (2023). Literature Study: The Effect of Cold-Water Immersion and Sport Massage Techniques on Muscle Pain. *Journal of Sport Science and Education*, 8(2), 77-84.
- Angelopoulos, P., Diakoronas, A., Panagiotopoulos, D., Tsekoura, M., Xaplanteri, P., Koumoundourou, D., Saki, F., Billis, E., Tsepis, E., & Fousekis, K. (2022). Cold-Water Immersion and Sports Massage Can Improve Pain Sensation but Not Functionality in Athletes with Delayed Onset Muscle Soreness. *Healthcare*, 10(12), 2449. <https://doi.org/10.3390/healthcare10122449>
- Baek, J. Y., Lee, E., Gil, B., Jung, H.-W., & Jang, I.-Y. (2022). Clinical effects of using a massage chair on stress measures in adults: A pilot randomized controlled trial. *Complementary Therapies in Medicine*, 66, 102825. <https://doi.org/10.1016/j.ctim.2022.102825>
- Lindgren, L., Rundgren, S., Winsö, O., Lehtipalo, S., Wiklund, U., Karlsson, M., Stenlund, H., Jacobsson, C., & Brulin, C. (2010). Physiological responses to touch massage in healthy volunteers. *Autonomic Neuroscience*, 158(1), 105-110. <https://doi.org/10.1016/j.autneu.2010.06.011>
- Setiawan, D., Hartono, S., Wahjuni, E. S., Muhammad, H. N., Ayubi, N., Mukhtarsyaf, F., Hariadi, N., & Rahayu, S. (2023). Effect of Circulated Flow of Hydrotherapy on Reduction of Lactic Acid Levels in the Body after Physical Exercise. *International Journal of Human Movement and Sports Sciences*, 11(2), 360-367. <https://doi.org/10.13189/saj.2023.110213>

Порівняння ефективності застосування різних комбінацій методів відновлення щодо покращення потужності м'язів нижніх кінцівок та рівня молочної кислоти в крові

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 3 табл., 1 рис., 42 джерел.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу різних методів відновлення на поліпшення потужності м'язів нижніх кінцівок та зниження рівнів молочної кислоти серед студентів-спортсменів.

Матеріали та методи. У цьому дослідженні використовувалася рандомізована контрольна група з претест-посттестовим дизайном. Учасників дослідження було відібрано за методом простої випадкової вибірки, яка складалася з сорока студентів, розподілених на чотири групи: група спортивного масажу та процедури з гарячою водою (МГВ), група спортивного масажу та процедури з холодною водою (МХВ), група занурення в гарячу воду (ГВЗ) та група занурення в холодну воду (ХВЗ). Збирання даних здійснювалося за допомогою силової платформи для вимірювання потужності м'язів нижніх кінцівок (Вт), тоді як для визначення рівня молочної кислоти використовувався лактометр (ммоль/л). Аналіз даних проводився із застосуванням критерію знакових рангів Вілкоксона з метою вивчення різниці вимірюваних змінних перед початком і після завершення дослідження. Наступний етап полягав у проведенні тесту Краскела-Волліса для вивчення міжгрупових відмінностей, з подальшим застосуванням post-hoc тестування за допомогою критерію Манна-Вітні.

Результати. Результати показали, що в усіх групах (МГВ, МХВ, ГВЗ та ХВЗ) спостерігалось підвищення потужності м'язів нижніх кінцівок та зниження рівнів молочної кислоти. Застосування методу МГВ виявилось найефективнішим у збільшенні потужності м'язів нижніх кінцівок на 11.63 Вт, тоді як метод ГВЗ мав найбільш позитивний вплив на зниження рівнів молочної кислоти на 7.16 ммоль/л.

Висновки. Отримані дані свідчать про важливість поєднання спортивного масажу з терапією гарячою та холодною водою в якості реабілітаційної стратегії. Дослідники підкреслюють значущість використання зазначених методів терапії у поліпшенні потужності м'язів нижніх кінцівок та зниженні накопичення молочної кислоти, що сприяє оптимальній фізичній підготовці та результативності під час спортивних змагань.

Ключові слова: лактат, потужність, відновлення, спортивний масаж, студенти, занурення у воду.

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Developing the Indonesian Student Health Index as an Instrument for Monitoring and Evaluating Student Health in Physical Education

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Abstract

Objectives. This study aimed to develop the Indonesian Student Health Index (ISHI), a valid, reliable, and practical instrument to comprehensively assess student health conditions in Indonesia, covering physical health, mental well-being, healthy lifestyle behaviors, and emotional-social functioning.

Materials and Methods. A Research and Development (R&D) design was employed using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The instrument development involved literature review, nominal group technique (NGT) with teachers, and field observations. Five experts validated the blueprint. The instrument underwent trials in two sports disciplines and was implemented in five school settings across educational levels. Data were analyzed using Pearson correlation for validity, Cronbach's Alpha for reliability, inter-rater correlation for objectivity, and exploratory factor analysis.

Results. The instrument showed good internal consistency ($\alpha = 0.88$), sufficient validity ($r = 0.62$), and high objectivity ($r = 0.91$). Practicality and effectiveness scored 88% and 84%, respectively. KMO (0.782) and Bartlett's Test ($p < 0.001$) confirmed the factorability of the data. Field implementation involving 1,300 respondents (teachers and students) yielded highly positive responses (90–95%). Expert validation rated the blueprint as "Highly Valid" (average score = 4.41).

Conclusions. The findings indicate that the ISHI instrument is scientifically robust and field-ready for nationwide implementation. It enables early identification of student health issues and supports integrating health and education policies. ISHI is expected to serve as a strategic tool for health monitoring, data-driven interventions, and developing holistic educational environments in Indonesia.

Keywords: health index, physical education, monitoring and evaluating.

Introduction

Student health is an essential factor that influences academic performance. This relationship is evidenced by factors such as learning adaptation and academic self-efficacy,

indicating that these can improve educational outcomes (Song & Hu, 2024). Healthier behaviors and optimal health status correlate with better education outcomes (Lederer et al., 2024). Research (Carter-Pokras et al., 2021) Highlights the detrimental effects of poor health on academic performance. Additionally, nutrition, body weight, and physical fitness are manageable aspects of students' health that significantly influence school performance. This suggests that educational programs targeting these areas can be beneficial (Shaw et al., 2015; Soenyoto et al., 2025).

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Furthermore, student well-being, which encompasses positive and negative dimensions, plays a role in academic achievement. Positive well-being can enhance academic performance, while negative aspects of well-being, such as anxiety and social problems, do not directly correlate with educational outcomes (Morinaj & Hascher, 2022). These studies emphasize the intertwined nature of student health and academic success, advocating for an integrated approach to support student well-being and educational achievement.

Many factors, including behavioral, psychological, and environmental dimensions, influence student health. Behavioral factors such as physical inactivity, alcohol abuse, smoking, and poor eating habits are common among students and contribute significantly to chronic diseases and poor well-being, with most students reporting insufficient physical activity and poor dietary habits (Kilroy et al., 2024). Psychological factors, especially during the COVID-19 pandemic, have exacerbated mental health issues, with increased anxiety and depression noted among students, particularly females, due to pandemic-related uncertainty and restrictions (Anser et al., 2021; S. et al., 2023). Environmental factors, such as pollution and inadequate healthcare support, further compound these challenges, especially during the pandemic, when students' outdoor activities were restricted (Anser et al., 2021). Additionally, institutional factors such as perceptions of a supportive environment and access to healthcare services are crucial, as international students often lack awareness and access to these services, impacting their mental health and academic performance (Aliriad et al., 2024; Sancu et al., 2022). Understanding these diverse factors is essential for developing effective health promotion strategies and interventions tailored to the unique needs of the student population.

Health data on Indonesian students reveal significant concerns regarding physical and mental health. A study of adolescents aged 15–19 years found a prevalence of 16.8% for prehypertension and 2.6% for hypertension, with risk factors including age, gender, and obesity, highlighting the early onset of cardiovascular risk in this population (Sudikno et al., 2023). Mental health issues are also prevalent, particularly among medical students, where 22.2% reported symptoms of depression and 48.1% reported anxiety, with dysfunctional coping strategies and low resilience identified as predictors (Ramadiano et al., 2022). Another study reinforces these findings, showing high levels of fatigue and mild mental illness among medical students, with 93% feeling disengaged and 95% feeling tired (Lili et al., 2022). Furthermore, a mixed-methods study of adolescents in Jakarta and South Sulawesi aimed to measure the burden of metabolic syndrome and poor mental health, emphasizing the need for comprehensive data to inform policy and intervention strategies (Azzopardi et al., 2020). These findings underscore the critical need for targeted health programs to address physical and mental health challenges among Indonesian students, with a focus on early intervention and support systems to mitigate these risks.

Implementing free nutritious meals in schools has been explored through various programs and studies, revealing both benefits and challenges. In the US, the School Lunch Program has faced criticism for its inefficiencies, such as eligibility issues and debt collection, which have led to practices like lunch shaming that negatively impact students'

social and emotional well-being. Reform suggestions include improved federal regulations and research on universal free meal programs to better support students' nutritional needs (Gagliano et al., 2023). In New Zealand, a government-funded healthy school lunch program introduced in 2020 has shown positive impacts, such as improved food security and reduced financial stress for families. However, challenges like low uptake and food waste remain. The success of this program is linked to a school environment that promotes participation and involves students and families in planning. Community Eligibility in the US allows universal free meals in areas with high poverty rates. The Community Eligibility Provision in the US enables universal free meals in high-poverty areas, reducing meal costs without compromising nutritional quality, although its effectiveness varies by school size. In Norway, a study on free healthy school meals showed increased vegetable intake among children, highlighting such programs' potential public health benefits. However, there were limited changes in other dietary behaviors (Vik et al., 2020). While free nutritious meal programs can improve food security and eating habits, their success depends on practical implementation, community engagement, and addressing logistical challenges. However, in Indonesia, research on free nutritious meals remains limited.

Although various instruments have been developed to assess student health and well-being, most previous studies still show significant limitations. First, the study by (Tang et al., 2024) Only the Health Information Preference Questionnaire was validated in a population of students in China, which limits the generalization of the results to different age, cultural, and educational contexts. Second, the study by (Tomin et al., 2020) The personal Well-Being Index for School Children revealed issues with cross-cultural alignment, particularly when analyzing data from Australia and Portugal, indicating potential bias in item structure across countries. Third, (Linden & Ecclestone, 2024) The Research faced external validity challenges due to a small and unbalanced follow-up sample size, thereby reducing the generalizability of findings from the Brief-PSSI. Fourth (Fiore et al., 2024), noted low reliability ($\alpha = 0.471$) in the interactive component of the Environmental Health Literacy Index (EHLI), which may cast doubt on the stability and accuracy of the tool in measuring specific literacy dimensions. Fifth, the adaptation of the instrument from the workplace to the educational setting by (Gómez-Chacón et al., 2021) Revealed factor structure mismatches in the new context, indicating that the conceptual model from the workplace cannot be directly applied to the student population without significant revisions.

From the preliminary study, it is clear that a student health index is needed. This is related to: (1) the limited availability of comprehensive data and information on student health in Indonesia. (2) It is essential to have a measurable and standardized student health index to monitor or evaluate the health status of students nationwide. (3) Identifying the most relevant health issues among students. (4) Formulating effective health policies and programs. (5) Allocating resources efficiently. (6) Monitoring and evaluating the impact of health interventions.

This research will contribute to a more comprehensive understanding of student health conditions in Indonesia. The results of this research can be used as a basis for developing

a valid and reliable Indonesian student health index. The resulting student health index can be a valuable tool for the government, educational institutions, health workers, and other relevant parties to improve student health in Indonesia.

Research Objectives:

- a) Developing a comprehensive and standardized Indonesian Student Health Index instrument.
- b) Testing the validity and reliability of the Indonesian Student Health Index instrument.
- c) Providing recommendations for improving student health programs and policies in Indonesia.

Materials and Methods

Type and Design of Research

This research is a research and development (R&D) study based on Dick and Carey's ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. This model was chosen because it integrates theoretical and empirical approaches and allows for systematic revisions at each stage, resulting in a final product that is scientifically accountable and ready for widespread implementation.

Research Procedures

Analysis Stage

This stage is conducted to obtain initial information through a needs assessment. The steps include:

1. Literature and theory review from various sources (books, journals, and scientific reports) related to the instrument to be developed.
2. Empirical data collection through the Nominal Group Technique (NGT) involving teachers to identify instrument items.
3. Field observations and questionnaire distribution to understand the conditions of Student Health Index (ISHI) data collection.

This stage's outcome is compiling a needs description and instrument items as the basis for the initial product design.

Design Stage

In this stage, the initial product design in an instrument blueprint is developed based on the initial study and NGT results. The blueprint includes:

1. Instrument grid
2. Components of validity, reliability, objectivity, practicality, and effectiveness.

Initial validation is conducted by five experts (two lecturers with doctoral degrees and three sports practitioners) to test the feasibility of the initial design.

Development Stage

This stage produces an initial product from a guidebook covering all aspects that have been designed. Expert validation is followed by testing on two sports branches to test the validity and reliability of the instrument, as well as factor analysis. If feedback is received, revisions are made

Table 1. Questionnaire Grid Table

Subject	This stage is conducted to obtain initial information through a needs assessment. The steps include:	Number of Items	Total Items
Subject Matter Expert	Literature and theory review from various sources (books, journals, and scientific reports) related to the instrument to be developed.	8	26
	Self contained	6	
	Stand alone	2	
	Adaptive	4	
	User friendly	6	
Trial	Validity	92	216
	Reliability	92	
	Objectivity	92	
	Practicality	19	
	Effectiveness	13	

to improve the product. Objectivity testing is conducted by correlating the assessment results of two or more evaluators.

Objectivity Testing:

The inter-rater correlation coefficient (r) is used, with the following interpretation:

- 0.95–1.00 = Very good
- 0.85–0.94 = Good
- 0.70–0.84 = Fair
- 0.00–0.69 = Unusable

Implementation Stage

Implementation is conducted in five priority sports branches in Semarang City to test the practicality and effectiveness of the ISHI instrument. Revisions are made based on field feedback to produce a product ready for broader use.

Statistical Analysis

Evaluation was conducted to ensure the readiness of the final ISHI product before dissemination.

Evaluation included:

- Expert validation.
- Validity test (Pearson).
- Reliability (Cronbach's Alpha).
- Objectivity (inter-rater r).
- Practicality and effectiveness for users.
- Exploratory factor analysis.

Analysis Techniques and Statistical Tests

- Validity Test.
- Reliability Test.
- Objectivity Test.
- Prerequisite Test for Factor Analysis.

To test the validity of the instrument through factor analysis, the following tests are conducted:

- Kaiser-Meyer-Olkin (KMO).
- Bartlett's Test of Sphericity.

- Measure of Sampling Adequacy (MSA).

Table 2. Criteria for Interpreting Validator Suitability Percentages

Score (%)	Validity	Decision
81–100	Highly Valid	No revision needed
61–80	Valid	Valid Minor revision
41–60	Sufficiently Valid	Valid Major revision
21–40	Less Valid	Valid Total revision
0–20	Not Valid	Not feasible

Table 3. Interpretation Criteria for Practicality and Effectiveness

Score (%)	Interpretation
81–100	Very Strong
61–80	Strong
41–60	Fairly Strong
21–40	Weak
0–20	Very Weak

Results

Table 4. Expert Validation Results for the ISHI Instrument Blueprint

No	Assessment Aspect	Average Validator Score	Validity Category	Revision Decision
1	Self Instruction	4.60	Highly Valid	No Revision Needed
2	Self Contained	4.40	Highly Valid	No Revision Needed
3	Stand Alone	4.20	Valid	Minor Revision
4	Adaptive	4.35	Valid	Minor Revision
5	User Friendly	4.50	Highly Valid	No Revision Needed
	Total Average	4.41	Highly Valid	Minor Revision (if necessary)

The Indonesian Students Health Index (ISHI) instrument was implemented in several stages, starting with expert validation, validity and reliability testing, practicality and effectiveness testing, and direct implementation in the field. The expert validation result for the instrument blueprint showed that all aspects received high scores, with an average total of 4.41. The self-instruction aspect received the highest score (4.40), and the user-friendly aspect (4.50). Meanwhile, the stand-alone and adaptive aspects scored 4.20 and 4.35, respectively, categorized as valid and requiring minor revisions. These results indicate that the instrument blueprint is suitable for use with minor improvements to some technical aspects (table 4).

Table 7. Factor Analysis Prerequisite Test

No	Test	Value	Criteria	Decision
1	Kaiser-Meyer-Olkin (KMO)	0.782	> 0.5	Suitable for Factor Analysis
2	Bartlett's Test	Sig. = 0.000	< 0.05	Proceed with Factor Analysis
3	MSA (all items)	> 0.6	≥ 0.5	Meets Requirements

Table 5. Results of Instrument Validity and Reliability Tests

No	Test Aspect	Number of Items	Average Coefficient Value	Category
1	Validity (Pearson)	92	0.62	Fair
2	Reliability (Cronbach's Alpha)	92	0.88	Good
3	Objectivity (inter-rater r)	92	0.91	Good

Furthermore, validity was measured through item-total correlation and deemed valid if $r > 0.3$, while Cronbach's Alpha reliability was considered good if $\alpha \geq 0.7$. The validity test on the 92 instrument items yielded an average coefficient value of 0.62, which falls under the sufficient validity category. Meanwhile, the reliability of the instrument measured using Cronbach's Alpha showed a value of 0.88, indicating a high level of internal consistency in the good category. The objectivity of the instrument was also proven to be good, with an inter-rater correlation coefficient of 0.91, meaning that the assessments between judges or evaluators had a high level of consistency (table 5).

Table 6. Practicality Test Results

No	Test Component	Average Score (%)	Category
1	Practicality	88%	Fair
2	Effectiveness	84%	Good

From the practicality test results, an average score of 88% was obtained, indicating that the instrument is reasonably practical for use by teachers and students in the data collection process. The instrument's effectiveness in its context of use also received a score of 84%, which falls into the good category. These two results indicate that, in addition to being valid and reliable, the ISHI instrument is also easy to implement in the field and can provide beneficial results in measuring student health (table 6).

The prerequisite tests for factor analysis indicate that the obtained data are suitable for further analysis. The Kaiser-Meyer-Olkin (KMO) value of 0.782 indicates the suitability of factor analysis. At the same time, the Bartlett's Test results show a significance value of 0.000 (< 0.05), meaning the data meet the criteria for exploratory factor analysis. In addition, the Measure of Sampling Adequacy (MSA) value for all items is above 0.6, reinforcing the feasibility of the analysis (table 7).

The instrument was tested across various educational levels during the field implementation stage with 1,300 respondents. One hundred physical education teachers showed a positive response of 95%, indicating excellent acceptance of the instrument. Similarly, elementary school students ($n = 400$) gave a positive response of 90%, junior

Table 8. Summary of Instrument Implementation Results in the Field

No	Respondents	Number of Respondents	Positive Responses (%)
1	PE Teachers	100	95 %
2	Elementary School Students	400	90 %
3	Junior High School Students	400	92 %
4	High School Students	400	91 %

high school students ($n = 400$) of 92%, and senior high school students ($n = 400$) of 91%. The high percentage of positive responses indicates that the ISHI instrument is well-received by teachers and students of various age levels. This strengthens the evidence that the ISHI instrument has high potential for widespread adoption in measuring student health in Indonesia (table 8).

Discussion

The health of elementary and secondary school students plays a crucial role in shaping the foundation for their academic success and character development. At this age, various health-related behaviors such as eating patterns, physical development, activity, and sleeping habits begin to form and contribute directly to concentration, learning, participation, and social interaction at school (Adi S et al., 2025; Hammoudi Halat et al., 2023). Protective behaviors such as regular exercise and consumption of nutritious foods have been shown to correlate positively with better academic achievement. In contrast, risky behaviors such as a sedentary lifestyle or unhealthy eating habits can impair students' learning performance (Riziq Amir et al., 2023). Additionally, physical fitness is an important indicator of actively engaging in learning activities (Teferi, 2020). The mental health of elementary and secondary education students also deserves serious attention. Academic pressure, social issues, and lack of access to emotional support can trigger stress and anxiety, ultimately disrupting their learning achievements.

Efforts to improve the quality of education for elementary and secondary school students must be carried out with systematic health monitoring to create a holistic learning approach. (Rosmalina & Elfrianto, 2024). At this level, students are in a highly dynamic phase of growth and development, where physical, mental, and social health greatly influence their involvement in the learning process. Students who experience fatigue, stress, malnutrition, or other health problems tend to have low concentration and declining academic performance. Therefore, routine health monitoring is not just an additional activity, but an integral part of efforts to create a healthy and productive learning environment (Gustiani et al., 2023).

Developing the Indonesian Student Health Index (ISHI) is a strategic response to Indonesia's lack of standardized instruments for monitoring student health. Until now, the health conditions of students at the elementary to secondary levels have only been partially and sporadically reflected through sectoral programs such as UKS or limited

survey results. Standardized instruments are crucial for comprehensively and accurately measuring student health, especially within Indonesia's education system's complex and diverse context. A reliable and valid assessment is needed to obtain an overview of the student's health status and inform targeted intervention strategies and support systems. Aspects but also covers dimensions of mental health, healthy lifestyle behaviors, and students' social-emotional well-being based on literature reviews and input from education and health practitioners. The validity and reliability of ISHI have been empirically tested, making it a trustworthy tool for evaluating students' health conditions across various educational levels (Hidayati et al., 2021).

The existence of this instrument aligns with international practices that have developed standardized measurement tools, such as the Warwick-Edinburgh Mental Well-being Scale (WEMWBS), which has been adapted to the Indonesian cultural context, demonstrating strong internal consistency and factorial validity (Ramadhana, 2023). ISHI also adapts to local needs, considering Indonesia's diversity of culture, society, and educational environmental conditions. The absence of a national student health index further emphasizes the urgency of developing this instrument. ISHI is crucial for addressing the need for accurate and measurable data in student health management within educational institutions (Widodo et al., 2024). Thus, ISHI serves as a measurement tool, a means to detect early health risks among students, and a foundation for more precise and personalized health interventions.

In the context of policy implementation, the ISHI plays a vital role in supporting evidence-based policy efforts, where every policy targeting students is based on valid and relevant data. Through ISHI, policymakers at the school, regional, and national levels can obtain structured data on students' health status, which can be used to design more targeted intervention programs in education, health promotion, or supporting facilities (Retnowati et al., 2023). Additionally, with the availability of periodic data generated from the use of ISHI, the evaluation process of effectiveness, such as UKS, the provision of unrestricted use of ISHI, or physical fitness programs, can be conducted more objectively (Wang et al., 2021). ISHI is also important for early detection of health issues such as rising rates of prehypertension, obesity, academic stress, and emotional mental disorders, which have recently become increasingly common among students but are often not systematically identified.

The development and implementation of the Indonesian Student Health Index (ISHI) enable schools to assess students' health conditions measurably based on indicators that cover physical, mental, and healthy lifestyle dimensions. The development of ISHI strengthens the integration between the education and health sectors in supporting holistic student development. Data obtained from this instrument can be used as feedback for teachers and educational staff in adjusting teaching strategies according to students' needs, as well as a basis for schools or policymakers in designing more targeted interventions. At the elementary and secondary school levels, students are not yet fully able to articulate their health conditions independently. ISHI-based monitoring is crucial for detecting learning barriers stemming from health issues. Thus, integrating the education and health monitoring systems through ISHI enhances the effectiveness of the learning process and ensures long-term well-being. Indonesia can establish a student health monitoring system

that is cross-level, cross-sectoral, and sustainable, which will ultimately contribute directly to improving the quality of education and the health status of the nation's youth.

Conclusions

This study successfully developed the Indonesian Student Health Index (ISHI) as a valid, reliable, and applicable tool for assessing the overall health condition of students. ISHI was developed through a systematic approach using the ADDIE model, which includes expert validation, validity testing, reliability testing, objectivity testing, practicality testing, and effectiveness testing. The research results indicate that this instrument is highly suitable for use, both in terms of structure and content, and has been well-received by field users such as physical education teachers and students from various educational levels.

The ISHI covers the dimensions of physical health, mental health, healthy lifestyle behaviors, and students' well-being, enabling early detection of health issues that may hinder learning. This instrument also provides a strong foundation for developing policies, intervention programs, and national monitoring and evaluation of students' health. Thus, ISHI significantly contributes to creating a holistic, data-driven education approach that physically prioritizes the well-being of students in a sustainable manner.

Conflict of Interest

The authors declare no conflict of interest.

References

- Song, X., & Hu, Q. (2024). The relationship between Freshman students' mental health and academic achievement: chain mediating effect of learning adaptation and academic self-efficacy. *BMC Public Health*, 24(1), 3207. <https://doi.org/10.1186/s12889-024-20738-9>
- Lederer, A.M., Oswalt, S.B., Parise, I.M., Rosenthal, M.N., & Horlick, R. (2024). U.S. postsecondary students' health and academic outcomes: A comprehensive scoping review. *Preventive Medicine*, 187, 108059. <https://doi.org/10.1016/j.ypmed.2024.108059>
- Carter-Pokras, O. D., Bugbee, B. A., Gold, R. S., Lauver, P. E., Aiken, R., & Arria, A. M. (2021). Utilizing Student Health and Academic Data: A County-Level Demonstration Project. *Health Promotion Practice*, 22(2), 193-203. <https://doi.org/10.1177/1524839919862796>
- Shaw, S.R., Gomes, P., Polotskaia, A., & Jankowska, A.M. (2015). The relationship between student health and academic performance: Implications for school psychologists. *School Psychology International*, 36(2), 115-134. <https://doi.org/10.1177/0143034314565425>
- Soenyoto, T., Adi, S., Darmawan, A., Aliriad, H., & Utama, M.B. R. (2025). Smart physical education: Integrating flipped classroom with IoT and android for enhanced learning. *Journal of Human Sport and Exercise*, 20(4), 1122-1132. <https://doi.org/10.55860/ydz9ex90>
- Morinaj, J., & Hascher, T. (2022). On the Relationship Between Student Well-Being and Academic Achievement. *Zeitschrift Für Psychologie*, 230(3), 201-214. <https://doi.org/10.1027/2151-2604/a000499>
- Kilroy, S., O'Connor, S., Hackett, F., & Gregory, N. (2024). 39 Are you well? An investigation into the health-related behaviours and wellbeing of Dundalk Institute of Technology (DKIT) students. A pilot study. *European Journal of Public Health*, 34(Suppl 2). <https://doi.org/10.1093/eurpub/ckae114.040>
- S., A., Ks., S., Rohidi, T. R., & Rustiadi, T. (2023). Digital literacy of physical education teachers in the 5.0 era. *SPORT TK-Revista EuroAmericana de Ciencias Del Deporte*, 12(SE), 13. <https://doi.org/10.6018/sportk.562941>
- Anser, M.K., Sharif, M., Khan, M.A., Nassani, A.A., Zaman, K., Abro, M.M. Q., & Kabbani, A. (2021). Demographic, psychological, and environmental factors affecting student's health during the COVID-19 pandemic: on the rocks. *Environmental Science and Pollution Research International*, 28(24), 31596-31606. <https://doi.org/10.1007/s11356-021-12991-x>
- Aliriad, H., Adi S, Manullang, J. G., Endrawan, I. B., & Satria, M. H. (2024). Improvement of Motor Skills and Motivation to Learn Physical Education Through the Use of Traditional Games. *Physical Education Theory and Methodology*, 24(1), 32-40. <https://doi.org/10.17309/tmf.2024.1.04>
- Sanci, L., Williams, I., Russell, M., Chondros, P., Duncan, A.-M., Tarzia, L., Peter, D., Lim, M.S. Y., Tomin, A., & Minas, H. (2022). Towards a health promoting university: descriptive findings on health, wellbeing and academic performance amongst university students in Australia. *BMC Public Health*, 22(1), 2430. <https://doi.org/10.1186/s12889-022-14690-9>
- Sudikno, S., Mubasyiroh, R., Rachmalina, R., Arfines, P.P., & Puspita, T. (2023). Prevalence and associated factors for prehypertension and hypertension among Indonesian adolescents: a cross-sectional community survey. *BMJ Open*, 13(3), e065056. <https://doi.org/10.1136/bmjopen-2022-065056>
- Ramadiano, A.S., Kusumadewi, I., Agiananda, F., & Raharjanti, N.W. (2022). Symptoms of depression and anxiety in Indonesian medical students: association with coping strategy and resilience. *BMC Psychiatry*, 22(1), 92. <https://doi.org/10.1186/s12888-022-03745-1>
- Lili, R., Molodyski, A., Farrell, S.M., Citraningtyas, T., & Kloping, N.A. (2022). Wellbeing and mental health among medical students in Indonesia: A descriptive study. *International Journal of Social Psychiatry*, 68(6), 1277-1282. <https://doi.org/10.1177/00207640211057709>
- Azzopardi, P.S., Willenberg, L., Wulan, N., Devaera, Y., Medise, B., Riyanti, A., Ansariadi, A., Sawyer, S., Wiguna, T., Kaligis, F., Fisher, J., Tran, T., Agius, P.A., Borschmann, R., Brown, A., Cini, K., Clifford, S., Kennedy, E.C., Pedrana, A., ... Luchters, S. (2020). Direct assessment of mental health and metabolic syndrome amongst Indonesian adolescents: a study design for a mixed-methods study sampled from school and community settings. *Global Health Action*, 13(1), 1732665. <https://doi.org/10.1080/16549716.2020.1732665>
- Gagliano, K.M., Yassa, M.O., & Winsler, A. (2023). Stop the shame and the hunger: The need for school meal program reform. *Children and Youth Services Review*, 155, 107245. <https://doi.org/10.1016/j.childyouth.2023.107245>
- Vik, F.N., Heslien, K.E. P., Van Lippevelde, W., & Øverby, N.C. (2020). Effect of a free healthy school meal on fruit, vegetables and unhealthy snacks intake in Norwegian 10- to 12-year-old children. *BMC Public Health*, 20(1), 1369. <https://doi.org/10.1186/s12889-020-09470-2>

- Tang, K., Yuan, J., & Luo, L. (2024). Validity evaluation of the Health Information Preferences Questionnaire among college students. *Frontiers in Public Health*, 12, 1249621. <https://doi.org/10.3389/fpubh.2024.1249621>
- Tomyn, A.J., Stokes, M.A., Cummins, R.A., & Dias, P.C. (2020). A Rasch Analysis of the Personal Well-Being Index in School Children. *Evaluation & the Health Professions*, 43(2), 110-119. <https://doi.org/10.1177/0163278718819219>
- Linden, B., & Ecclestone, A. (2024). Preliminary evidence for the validity of the Brief Post-Secondary Student Stressors Index (Brief-PSSI): A cross-sectional psychometric assessment. *PloS One*, 19(1), e0297171. <https://doi.org/10.1371/journal.pone.0297171>
- Fiore, M., Lorini, C., Bonaccorsi, G., Paoli, S., Vaccaro, G., Verani, M., Federigi, I., Ferrante, M., & Carducci, A. (2024). Development and validation of the Environmental Health Literacy Index: a new tool to assess the environmental health literacy among university students. *European Journal of Public Health*, 34(5), 1001-1007. <https://doi.org/10.1093/eurpub/ckae120>
- Gómez-Chacón, R., Fernández-Martínez, N., & Gálvez-Ruiz, P. (2021). Healthy Students: Adaptation and Validation of the Instrument from the Workplace to the Educational Field. *Sustainability*, 13(3). <https://doi.org/10.3390/su13031134>
- Adi S, Soenyoto, T., Yuwono, C., & Nurharsono, T. (2025). Exploring physical literacy, physical activity, motivation, and learning outcomes in elementary school PE. *Edu Sportivo: Indonesian Journal of Physical Education*, 6(1), 67-77. [https://doi.org/10.25299/esijope.2025.vol6\(1\).17879](https://doi.org/10.25299/esijope.2025.vol6(1).17879)
- Hammoudi Halat, D., Hallit, S., Younes, S., Alfikany, M., Khaled, S., Krayem, M., El Khatib, S., & Rahal, M. (2023). Exploring the effects of health behaviors and mental health on students' academic achievement: a cross-sectional study on Lebanese university students. *BMC Public Health*, 23(1), 1228. <https://doi.org/10.1186/s12889-023-16184-8>
- Riziq Amir, O. A., Almobasher, Z. M., & Abbas, I. M. (2023). Health-Related Physical Fitness and its Relationship to the Level of Academic Achievement among A Sample of Secondary School Students in the City of Amman. *International Journal of Membrane Science and Technology*, 10(2), 112-120. <https://doi.org/10.15379/ijmst.v10i2.1176>
- Teferi, G. (2020). The Effect of Physical Activity on Academic Performance and Mental Health: Systematic Review. *American Journal of Science, Engineering and Technology*, 5, 131. <https://doi.org/10.11648/j.ajset.20200503.12>
- Rosmalina, R., & Elfrianto, E. (2024). Evaluation And Monitoring as An Effort to Improve the Quality of Education. *Indonesian Journal Education*, 3, 8-15. <https://doi.org/10.56495/ije.v3i1.567>
- Gustiani, F., Barus, I., & Elfrianto, E. (2023). Monitoring and Evaluation to Improve School Quality. *Indonesian Journal Education*, 2, 99-103. <https://doi.org/10.56495/ije.v2i4.564>
- Hidayati, H.N., Hayat, B., & Rahayu, W. (2021). Assessment of the Validity and Reliability of Mental Health Instruments of High School Student in Indonesia. *Başlık*, 10(2), 729-742. <https://doi.org/10.12973/eu-jer.10.2.729>
- Ramadhana, M.R. (2023). Psychometric Evaluation of the Warwick-Edinburgh Mental Well-Being Scale on Indonesian Students. *Journal An-Nafs: Kajian Penelitian Psikologi*, 8(2), 182-198. <https://doi.org/10.33367/psi.v8i2.3817>
- Widodo, W., Degeng, I.N. S., Pali, M., & Hitipeuw, I. (2024). Development and Validation of the Student Well-Being Scale for Elementary School Using Rasch Model Analysis. *Journal of Educational, Health and Community Psychology*, 13(2), 454-479. <https://doi.org/10.12928/jehcp.v13i2.28768>
- Retnowati, R., Siregar, K., Nuridzin, D., & Ilyas, A. (2023). Towards Digital Health Transformation: The Urgency of Electronic-Based Student Health Records. *Jurnal Biostatistik, Kependudukan, Dan Informatika Kesehatan*, 4. <https://doi.org/10.51181/bikfokes.v4i1.7327>
- Wang, H., Wang, N., Li, M., Mi, S., & Shi, Y. (2021). Student Physical Health Information Management Model under Big Data Environment. *Scientific Programming*, 2021(1), 5795884. <https://doi.org/10.1155/2021/5795884>

Розроблення індексу здоров'я індонезійських учнів як інструменту моніторингу та оцінки здоров'я учнів у фізичному вихованні

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 8 табл., 34 джерела.

Мета дослідження. Мета цього дослідження полягала у розробленні Індекс здоров'я індонезійських учнів (ІЗІУ) – валідного, надійного та практичного інструменту для комплексного оцінювання стану здоров'я учнів в Індонезії, що охоплює фізичне здоров'я, психічне благополуччя, здоровий спосіб життя та емоційно-соціальне функціонування.

Матеріали та методи. Застосовано дизайн науково-дослідних та дослідно-конструкторських робіт (НДДКР) із використанням моделі ADDIE (аналіз, дизайн, розробка, впровадження, оцінка). Розробка інструменту включала огляд літератури, метод номінальних груп (МНГ) із викладачами та польові спостереження. П'ять експертів підтвердили достовірність проекту. Інструмент пройшов випробування у двох спортивних дисциплінах і був впроваджений у п'яти шкільних навчальних закладах різних рівнів освіти. Аналіз даних проводився за допомогою коефіцієнта кореляції Пірсона для перевірки валідності, коефіцієнта альфа Кронбаха з метою оцінки надійності, міжекспертної кореляції об'єктивності та експлораторного факторного аналізу.

Результати. Інструмент показав добру внутрішню узгодженість ($\alpha = 0.88$), достатню валідність ($r = 0.62$) та високу об'єктивність ($r = 0.91$). Практичність та ефективність становили відповідно 88% та 84%. Критерій Кайзера-Майєра-Олкіна (0.782) та критерій Бартлетта ($p < 0.001$) підтвердили факторизованість даних. Реалізація проекту за участі 1,300 респондентів (вчителів та учнів) отримала високопозитивні відгуки (90–95%). Експертна валідація оцінила проект як «високовалідний» (середній бал = 4.41).

Висновки. Результати дослідження свідчать про наукову обґрунтованість інструменту ІЗІУ та практичну готовність до впровадження на національному рівні. Застосування цього інструменту дозволяє на ранній стадії виявляти проблеми зі здоров'ям учнів та сприяє інтеграції стратегій у сфері охорони здоров'я та освіти. Передбачається, що ІЗІУ слугуватиме стратегічним інструментом для моніторингу здоров'я, інтервенцій на основі даних та розвитку комплексних освітніх середовищ в Індонезії.

Ключові слова: індекс здоров'я, фізичне виховання, моніторинг та оцінка.

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The Efficiency of Physical Therapy for Women with Degenerative Diseases of the Cervical and Thoracic Spine Based on the BodyArt Fitness Method

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Abstract

Objectives. This study aimed to scientifically substantiate, develop and evaluate the effectiveness of including the BodyArt fitness method in the rehabilitation plan of female patients with cervicothoracic osteochondrosis in the phase of periodic maintenance rehabilitation.

Materials and Methods. The study involved 57 women who were randomly divided into a control group (CG, n = 27, age 49.3 ± 1.5 years) and a main group (MG, n = 30, age 50.1 ± 1.2 years) using the sealed envelope method. Inclusion criteria comprised females aged 40 to 60 years with a diagnosis of osteochondrosis of the cervicothoracic region (OCT), confirmed by instrumental methods (X-ray, CT or MRI), established at least one year before the onset of the study. Exclusion criteria were: acute pain, severe somatic pathology, fractures or tumors of the vertebrae. All participants provided written informed consent to be involved in the study. The CG underwent standard rehabilitation according to the hospital protocol (training — 30 min, 4-6 sessions; therapeutic gymnastics — 3 times a week for 1 hour; manual therapy — 6-8 sessions). The MG program included the BodyArt fitness method instead of standard exercises. The study spanned two rehabilitation cycles (28 days). To assess the effectiveness of the intervention, clinical and instrumental methods and scales were used (McGill Pain Questionnaire, MMT of the back and shoulder girdle muscles, cervical and thoracic spine mobility, Index of disability due to neck pain (Neck Disability Index, NDI)), as well as statistical methods.

Results. In patients of the main group, after using BodyArt fitness, there was a significant decrease in pain intensity according to the results of the McGill Pain Questionnaire (MPQ) ($p < 0.01$), an improvement in muscle strength ($p < 0.05$), and an increase in the range of motion in the cervical and thoracic spine (p5). In particular, the NDI disability index decreased by 34.7% ($p < 0.01$).

Conclusions. The findings revealed that incorporating BodyArt fitness into the physical therapy program is an effective means of rehabilitation for patients with cervicothoracic osteochondrosis, helping to reduce pain, improve spinal mobility and restore functional activity.

Keywords: cervicothoracic osteochondrosis, BodyArt fitness, physical therapy, manual muscle testing and goniometry, Neck Disability Index, McGill Pain Questionnaire.

Introduction

Degenerative diseases of the spine, in particular osteochondrosis of the cervicothoracic region (OCR), occupy

a leading place among diseases of the musculoskeletal system in the adult population. Their frequency increases with age, but modern data indicate that the initial signs of degenerative changes in the intervertebral discs can appear already in adolescence, and by the age of 50 these changes are recorded in almost 10% of people, and by the age of 70 - already in half of the population (Fakhoury & Dowling, 2023).

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Neck pain is not only one of the most common symptoms of OCT, but also a serious public health problem. It is known that neck pain is often accompanied by a decrease in quality of life, impaired performance, and sometimes neurological complications. In a meta-analysis by Fejer et al., it was found that the annual prevalence of neck pain is 7.6%, while the lifetime prevalence reaches 48.5%, with women suffering more often than men (Fejer et al., 2006).

The anatomical and functional features of the cervical spine, in particular its high mobility, complex structure and participation in many movements of the head and neck, determine its vulnerability to overloads and injuries. Chronic static loads, work in uncomfortable positions, decreased physical activity and excessive use of mobile devices - this significantly increases the risk of developing degenerative changes. Significant pressure on the intervertebral discs even with a slight tilt of the head, for example, when using a smartphone, can reach 27 kg, which contributes to premature aging of the spinal structures (Frost et al., 2019).

Research shows that the development of OCT is based on gradual degradation of the intervertebral disc – from loss of moisture and elasticity to the appearance of cracks in the fibrous ring and sequestration. Most often, the pathological process is localized at the levels of C5-C6 and C6-C7, where pronounced osteophytes, a decrease in disc height and sclerosis of the end plates are detected (Kong et al., 2017).

There is a clear age dependence of degenerative changes, but other factors - genetic predisposition, smoking, obesity, past injuries, long-term psycho-emotional stress – also influence the development of the disease (Seok & Kim, 2020; Kalmykova, 2023). In this context, it is important to pay attention to psychosocial aspects: low social support, lack of autonomy in decision-making, as well as job dissatisfaction are associated with an increased risk of developing neck pain (Ariëns et al., 2001).

Special attention is paid to the gender factor. Female gender remains one of the most frequently mentioned risk factors, although research results vary. Some scientific papers indicate a higher incidence and a greater number of years lived with disability due to neck pain among women (Safiri et al., 2017). According to the Global Burden of Disease, 166 million women suffered from neck pain in 2017, compared to 122 million men, highlighting the need for a gender-specific approach to treatment. (Cieza et al., 2020).

Given the complexity of the pathogenesis of cervical-thoracic spine degeneration, which includes both morphological changes and psychosocial factors, it is important to introduce modern non-drug approaches aimed at reducing pain, improving mobility, correcting posture and improving the overall functional state. One of the promising areas of rehabilitation is the use of the Body Art fitness method – a functional area of physical therapy that combines breathing, stabilization and neuromuscular exercises that take into account the individual characteristics of the female body in the context of degenerative diseases of the cervical-thoracic spine. That is, this type of fitness is justified for inclusion in the periodic supporting rehabilitation of the OCT for most effects. Physical therapy of the OCT is an important component of therapy, and new technologies open the way to the development of more effective methods, which determined the relevance of the study.

Purpose: To evaluate the impact of physical therapy in women with degenerative diseases of the cervical-thoracic spine based on the body art fitness method.

Materials and Methods

Participants

The study involved 57 women with a clinically and instrumentally confirmed diagnosis of OCT. The diagnosis was verified using radiography, computed tomography (CT) or magnetic resonance imaging (MRI) within one or two years before the start of the study.

All participants provided written informed consent to participate in the study in accordance with the principles of the Declaration of Helsinki.

Inclusion criteria were: females aged 40 to 60 years with a diagnosis of osteochondrosis of the cervicothoracic region (OCT), confirmed by instrumental methods (X-ray, CT or MRI), established at least one year before the start of the study. Age from 40 to 60 years, the presence of a diagnosis of OCT in remission, the ability to move independently and participate in physical exercise. Exclusion criteria were acute pain syndrome, severe somatic pathology, verified compression fractures of the vertebrae, spinal neoplasm, neurological deficit or systemic diseases of the musculoskeletal system. Evaluators were blinded.

The participants were randomly divided into two groups – control group (CG, $n = 27$, age 49.3 ± 1.5 years) and main group (MG, $n = 30$, age 50.1 ± 1.2 years). Randomization was carried out using closed opaque envelopes: pre-prepared envelopes marked “Control” or “Study” were mixed by an independent assistant and given to the participants in the order of their inclusion in the study.

In the control group (CG, $n = 27$), traditional therapeutic interventions were used: therapeutic gymnastics (3 times/week for 60 min.), manual therapy (6–8 procedures), and an educational component.

In the main group (MG, $n=30$), standard exercises were replaced by BodyArt training with the same frequency and duration (Table 1).

Table 1. Baseline characteristics of the study participants

Characteristic	CG, $X \pm m$ ($n = 27$)	MG, $X \pm m$ ($n = 30$)	P
Age, years	49.3 ± 1.5	50.1 ± 1.2	>0.05
Diagnosis confirmation method, %			>0.05
	15 (55.6%)	16 (53.3%)	
Radiography	6 (22.2%)	8 (26.7%)	>0.05
CT	6 (22.2%)	6 (20.0%)	>0.05
MRI	1.6 ± 0.4	1.7 ± 0.3	>0.05
Time since diagnosis	27 (100%)	30 (100%)	-
Ability to move independently, %	27 (100%)	30 (100%)	-

Procedure

The rehabilitation intervention in the study involved the development and implementation of an individualized outpatient physical therapy program for women with cervicothoracic osteochondrosis that included BodyArt training as the primary form of general therapeutic exercise

(ICF code 96129-00 – “therapeutic exercises for the whole body”). The BodyArt program is a holistic system of physical activity based on a combination of elements of yoga, Pilates, functional training, tai chi techniques and breathing practices. Its author, Swiss physiotherapist Robert Steinbacher, developed a concept integrating the philosophy of Yin-Yang and models of energy cycles through five phases: earth, wood, fire, metal and water, each of which is represented by appropriate types of exercises, moving from a warm-up to peak loads and ending with relaxation.

The training was adapted to the needs of patients with degenerative changes in the spine and included:

- exercises for postural control and stabilization,
- isometric activation of the muscles of the deep stabilization complex,
- controlled mobilization of the cervicothoracic segment of the spine,
- breathing practices and elements of conscious movement (mindfulness).

Additionally, the program for both groups included educational sessions (ICF code 96076-00) on ergonomics, back pain prevention, and healthy lifestyle (4–6 sessions of 30 minutes).

The rehabilitation intervention lasted 28 days (two cycles of 14 days, a total of at least 26–28 sessions), and was performed on an outpatient basis under the supervision of physical therapy specialists.

Instruments

To assess the effectiveness of the intervention, clinical and instrumental methods and scales were used (McGill pain questionnaire, MMT of the back and shoulder girdle muscles, mobility of the cervical and thoracic spine, Index of disability due to neck pain (Neck Disability Index, NDI)), statistical methods.

The McGill Pain Questionnaire (MPQ) is a tool for the qualitative and quantitative assessment of a patient's pain experience. It consists of 78 descriptors (words of description) grouped into 22 categories reflecting different aspects of pain: sensory, affective and evaluative components. The patient selects the words that most accurately describe his sensations, which allows the clinician to obtain a detailed description of the pain and its impact on the patient's condition (Katz & Melzack, 2022).

Measurement of the range of motion to assess the mobility of the cervical and thoracic spine was performed using a universal plastic goniometer, aligning it with anatomical landmarks in accordance with the neutral zero position method (0–180°). All measurements were performed by the same researcher at the same time of day. To increase reliability, each measurement was performed three times, after which the average value was calculated.

The MMT of the trunk and upper limb muscles was assessed using a 6-point scale. The patient's position for testing the trunk muscles is lying on his back or stomach, with stabilization of the body part within which this muscle is located. To assess the performance of the movement, the amplitude of movement and the activity that the patient must reveal are examined. Without the patient's cooperation, the study will not give the required result. Resistance should be applied in accordance with the age, gender and general

condition of the patient. The study assessed the extensor muscles of the spine, the stabilizing muscles of the scapula and the muscles of the upper limbs (Brown et al., 2013).

Neck Disability Index (NDI), also known as the Neck Pain Disability Index, is a 10-question questionnaire that assesses the impact of neck pain on daily activities, including aspects such as work, sleep, rest, personal hygiene, lifting, reading, driving, headache, concentration, and pain intensity (Shkolina et al., 2021). Each question is rated on a scale of 0 to 5, with 0 representing no pain or limitation and 5 representing the most severe pain and limitation. This questionnaire can be a useful tool for assessing the degree of disability in patients with neck pain and can help in planning appropriate treatment.

Statistical Analysis

The following methods of mathematical statistics were used: descriptive statistics and nonparametric tests. Descriptive data are presented as mean (standard error), median (range) or count (percentage) in accordance with the requirements of the study. Nonparametric statistics were used to test differences between groups over time as a result of a small number of observations. Nonparametric tests for comparing mean values for 2 groups in independent populations were introduced – the Kruskal-Wallis test, and in related populations – the Friedman test. McNemara's exact test was used to compare relative values. The null hypothesis was taken into account during testing – the statement that there is no difference between the groups, that is, the probability (p) that the groups have the same results.

The value $p > 0.05$ meant that the probability of the null hypothesis was greater than 5%, i.e. there was no difference between the populations; $p < 0.05$ the probability of the null hypothesis was less than 5%, i.e. there was a difference with a probability of 95%; $p < 0.01$ the probability of the null hypothesis was less than 1%, i.e. there was a difference with a probability of 99%. Statistical analysis was performed using Excel and the statistical computer program SPSS, version 16.0 (Landou & Everitt, 2003).

Results

At the beginning of the study, all women were examined by a multidisciplinary team – a physician of physical and rehabilitation medicine (PRM), a physical therapist (PT), an occupational therapist (OT), and a psychologist. An individual rehabilitation plan was developed for each of the women depending on the existing difficulties in functioning, activity, and participation. The average age in the CG was 49.3 ± 1.5 years, in the MG – 50.1 ± 1.2 years ($p > 0.05$). Between-group differences in age and duration of the disease at the beginning of the intervention were not statistically significant ($p > 0.05$), statistical analysis did not reveal reliable differences between the groups in other indicators ($p > 0.05$), which also indicates the homogeneity of the comparison groups.

The International Classification of Functioning (ICF) was used to assess the functional state of patients with osteochondrosis of the cervicothoracic spine. The definition of profiles was based on the results of muscle strength and spinal mobility.

Table 2. Dynamics of the McGill Pain Questionnaire (MPQ) scores in patients of the main (MG) and control (CG) groups with cervicothoracic osteochondrosis (conventional units)

Type of pain	Group	At the beginning	After 4 weeks	Wilcoxon test (dynamics within a group t, p)	Mann-Whitney test (between groups, U, p)
		X ± m	X ± m		
Pain intensity, conventional units	Control Main	3.8 ± 0.8	1.8 ± 0.5 ^{*&}	3.45; 0.001	225.0; 0.004
		3.9 ± 0.7	0.9 ± 0.3 ^{*&}	4.12; 0.002	
Overall pain assessment, conventional units	Control Main	2.8 ± 0.4	1.3 ± 0.4 ^{*&}	4.53; 0.002	210.0; 0.002
		2.7 ± 0.5	0.5 ± 0.1 ^{*&}	3.42; 0.001	

Note: * - significant difference in dynamics within a group (Wilcoxon test); p between groups - Mann-Whitney test; & - significant difference in dynamics groups (Mann-Whitney test)

Table 3. Dynamics of mobility indicators of the cervical-thoracic spine (key movements) (degrees)

Mobility indicators	Group	At the beginning	After 4 weeks	Wilcoxon test (dynamics within a group t, p)	Mann-Whitney test (between groups, U, p)
		X ± m	X ± m		
Neck extension, degrees	Control Main	17.0 ± 2.2	32.0 ± 2.5 [*]	3.25; 0.005	190.0; 0.001
		16.0 ± 3.3	20.0 ± 3.2 ^{&}	>0.05	
Thoracic extension, degrees	Control Main	14.0 ± 3.7	18.0 ± 3.2	>0.05	215.0; 0.004
		15.0 ± 2.9	25.0 ± 2.5 ^{*&}	3.40; 0.001	
Thoracic rotation, degrees	Control Main	21.0 ± 3.7	28.0 ± 2.1	>0.05	205.0; 0.003
		24.0 ± 3.1	36.0 ± 3.8 ^{*&}	3.42; 0.001	
Thoracic lateroflexion, degrees	Control Main	18.0 ± 1.6	21.0 ± 2.3	>0.05	198.0; 0.002
		18.0 ± 2.0	28.0 ± 2.2 ^{*&}	3.42; 0.001	

Note: * - significant difference in dynamics within a group (Wilcoxon test); p between groups - Mann-Whitney test; & - significant difference in dynamics groups (Mann-Whitney test)

Table 4. Dynamics of strength indicators of the cervical-thoracic spine (basic movements) (points)

Strength indicators	Group	At the beginning	After 4 weeks	Wilcoxon test (dynamics within a group t, p)	Mann-Whitney test (between groups, U, p)
		X ± m	X ± m		
Spinal extensors, points	Control Main	4.2 ± 0.2	4.1 ± 0.1	>0.05	208.0; 0.002
		4.1 ± 0.1	4.9 ± 0.2 ^{*&}	3.40; 0.001	
Rhomboids, points	Control Main	3.8 ± 0.2	3.9 ± 0.1	>0.05	190.0; 0.001
		3.9 ± 0.1	4.9 ± 0.1 ^{*&}	3.40; 0.001	
Right supraspinatus, points	Control Main	3.9 ± 0.1	4.0 ± 0.1	>0.05	200.0; 0.001
		4.0 ± 0.1	4.6 ± 0.1 ^{*&}	3.39; 0.001	
Left supraspinatus, points	Control Main	4.0 ± 0.1	4.0 ± 0.2	>0.05	212.0; 0.003
		4.0 ± 0.2	4.5 ± 0.2 ^{*&}	3.41; 0.001	
Left wrist extensors, points	Control Main	4.1 ± 0.1	4.1 ± 0.1	>0.05	195.0; 0.001
		4.1 ± 0.1	4.8 ± 0.1 ^{*&}	3.41; 0.001	

Note: * - significant difference in dynamics within a group (Wilcoxon test); p between groups - Mann-Whitney test; & - significant difference in dynamics groups (Mann-Whitney test)

The key difficulties were the ICF components “Structure and Function” (b280 Pain Perception, b134 Sleep Functions, b710 Joint Mobility Functions), but many queries also related to the component “Activities and Participation”. The domains d850 Work Relationships, d920 Leisure and Rest, d166 Reading, d475 Management caused varying degrees of difficulty for all study participants.

The dynamics of the McGill Pain Questionnaire (MPQ) scores showed a significant decrease in the intensity and overall pain score in both groups after the four-week rehabilitation program ($p < 0.05$ according to the Wilcoxon test) (Table 2).

However, in the main group, these changes were statistically more significant compared to the control group ($p < 0.05$ according to the Mann-Whitney criterion), which

confirms the higher efficiency of the applied method with the inclusion of BodyArt fitness.

After completing two rehabilitation cycles, an improvement in the range of motion in the cervical and thoracic spine was recorded in both groups (Table 3).

The changes were especially pronounced in the thoracic region in patients in the MG (extension, rotation, lateroflexion; $p < 0.05$), while in the CG the most noticeable improvement was in neck extension. Intergroup differences in most thoracic mobility indices were statistically significant ($p < 0.05$), indicating different directions of the interventions.

Manual muscle testing (MMT) indices indicate a significant improvement in the strength of the back muscles (spinal extensors and rhomboid muscles) and individual

Table 5. Dynamics of assessment according to the NDI (Neck Disability Index) scale (conventional units)

Neck Disability subscale	Group	At the beginning	After 4 weeks	Wilcoxon test (dynamics within a group t, p)	Mann–Whitney test (between groups, U, p)
		X ± m	X ± m		
Pain intensity, conventional units	Control Main	3.1 ± 0.6	1.1 ± 0.2*	3.40; 0.001	>0.05
		3.6 ± 0.5	1.2 ± 0.7*	4.60; 0.003	
Lifting objects, conventional units	Control Main	1.8 ± 0.6	1.5 ± 0.1	>0.05	190.0; 0.001
		1.5 ± 0.6	0.1 ± 0.1*&	3.39; 0.001	
Work, conventional units	Control Main	2.3 ± 0.4	2.0 ± 0.1	>0.05	185; 0.001
		1.9 ± 0.3	0.1 ± 0.1*&	3.40; 0.001	
Driving a car, conventional units	Control Main	1.5 ± 0.3	1.0 ± 0.2	>0.05	200.0; 0.002
		1.4 ± 0.3	0.1 ± 0.1*&	4.51; 0.003	
Sleep, conventional units	Control Main	2,1 ± 0,3	1.1 ± 0.2	>0.05	185.0; 0.001
		1.8 ± 0.2	0.1 ± 0.1*&	4.01; 0.002	
Rest and leisure, conventional units	Control Main	2.7 ± 0.3	2.0 ± 0.5	>0.05	210.0; 0.003
		2.3 ± 0.5	0.9 ± 0.4*&	5.40; 0.005	
Total score (NDI), conventional units	Control Main	19.5 ± 1.5	14.5 ± 1.7	>0.05	205.0; 0.002
		16.4 ± 1.7	9.6 ± 1.7*&	3.41; 0.001	

Note: * - significant difference in dynamics within a group (Wilcoxon test); p between groups - Mann-Whitney test; & - significant difference in dynamics groups (Mann-Whitney test)

muscles of the upper limbs (supraspinatus muscle, left wrist extensors) in the main group (Table 4).

Similar dynamics were not observed in the control group. Statistically significant intergroup differences in these indicators confirm the greater effectiveness of the intervention using BodyArt.

Changes in the level of activity and participation

According to the results of the NDI (Neck Disability Index) questionnaire, the overall assessment of functional limitations significantly decreased in both groups ($p < 0.05$), but in patients of the main group the decrease was more pronounced (from 16.4 ± 4.1 to 9.6 ± 1.9 points) (Table 5).

The intergroup difference after the intervention was statistically significant ($p < 0.05$). The most significant changes in MG were observed in the categories: lifting objects, performing work duties, driving a car, quality of sleep and leisure.

The obtained results indicate the effectiveness of the developed individualized outpatient rehabilitation program using BodyArt fitness as a means of physical therapy in women with cervicothoracic osteochondrosis.

Discussion

The present study was based on the hypothesis that integrating BodyArt fitness into a structured physical therapy program would yield superior functional and pain-related outcomes in women with cervicothoracic osteochondrosis (OCT) compared to traditional therapeutic modalities. This hypothesis stems from the understanding that chronic neck and upper back pain syndromes are not only biomechanical in nature but also involve disturbances in motor control, postural balance, and neuromuscular coordination.

An essential feature of our therapeutic strategy was the use of BodyArt fitness as a central, non-pharmacological modality. This method combines yoga, Pilates, breathing techniques, and stabilization exercises that holistically target balance, flex-

ibility, strength, and proprioception. In contrast to traditional physiotherapeutic programs, BodyArt emphasizes controlled movement and awareness of body position, which is crucial in conditions such as OCT, where postural dysfunction and compensatory movement patterns are common.

Our results confirmed the hypothesis: participants in the experimental group showed significantly greater improvements in pain intensity, spinal mobility (particularly extension and rotation), muscle strength (rhomboids, scapular stabilizers, wrist extensors), and functional activity (NDI subscales) than those in the control group. These findings are in line with prior evidence supporting the efficacy of therapeutic exercise in managing chronic neck pain. In particular, multiple studies have demonstrated the benefits of scapular muscle training (Andersen et al., 2011; Kang et al., 2021), resistance-based strengthening (Ma et al., 2011; Li et al., 2017), and multimodal rehabilitation programs (Ylinen et al., 2004; Borisut et al., 2013) in reducing pain and improving functional status.

A frequency of 3–4 sessions per week is considered optimal for therapeutic benefit in chronic pain management (O’Riordan et al., 2014; Jones et al., 2024). Our program adhered to these recommendations, suggesting that the observed improvements were not only due to the content of the intervention (BodyArt) but also to its appropriate dosage and progression. Furthermore, the emphasis on movement control, breathing, and mental focus may have contributed to pain reduction via central mechanisms such as downregulation of sensitization pathways, which warrants further neurophysiological investigation.

Pain, often underestimated as a clinical marker, plays a central role in limiting physical performance. Our results, showing reduced force production in the rhomboids, supraspinatus, and forearm extensors, support the findings of Ylinen et al. (2004), who emphasized the inhibitory effects of pain on maximal voluntary muscle contraction. The recovery of muscle strength observed in the experimental group may thus reflect not only mechanical adaptation but also normalization of motor output due to decreased nociceptive interference.

Mobility deficits were most prominent in the extension of the cervical (16–17°) and thoracic spine (14–15°), which may result from muscle hypertonicity, imbalance, or degenerative disc changes. These values are comparable with those reported in the literature for similar populations and reinforce the clinical significance of targeted mobility training (Ylinen et al., 2004; Wegner et al., 2010). BodyArt fitness, through its fluid and controlled movement patterns, may improve fascial elasticity and restore segmental motion, contributing to the significant mobility gains observed.

Altered scapular positioning is a hallmark of chronic cervicothoracic dysfunction. Studies by Cagnie et al. (2014) and Wannaprom et al. (2021) highlighted the impact of scapular dyskinesis on cervical spine load and pain perception. Active correction of scapular alignment has been shown to improve clinical outcomes (Lluch et al., 2014; Seok & Kim, 2020), and our findings corroborate these observations. The BodyArt approach, which emphasizes scapular stabilization, offers a practical and effective solution that could be implemented in various rehabilitation settings.

From a practical standpoint, BodyArt fitness requires minimal equipment and can be delivered in group or individual formats, making it a cost-effective option for outpatient or home-based rehabilitation. The inclusion of cognitive and respiratory elements also promotes patient engagement and may support long-term adherence, which is often a limiting factor in rehabilitation success. The structured yet adaptable nature of BodyArt exercises allows therapists to tailor intensity and complexity based on patient condition, ensuring safety and individualization.

Importantly, our findings underscore the need for a paradigm shift from passive to active rehabilitation strategies in patients with degenerative spinal disorders. The improvement observed across multiple outcome domains suggests that BodyArt fitness addresses both the mechanical and neurophysiological components of chronic cervicothoracic pain. This holistic effect is particularly relevant for women in midlife, who often face cumulative biomechanical stressors and hormonal changes that affect connective tissue quality and pain perception.

Nevertheless, certain limitations must be acknowledged. The relatively small sample size and short intervention period restrict the generalizability of our results. The absence of long-term follow-up precludes conclusions regarding the durability of therapeutic effects. Furthermore, the lack of direct neurophysiological assessments (e.g., EMG, pain sensitization indices) limits our ability to explain the observed changes at the mechanistic level. Future studies should incorporate these aspects and include control groups receiving alternative active interventions to better isolate the unique effects of BodyArt fitness.

Perspective and future research

The results obtained indicate that BodyArt fitness is a promising, safe, and effective intervention for the rehabilitation of women with cervicothoracic osteochondrosis. However, future multicenter randomized controlled trials with larger sample sizes, longer follow-up periods, and objective measures of neuromuscular function are needed to confirm and expand these findings. In addition, studies investigating the impact of BodyArt on psychological outcomes, quality of life, and central

pain mechanisms would provide a more comprehensive understanding of its therapeutic potential. Expanding the use of BodyArt into clinical guidelines and integrating it into multidisciplinary care pathways for chronic spinal pain may enhance both short-term outcomes and long-term self-management.

Conclusions

Chronic cervicothoracic osteochondrosis in women is accompanied by pain syndrome, muscle weakness and limited mobility of the spine, which negatively affects the quality of life and work capacity. According to the results of the study, the inclusion of BodyArt fitness in the physical therapy program significantly reduced the intensity of pain ($p < 0.01$), increased muscle strength ($p < 0.05$) and improved the mobility of the cervical and thoracic spine ($p < 0.05$). In particular, the NDI disability index decreased by 34.7% compared to the initial level ($p < 0.01$).

Regular performance of BodyArt exercises 3–4 times a week contributed to the normalization of muscle balance, correction of the position of the scapula and an increase in functional activity, which is consistent with modern scientific data.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Fakhoury, J., & Dowling, T. J. (2023). *Cervical Degenerative Disc Disease*. In StatPearls [Internet]. StatPearls Publishing. PMID: 32809607.
- Fejer, R., Kyvik, K. O., & Hartvigsen, J. (2006). The prevalence of neck pain in the world population: a systematic critical review of the literature. *European spine journal*, 15, 834–848. <https://doi.org/10.1007/s00586-004-0864-4>
- Frost, B. A., Camarero-Espinosa, S., & Foster, E. J. (2019). Materials for the Spine: Anatomy, Problems, and Solutions. *Materials*, 12(2), 253. <https://doi.org/10.3390/ma12020253>
- Kong, L., Tian, W., Cao, P., Wang, H., Zhang, B., & Shen, Y. (2017). Predictive factors associated with neck pain in patients with cervical disc degeneration: A cross-sectional study focusing on Modic changes. *Medicine*, 96(43), e8447. <https://doi.org/10.1097/MD.0000000000000847>
- Seok, J. H., & Kim, T. H. (2020). The effects of scapular alignment exercise and nerve mobilization on pain and muscle activity in subjects with scapular depression alignment. *Journal of Musculoskeletal Science and Technology*, 4(2), 58–65. <https://doi.org/10.29273/jmst.2020.4.2.58>

- Kalmykova, Y. S. (2023). Prevalence of obesity and metabolic syndrome in young people: current state of the problem. *Rehabilitation and Recreation*, 14, 49-55. <https://doi.org/10.32782/2522-1795.2023.14.5>
- Ariëns, G. A., van Mechelen, W., Bongers, P. M., Bouter, L. M., & van der Wal, G. (2001). Psychosocial risk factors for neck pain: a systematic review. *American journal of industrial medicine*, 39(2), 180-193. [https://doi.org/10.1002/1097-0274\(200102\)39:2<180::AID-AJIM1005>3.0.CO;2-#](https://doi.org/10.1002/1097-0274(200102)39:2<180::AID-AJIM1005>3.0.CO;2-#)
- Safiri, S., Kolahi, A. A., Hoy, D., Buchbinder, R., Mansournia, M. A., Bettampadi, D., ... & Ferreira, M. L. (2020). Global, regional, and national burden of neck pain in the general population, 1990-2017: systematic analysis of the Global Burden of Disease Study 2017. *BMJ*, 368. <https://doi.org/10.1136/bmj.m791>
- Cieza, A., Causey, K., Kamenov, K., Hanson, S. W., Chatterji, S., & Vos, T. (2020). Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, 396(10267), 2006-2017. [https://doi.org/10.1016/S0140-6736\(20\)32340-0](https://doi.org/10.1016/S0140-6736(20)32340-0)
- Katz, J., Melzack, R. (2022). *McGill Pain Questionnaire*. In: Maggino, F. (eds) *Encyclopedia of Quality of Life and Well-Being Research*. Springer, Cham. https://doi.org/10.1007/978-3-319-69909-7_1748-2
- Brown, M., Hislop, H., & Avers, D. (2013). *Daniels and Worthingham's Muscle Testing-E-Book*. Elsevier Health Sciences.
- Shkolina, N.V., Shapoval, I.I., & Stanislavchuk, M.A. (2021). Adaptation and validation of the Ukrainian version of the neck disability index (index of limitation of life activity due to neck pain) in patients with ankylosing spondylitis. *Ukrainian Journal of Rheumatology*, 85(3), 1-6. <https://doi.org/10.32471/rheumatology.2707-6970.85.16408>
- Landau, S., & Everitt, B. S. (2003). *A handbook of statistical analyses using SPSS*. Chapman and Hall/CRC. <https://doi.org/10.1201/9780203009765>
- Andersen, L. L., Saervoll, C. A., Mortensen, O. S., Poulsen, O. M., Hannerz, H., & Zebis, M. K. (2011). Effectiveness of small daily amounts of progressive resistance training for frequent neck/shoulder pain: randomised controlled trial. *Pain*, 152(2), 440-446. <https://doi.org/10.1016/j.pain.2010.11.016>
- Kang, N. Y., Im, S. C., & Kim, K. (2021). Effects of a combination of scapular stabilization and thoracic extension exercises for office workers with forward head posture on the craniovertebral angle, respiration, pain, and disability: A randomized-controlled trial. *Turkish journal of physical medicine and rehabilitation*, 67(3), 291-299. <https://doi.org/10.5606/tftrd.2021.6397>
- Ma, C., Szeto, G. P., Yan, T., Wu, S., Lin, C., & Li, L. (2011). Comparing biofeedback with active exercise and passive treatment for the management of work-related neck and shoulder pain: a randomized controlled trial. *Archives of physical medicine and rehabilitation*, 92(6), 849-858. <https://doi.org/10.1016/j.apmr.2010.12.037>
- Li, X., Lin, C., Liu, C., Ke, S., Wan, Q., Luo, H., ... & Wu, S. (2017). Comparison of the effectiveness of resistance training in women with chronic computer-related neck pain: a randomized controlled study. *International archives of occupational and environmental health*, 90, 673-683. <https://doi.org/10.1007/s00420-017-1230-2>
- Ylinen, J., Takala, E. P., Kautiainen, H., Nykänen, M., Häkkinen, A., Pohjolainen, T., ... & Airaksinen, O. (2004). Association of neck pain, disability and neck pain during maximal effort with neck muscle strength and range of movement in women with chronic non-specific neck pain. *European journal of pain*, 8(5), 473-478. <https://doi.org/10.1016/j.ejpain.2003.11.005>
- Borisut, S., Vongsirinararat, M., Vachalathiti, R., & Sakulsriprasert, P. (2013). Effects of strength and endurance training of superficial and deep neck muscles on muscle activities and pain levels of females with chronic neck pain. *Journal of physical therapy science*, 25(9), 1157-1162. <https://doi.org/10.1589/jpts.25.1157>
- O'Riordan, C., Clifford, A., Van De Ven, P., & Nelson, J. (2014). Chronic neck pain and exercise interventions: frequency, intensity, time, and type principle. *Archives of physical medicine and rehabilitation*, 95(4), 770-783. <https://doi.org/10.1016/j.apmr.2013.11.015>
- Jones, L. B., Jadhakhan, F., & Falla, D. (2024). The influence of exercise on pain, disability and quality of life in office workers with chronic neck pain: a systematic review and meta-analysis. *Applied ergonomics*, 117, 104216. <https://doi.org/10.1016/j.apergo.2023.104216>
- Wegner, S., Jull, G., O'Leary, S., & Johnston, V. (2010). The effect of a scapular postural correction strategy on trapezius activity in patients with neck pain. *Manual therapy*, 15(6), 562-566. <https://doi.org/10.1016/j.math.2010.06.006>
- Cagnie, B., Struyf, F., Cools, A., Castelein, B., Danneels, L., & O'leary, S. (2014). The relevance of scapular dysfunction in neck pain: a brief commentary. *Journal of orthopaedic & sports physical therapy*, 44(6), 435-439. <https://www.jospt.org/doi/10.2519/jospt.2014.5038>
- Wannaprom, N., Treleaven, J., Jull, G., & Uthairak, S. (2021). Response rate and comparison of clinical features associated with positive or negative responses to a scapular positioning test in patients with neck pain and altered scapular alignment: a cross-sectional study. *BMJ open*, 11(12), e057459. <https://doi.org/10.1136/bmjopen-2021-057459>
- Lluch, E., Arguisuelas, M. D., Quesada, O. C., Noguera, E. M., Puchades, M. P., Rodríguez, J. A. P., & Falla, D. (2014). Immediate effects of active versus passive scapular correction on pain and pressure pain threshold in patients with chronic neck pain. *Journal of manipulative and physiological therapeutics*, 37(9), 660-666. <https://doi.org/10.1016/j.jmpt.2014.08.007>

Ефективність фізичної терапії жінок з дегенеративними захворюваннями шийно-грудного відділу хребта на основі методики BodyArt-фітнес

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Реферат. Стаття: 8 с., 5 табл., 25 джерел.

Мета дослідження. Науково обґрунтувати, розробити та оцінити ефективність включення методики BodyArt-фітнесу до реабілітаційного плану пацієнток із шийно-грудним остеохондрозом у фазі періодичної підтримувальної реабілітації.

Матеріал і методи. У дослідженні взяли участь 57 жінок, які були рандомно (метод закритих конвертів) розподілені на контрольну (КГ, n = 27, вік 49,3 ± 1,5 роки) та основну групу (ОГ, n = 30, вік 50,1 ± 1,2 роки). Критерії включення: особи жіночої статі віком від 40 до 60 років із діагнозом остеохондроз шийно-грудного відділу хребта (ОШГВХ), підтверджений інструментальними методами (рентгенографія, КТ або МРТ), який було встановлено не менш ніж за рік до початку дослідження. Критеріями виключення були: гострий біль, тяжка соматична патологія, переломи або пухлини хребців. Усі учасниці надали письмову інформовану згоду на участь у дослідженні. КГ проходила стандартну реабілітацію за лікарняним протоколом (навчання — 30 хв., 4–6 занять; лікувальна гімнастика – 3 рази на тиждень по 1 год.; мануальна терапія — 6–8 сеансів). У програму ОГ замість стандартних вправ була включена методика BodyArt-фітнесу. Тривалість дослідження становила два реабілітаційні цикли (28 днів). Для оцінки ефективності втручання використовувалися клініко-інструментальні методи та шкали (опитувальник болю Мак-Гілла - MPQ (McGill Pain Questionnaire), ММТ м'язів спини та плечового поясу, рухливість шийного та грудного відділів хребта, Індекс обмеження життєдіяльності через біль у шиї (Neck Disability Index, NDI)), статистичні методи.

Результати. У пацієнток основної групи після застосування BodyArt-фітнесу спостерігалось достовірне зниження інтенсивності болю за результатами опитувальника болю Мак-Гілла (MPQ) (p < 0,01), покращення м'язової сили (p < 0,05) та збільшення амплітуди рухів у шийному та грудному відділах хребта (p < 0,05) порівняно з контрольною групою. Зокрема, індекс непрацездатності NDI зменшився на 34,7 % (p < 0,01).

Висновки. Включення BodyArt-фітнесу до програми фізичної терапії є ефективним засобом реабілітації пацієнток із шийно-грудним остеохондрозом, сприяючи зменшенню болю, покращенню рухливості хребта та відновленню функціональної активності.

Ключові слова: шийно-грудний остеохондроз, фітнес BodyArt, фізична терапія, мануальне м'язове тестування та гоніометрія, Індекс обмеження життєдіяльності через біль у шиї (Neck Disability Index, NDI), опитувальник болю Мак-Гілла - MPQ (McGill Pain Questionnaire).

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Determining the Effects of High-Intensity Interval Training Versus Plyometric Training on Speed, Agility, and Lower-Limb Explosive Performance in Male Basketball Players

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Abstract

Background. High-Intensity Interval Training (HIIT) and Plyometric Training (PT) are commonly used to enhance athletic performance in sports requiring speed, agility, and explosive lower-limb power, such as basketball. While both methods improve neuromuscular and physiological capacities, their comparative effectiveness on specific motor abilities remains unclear.

Objectives. This study aimed to evaluate and compare the effects of HIIT and PT on speed, agility, and lower-limb explosive performance in male basketball players.

Materials and Methods. A total of 22 male basketball players (overall age; 21.27 ± 1.34 years) were randomly assigned to two intervention groups: High-Intensity Interval Training (HIIT, $n = 8$) and Plyometric Training (PT, $n = 14$). Both groups underwent their respective training programs over a specified intervention period. Key performance variables, including speed, agility, squat jump (SJ), and countermovement jump (CMJ), were assessed before and after the training. A two-way repeated measures ANOVA (2×2) was employed to evaluate the interaction effects between time (pre- and post-intervention) and group (HIIT vs. PT) on all outcome measures.

Results. Both the HIIT and PT groups showed significant improvements in sprint time, agility, jump height, velocity, power, and power-to-bodyweight ratio (all $p < .001$). No marked changes were found in SJ force. A two-way ANOVA

revealed a significant time effect for all variables ($p < .001$), with no substantial group or interaction effects ($p > .05$), indicating comparable improvements across both interventions.

Conclusions. These findings confirmed that both High-Intensity Interval Training and Plyometric Training were effective in enhancing speed, agility, and lower-limb explosive performance among male basketball players. The absence of significant differences between groups suggests that either training method can be effectively incorporated into performance enhancement programs based on athlete preference, training context, or resource availability.

Keywords: neuromuscular adaptation, anaerobic performance, explosive strength, jump mechanics, basketball athletes.

Introduction

Basketball performance hinges on speed, agility, and explosive lower-limb power (J. Wang et al., 2025). It is a fast-paced, high-impact team sport which involves short, repeated bursts of activity including sprinting, jumping, rapid acceleration and deceleration, change of direction and lateral movements, often in combination with periods of rest (Stojanović et al., 2018). These activities place a high-demand upon neuromuscular coordination, anaerobic fitness, agility, and power characteristics of the lower extremity, especially in male athletes while performing competition-simulated play (McGill et al., 2010; Miller et al., 2006). Since repeated high-speed accelerations, vertical jumps and direction change (COD) displacements are frequently performed during a basketball game, therefore the optimization of these biomotor qualities by the means of a well-structured training program plays a pivotal role for performance and injury prevention.

Over the years, multiple training modalities have been developed and applied in basketball-specific contexts to address these physiological demands. Two of the most widely adopted and evidence-backed methods are High-Intensity Interval Training (HIIT) and Plyometric Training (PT) (Laursen & Buchheit, 2019; Ramirez-Campillo et al., 2023). HIIT—short, repeated bursts of high-intensity effort has proven to elevate both aerobic and anaerobic performance ($\text{VO}_{2\text{max}}$, sprint capacity, lactate threshold, and directional quickness) with remarkable efficiency (Atakan et al., 2021; Helgerud et al., 2007). In sports like basketball, which demand repeated high-intensity efforts interspersed with active recovery, HIIT is both physiologically relevant and logistically efficient (Buchheit & Laursen, 2013a; Milanović et al., 2015a). Unlike traditional endurance training, which often lacks transferability to explosive court actions, HIIT prepares athletes to perform optimally under the intermittent and intense conditions characteristic of basketball (Coates et al., 2023).

Moreover, a well-structured HIIT regimen can elicit significant performance gains in a shorter time compared to moderate-intensity continuous training. This is because high-intensity bouts preferentially recruit fast-twitch muscle fibers, enhance mitochondrial density, and improve neuromuscular coordination (Hung et al., 2025; Skelly et al., 2021; Torma et al., 2019). Importantly, when sport-specific elements such as directional sprints or acceleration-deceleration drills are integrated, HIIT has demonstrated improvements in agility and short-distance sprinting (Beato et al., 2019; Clemente & Sarmiento, 2021).

In contrast, Plyometric Training adopts a biomechanical perspective by targeting the stretch-shortening cycle (SSC) of muscles to enhance reactive strength and the rate of force development (Davies et al., 2015). Exercises such as depth jumps, bounding, and tuck jumps impose high eccentric

loading followed by explosive concentric output closely mirroring movements in basketball like rebounding, layups, and quick transitions. The neuromuscular demands of PT align perfectly with the reactive nature of basketball (Abdel-Rahman, 2013; Aboodarda et al., 2015). These exercises are critical for developing muscular power, reactive strength, and neuromuscular coordination all of which directly relate to performance in actions like vertical jumping and quick take-offs common in basketball (Markovic & Mikulic, 2010; Ramírez-Campillo et al., 2015). Previous meta-analyses have demonstrated significant improvements in vertical jump height, sprint time, and agility scores following PT programs in athletes from various team sports, including basketball, soccer, and volleyball (Moran et al., 2018; Slimani et al., 2016).

In addition, both HIIT and PT have been investigated by various researchers for their effects on physical fitness in athletes. For example, Beato et al. (2019) found meaningful improvements in sprint and agility with a 6 weeks HIIT protocol in soccer players. Similarly, Ramírez-Campillo et al. (2015) reported that PT resulted in significant improvements in lower-limb explosive power and sprint speed in young athletes. In addition, new research has expanded the effects of plyometry exercises to sports related outcomes, and has demonstrated that even a short-term PT intervention (4–6 weeks) could produce relevant performance adaptations (Ramirez-Campillo et al., 2023).

In basketball players, PT exercises are extensively used as part of the preseason and in-season conditioning programmes because of concomitant effects on jumping and quick-reactive abilities (Matavulj et al., 2001). HIIT on the other hand, has been preferred due to the time saving's and the possibility of enhancing both aerobic and anaerobic systems at the same time (Buchheit & Laursen, 2013a).

Despite the well-documented benefits of HIIT and PT as standalone interventions, literature directly comparing their effects particularly using randomized controlled designs is sparse. A few studies have attempted to compare different training modalities (e.g., resistance training vs. PT, or HIIT vs. traditional endurance training), but these often vary in duration, frequency, or intensity, making direct comparisons difficult (Foster et al., 2015; Jagsz & Sikora, 2025; Tuttur et al., 2020). Moreover, the combined use of HIIT and PT has been investigated primarily in soccer (Oliver et al., 2024; Yang et al., 2024), but such comparisons are rare in basketball-specific contexts.

Although both HIIT and PT are frequently used in the athletic development of basketball players, the comparative effects of these two interventions on key performance metrics speed, agility, and lower-limb explosiveness remain underexplored. Specifically, few randomized controlled trials have examined how each modality distinctly influences

short-distance sprint performance, change-of-direction ability, and vertical jump capacity in male basketball athletes. Furthermore, most existing studies focus either on youth or mixed-gender samples, limiting their applicability to adult male athletes engaged in competitive training cycles.

In addition, the physiological mechanisms underlying performance adaptations to HIIT and PT differ. While HIIT predominantly enhances metabolic and cardiovascular parameters, PT is more focused on neuromuscular development. Therefore, understanding the differential impact of these methods on sport-specific movements in basketball is essential for coaches, trainers, and sports scientists aiming to optimize training periodization and resource allocation.

To date, there is no comprehensive study that directly compares the isolated effects of HIIT and PT in basketball using a randomized controlled design and a uniform training duration. The lack of head-to-head evidence prevents practitioners from making informed decisions on which modality may be more beneficial for specific performance outcomes.

Given the aforementioned gaps, the present study aims to compare the effects of High-Intensity Interval Training and Plyometric Training on speed, agility, and lower-limb explosive performance in male basketball players. It is anticipated that both training modalities will yield significant improvements across all performance outcomes due to their distinct, yet complementary, physiological mechanisms. Specifically, Plyometric Training is expected to elicit greater gains in vertical jump height by targeting lower-limb power through enhanced neuromuscular function. In contrast, High-Intensity Interval Training is hypothesized to produce superior improvements in sprinting and agility due to its emphasis on repeated high-speed movement patterns and anaerobic conditioning. By directly comparing these interventions, this study seeks to offer practical insights for strength and conditioning professionals aiming to optimize sport-specific performance in competitive basketball.

Materials and Methods

Study Participants

The required sample size for this study was determined through an a priori power analysis using G*Power software (version 3.1.9.7). A repeated measures ANOVA (within-between interaction) was selected as the statistical model, assuming two groups (HIIT and PT) and two time points (pre- and post-intervention). Based on a medium effect size ($f = 0.25$), an alpha level of 0.05, statistical power of 0.80, correlation among repeated measures set at 0.70, and non-sphericity correction set to 1, the analysis indicated that a minimum of 11 participants would be needed to detect a statistically significant interaction effect. Given the lack of prior comparative studies between High-Intensity Interval Training (HIIT) and Plyometric Training (PT) for performance outcomes such as sprint speed, agility, and lower-limb explosive power in basketball players, a medium effect size was considered justifiable. To account for potential dropouts and ensure sufficient statistical power, 51 male basketball players were initially approached for participation. Participants were screened based on the following inclusion criteria: (a)

current engagement in competitive or recreational basketball training; (b) no musculoskeletal injuries within the past six months; (c) prior exposure to structured HIIT or plyometric training; (d) ability to safely perform explosive lower-limb movements, such as vertical jumps, accelerative sprints, and lateral shuffles, without physical limitations; (e) willingness to complete a 12-week intervention with pre- and post-testing sessions. Those meeting the criteria and providing written informed consent were randomly allocated to either the HIIT or PT group in a 1:1 ratio using an online randomization tool (www.randomizer.org). Anthropometric and baseline demographic data for all enrolled participants are detailed in Table 1. Before enrollment, participants were fully informed of the purpose, benefits, and potential risks associated with the training interventions. Ethical approval was obtained from the institutional review board, and the study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Participants who failed to complete at least 80% of the scheduled training sessions were excluded from the final analysis to maintain intervention fidelity.

Study Design

This study employed a randomized, two-group pre-test–posttest design to compare the effects of High-Intensity Interval Training (HIIT) and Plyometric Training (PT) on selected physical performance variables in male basketball players. Participants were randomly assigned to either the HIIT or PT intervention group, and both groups underwent baseline and post-intervention assessments. The intervention period lasted twelve weeks. To ensure consistency and control for potential diurnal variation, all performance assessments were conducted at similar times of day for each participant during both testing sessions. Additionally, each assessment was scheduled after a minimum 48-hour recovery period following the final training session to mitigate the influence of residual fatigue and acute performance fluctuations. The testing sequence including warm-up protocols and the order of performance measures (e.g., sprint, agility, jump tests) was identical at baseline and follow-up for each participant to maintain procedural reliability. Although randomization was employed to assign participants to the two experimental groups, blinding of researchers and assessors was not feasible due to logistical constraints related to scheduling and personnel involvement. However, the same trained staff conducted all assessments to reduce measurement variability.

Table 1. Demographic information of participants

Variable	HIITG (n = 8)	PTG (n = 14)	p
Age (years)	21.92 ± 1.19	20.89 ± 1.42	0.1
Height (cm)	178.76 ± 2.01	180.11 ± 4.62	0.446
Weight (kg)	70.32 ± 4.67	74.64 ± 6.64	0.122
Playing Experience (years)	3.91 ± 1.56	4.35 ± 1.61	0.539

Familiarization and Pre-Assessment Procedures

A one-week familiarization phase was conducted prior to baseline testing to ensure participant readiness and to reduce potential learning effects associated with the physical

performance assessments. During this period, all participants were introduced to the testing procedures and practiced each outcome measure, including sprint tests, agility drills, and vertical jump assessments, under supervision. This helped standardize technique and minimize variability in execution during the actual pre- and post-intervention data collection. Participants were also exposed to sample training sessions representing the structure and intensity of their assigned intervention either High-Intensity Interval Training (HIIT) or Plyometric Training (PT). These sessions provided a clear understanding of the exercises, rest intervals, and effort expectations specific to their group, thus enhancing compliance and minimizing dropouts during the study period. Anthropometric and demographic data were recorded during this familiarization week. Participants were instructed to refrain from strenuous physical activity for at least 48 hours prior to testing to eliminate residual fatigue. They were also advised to maintain their usual dietary and hydration routines throughout the study, with the exception of avoiding heavy meals within three hours of testing sessions to ensure physiological consistency. All instructions were reinforced verbally and through periodic reminders to ensure adherence throughout the study period. A schematic overview of the study timeline and procedures is presented in Figure 1.

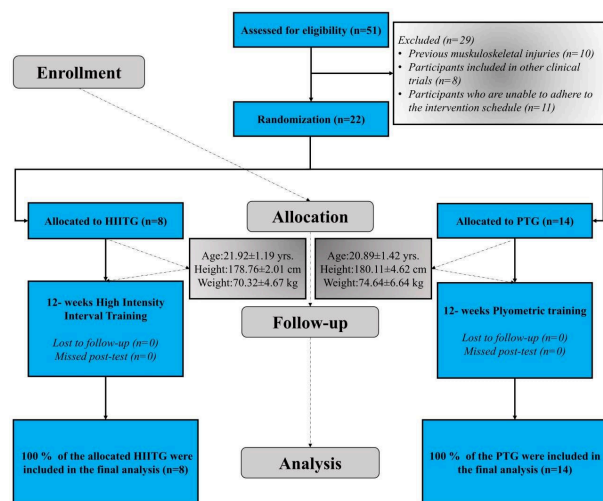


Fig. 1. CONSORT-Based Flow Diagram Depicting Study Progression

Test Procedures

50 m Sprint

The 50-meter sprint test was used to evaluate linear sprinting speed. Participants performed two maximal effort sprints over a straight 50 m track, separated by a 3-minute passive recovery. Sprint times were recorded using electronic timing gates (Microgate Witty, Bolzano, Italy), with one gate placed at the start line and the other at the 50 m mark. Participants started from a standing position 0.5 m behind the first gate to avoid early triggering. The best time (in seconds) of two trials was recorded for analysis (Cronin & Hansen, 2005).

T-Agility

The T-Test Agility Test was used to assess multidirectional agility involving forward sprinting, lateral shuffling, and backpedaling. The test was conducted on a flat indoor court following the standard T-pattern layout: 9.14 m (10 yards) forward sprint to cone B, 4.57 m (5 yards) shuffle left to cone C, 9.14 m (10 yards) shuffle right to cone D, 4.57 m (5 yards) shuffle left back to cone B, and 9.14 m (10 yards) backpedal to the starting point (cone A). Timing was captured using electronic photocells (Brower Timing Systems, Utah, USA). Participants were given one familiarization trial and two recorded trials, with the fastest time used for analysis (Paule et al., 2000).

Squat Jump (SJ) and Countermovement Jump (CMJ)

To assess lower-limb explosive performance, both Squat Jump (SJ) and Countermovement Jump (CMJ) were administered using a force platform system (Quattro Jump, Version 1.04; Kistler Instrumente AG, Winterthur, Switzerland). This system enabled the detailed evaluation of kinetic and kinematic parameters during take-off and flight phases. Participants performed the Squat Jump (SJ) from a static semi-squat position, maintaining a knee flexion angle of approximately 90 degrees. To eliminate any pre-stretch or elastic contribution, athletes were instructed to hold the squat for 2–3 seconds without any countermovement. From this position, they executed a maximal vertical jump, extending the knees and hips while keeping the trunk upright. Arm movement was restricted by placing hands on the hips throughout the jump to avoid momentum influence. For the Countermovement Jump (CMJ), participants began in an upright stance and executed a rapid downward movement (eccentric phase) followed by an immediate upward propulsion (concentric phase), again with hands placed on the hips. This action utilized the stretch-shortening cycle (SSC) to enhance jump performance. All jumps were performed barefoot or in minimal footwear, and athletes were given two familiarization trials before recording three valid attempts for each condition. The best performance for each variable was selected for analysis. A rest interval of 90–120 seconds was maintained between trials to minimize fatigue effect (Hammami et al., 2019).

Training Intervention

The study involved two experimental groups that participated in bi-weekly training sessions over a period of twelve consecutive weeks, with at least 48 hours of recovery between sessions to ensure adequate neuromuscular recovery. Participants were randomly allocated to either the High-Intensity Interval Training (HIIT) group or the Plyometric Training (PT) group. The training content, intensity, and progression were based on established guidelines in the literature for improving speed, agility, and lower-limb power (Beato et al., 2019; Markovic & Mikulic, 2010). The HIIT group engaged in short bursts of anaerobic running intervals at intensities ranging between 85–95% of maximal heart rate (HRmax), interspersed with brief recovery periods, aiming to enhance cardiorespiratory efficiency and neuromuscular resilience. Each session

Table 2. Summary of the 12-week training programs

Week Range	Group	Exercise	Sets × Reps / Bouts (each drill)	Rest Interval (between drills)	Intensity / Load
1–3	HIIT	Sprint drills (10–20 m), Cone drills, Lateral bounds, High knees, Burpees, Squat jumps	2 × 8–10	60–90 s	Moderate (70–75%)
	PT	Depth jumps, Lateral bounds, Bounding, Single-leg hops, Tuck jumps, Box jumps	2 × 8–10	90–120 s	Moderate (70–75%)
4–6	HIIT	Sprint drills (10–20 m), Cone drills, Lateral bounds, High knees, Burpees, Squat jumps	3 × 8–10	60 s	High (75–80%)
	PT	Depth jumps, Lateral bounds, Bounding, Single-leg hops, Tuck jumps, Box jumps	3 × 8–10	90 s	High (75–80%)
7–9	HIIT	Sprint drills (10–20 m), Cone drills, Lateral bounds, High knees, Burpees, Squat jumps	3–4 × 10–12	45–60 s	Very High (80–85%)
	PT	Depth jumps, Lateral bounds, Bounding, Single-leg hops, Tuck jumps, Box jumps	3–4 × 10–12	60–90 s	Very High (80–85%)
10–12	HIIT	Sprint drills (10–20 m), Cone drills, Lateral bounds, High knees, Burpees, Squat jumps	2–3 × 6–8	90 s	Maximum effort (85–90%)
	PT	Depth jumps, Lateral bounds, Bounding, Single-leg hops, Tuck jumps, Box jumps	2–3 × 6–8	90–120 s	Maximum effort (85–90%)

included 4–6 bouts of 30–60 second high-speed shuttle runs, with a work-to-rest ratio of 1:1 or 1:1.5, depending on the week of progression. Session intensity was monitored using heart rate monitors and rate of perceived exertion (RPE) to maintain training load consistency (Buchheit & Laursen, 2013). Conversely, the PT group performed jump-based exercises focused on enhancing neuromuscular reactivity and lower-limb explosive strength. The exercises included vertical jumps, squat jumps, bounding drills, lateral hops, and depth jumps, following a structured progression model in terms of volume and complexity. Training sessions typically comprised 3–4 sets of 8–10 repetitions of each exercise, with a focus on maximal intent and proper landing mechanics, as recommended in previous plyometric training frameworks (Ramírez-Campillo et al., 2015).

All sessions began with a standardized dynamic warm-up (~10 minutes) consisting of light jogging, dynamic stretching, and movement-specific drills. No fixed cool-down protocol was enforced; however, participants were encouraged to perform their usual post-exercise recovery routines (e.g., static stretching or walking). Both training programs were designed to match in duration (~45–60 minutes) and general workload, while differing in modality and physiological focus. Table 2 outlines the weekly training structure, intensity parameters, and exercise progressions employed for each group.

Statistical Analysis

All data were assessed for normal distribution using the Shapiro–Wilk test, which is considered appropriate for small to moderate sample sizes (Razali & Yap, 2011). Descriptive statistics were expressed as means and standard deviations (mean ± SD). A two-way mixed-design analysis of variance (ANOVA) was used to evaluate the effects of time (pre vs. post) and group (HIIT vs. PT) on all outcome variables. This design is commonly used to analyze repeated measures within and between independent groups (Field, 2013).

When significant interaction or main effects were observed, Bonferroni-adjusted post hoc tests were applied to identify pairwise differences. The effect sizes for within-group changes were calculated using Cohen's *d*, with thresholds defined as small (0.2), medium (0.5), and large (0.8) as per Cohen's guidelines (Cohen, 2013). Statistical significance was set at $p < 0.05$. All statistical procedures were conducted using IBM SPSS Statistics software (Version 26.0, IBM Corp., Armonk, NY, USA).

Results

Table 1 presents the anthropometric and demographic details of the participants. No statistically significant differences were found between the High-Intensity Interval Training Group (HIITG) and the Plyometric Training Group (PTG) in terms of age, body mass, height, or years of playing experience, indicating baseline comparability between the two groups. Significant improvements were observed across key performance variables in both the HIITG and PTG from pre- to post-intervention. In the 50 m sprint, the HIITG showed a large performance gain ($t = 7.156$, $p < .001$, $d = 2.530$), while the PTG demonstrated an even greater improvement ($t = 19.676$, $p < .001$, $d = 5.259$). Agility (T-Test) improved significantly in the HIITG ($t = 6.038$, $p < .001$, $d = 2.135$) and PTG ($t = 12.302$, $p < .001$, $d = 3.288$). Squat jump height increased notably in both groups: HIITG ($t = -8.117$, $p < .001$, $d = -2.870$) and PTG ($t = -42.260$, $p < .001$, $d = -11.294$). Improvements in jump power were significant for HIITG ($t = -5.921$, $p < .001$, $d = -2.094$) and PTG ($t = -6.485$, $p < .001$, $d = -1.733$). Take-off velocity also improved: HIITG ($t = -5.548$, $p < .001$, $d = -1.961$), PTG ($t = -3.187$, $p = .007$, $d = -0.852$). Maximal jump force showed moderate to large gains: HIITG ($t = -2.759$, $p = .028$, $d = -0.975$), PTG ($t = -5.516$, $p < .001$, $d = -1.474$). The explosive rate of muscle contraction increased significantly: HIITG ($t = -19.858$, $p < .001$, $d = -7.021$), PTG ($t = -7.713$, $p < .001$, $d = -2.061$). Improvements in

functional power relative to body mass were also significant in both HIITG ($t = -9.790$, $p < .001$, $d = -3.461$) and PTG ($t = -8.354$, $p < .001$, $d = -2.233$). Non-significant changes were noted for maximal force before take-off ($t = -2.144$, $p = .069$, $d = -0.758$) and force output ($t = -1.060$, $p = .309$, $d = -0.283$). Significant changes from pre- to post-intervention are illustrated graphically Figure 2.

Time

The analysis revealed significant time effects across most performance variables, indicating that both training interventions HIITG and PTG led to improvements over the training period Table 3. Notably, large effect sizes were observed for 50 m sprint time, agility, jump height, and

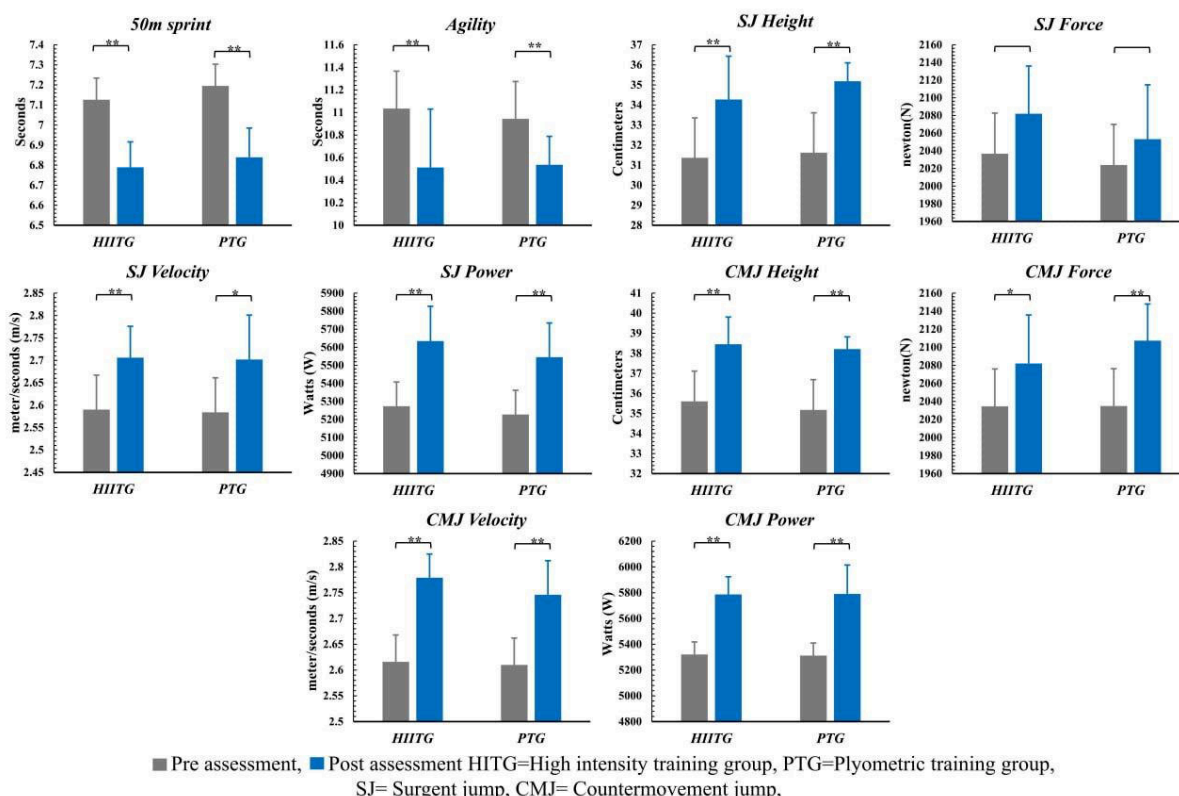


Fig. 2. Visual depiction of statistically significant differences between pre- and post-intervention measurements. * $p < 0.05$, ** $p < 0.001$

Table 3. Statistical Comparison of Outcomes Between HIIT and PT Training

High-Intensity Interval Training (HIIT) (n=8)						Plyometric Training (PT) (n=14)							
Variable	Pre Test		Post Test		P	Pre Test		Post Test		P	p (η² _p)		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Time	Group	Group × Time
50 m sprint	7.12	0.10	6.789	0.12	< .001	7.19	0.10	6.83	0.14	< .001	< .001 (0.93)	0.255 (0.06)	0.661 (0.01)
Agility	11.03	0.33	10.51	0.51	< .001	10.94	0.19	10.53	0.25	< .001	< .001 (0.87)	0.801 (0.00)	0.157 (0.09)
SJ Height	31.36	1.98	34.27	2.15	< .001	31.62	0.87	35.18	0.91	< .001	< .001 (0.96)	0.353 (0.04)	0.035 (0.20)
SJ Force	2036.62	46.02	2081.93	54.06	0.06	2023.85	58.37	2053.18	61.50	0.309	0.078 (0.14)	0.185 (0.08)	0.695 (0.00)
SJ Velocity	2.59	0.07	2.70	0.07	< .001	2.58	0.08	2.70	0.09	0.007	< .001 (0.50)	0.857 (0.00)	0.965 (9.91)
SJ Power	5273.26	134.26	5634.43	192.73	< .001	5227.34	135.18	5545.25	189.54	< .001	< .001 (0.50)	0.857 (0.00)	0.965 (9.91)
SJ Power/N	2.59	0.07	2.70	0.07	< .001	2.58	0.08	2.70	0.09	0.007	< .001 (0.50)	0.857 (0.00)	0.965 (9.91)
CMJ Height	35.60	1.51	38.45	1.35	< .001	35.17	0.43	38.21	0.60	< .001	< .001 (0.94)	0.402 (0.03)	0.553 (0.01)
CMJ Force	2034.60	41.41	2082.07	53.70	0.02	2034.87	35.18	2107.27	40.67	0.028	< .001 (0.60)	0.406 (0.03)	0.264 (0.06)
CMJ Velocity	2.61	0.05	2.77	0.04	< .001	2.61	0.04	2.74	0.06	< .001	< .001 (0.88)	0.349 (0.04)	0.283 (0.05)
CMJ Power	5320.51	97.40	5786.46	137.61	< .001	5312.05	131.82	5790.10	224.79	< .001	< .001 (0.86)	0.968 (8.17)	0.887 (0.00)
CMJ Power/N	2.61	0.05	2.77	0.04	< .001	2.61	0.04	2.74	0.06	< .001	< .001 (0.88)	0.349 (0.04)	0.283 (0.05)

Note: SG = Squat Jump; CMJ = Countermovement Jump

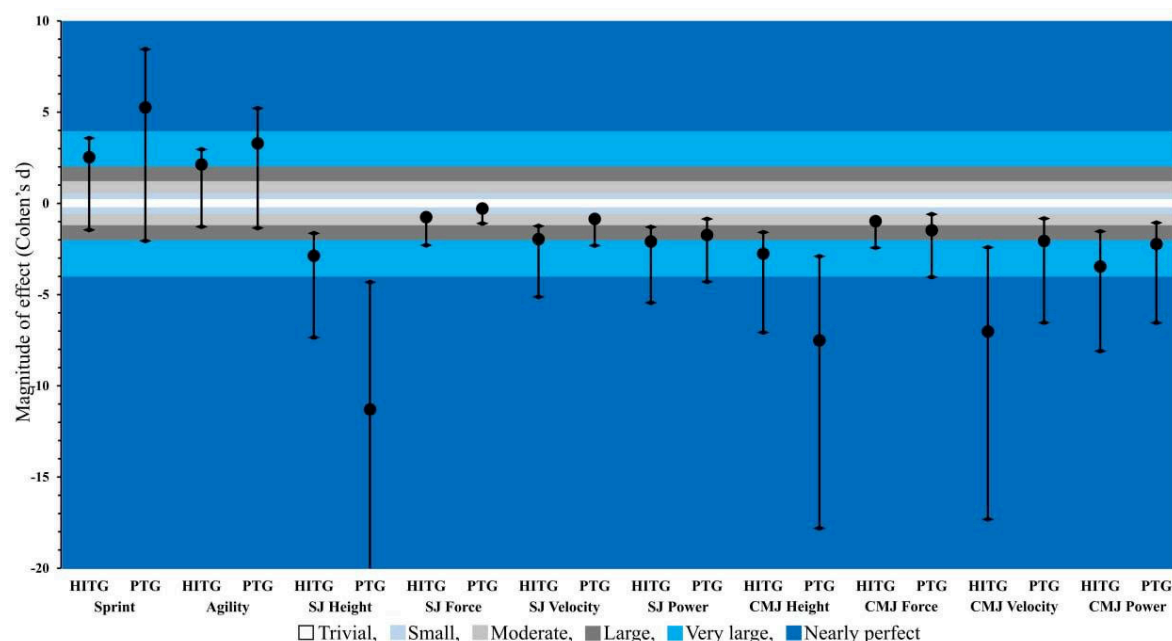


Fig. 3. Visualization of Effect Size (Cohen's d)

power, suggesting substantial gains in speed, agility, and lower-body power due to training. Visualization of Effect Size (Cohen's d) Figure 3.

Group

However, no significant group effects were found, which implies that overall performance levels between the HIITG and PTG groups were similar when averaged across time points.

Group $\times$ Time Interaction

Importantly, a significant group $\times$ time interaction was observed only for squat jump (SJ) height. This suggests that the improvement in SJ height varied between the two groups, with one group likely experiencing a greater benefit than the other. For all other variables, the interaction was not significant, indicating that both groups improved similarly over time without a meaningful difference in the rate or magnitude of change.

Discussion

The present findings demonstrate that both High Intensity Interval Training Group (HIITG) and Plyometric Training Group (PTG) elicited statistically significant improvements in 50m sprint performance and agility, with the superior outcomes attributable to the distinct yet complementary neuromuscular adaptations induced by each training modality. Plyometric training has been consistently shown to enhance sprint performance, power, strength, and agility through the stretch-shortening cycle mechanism, which optimizes the rapid transition from eccentric to concentric muscle contractions (Hasan, 2023; Kons et al., 2023). The PTG's improvements in sprint and agility performance align with established research demonstrating that plyometric

exercises enhance neuromuscular coordination, reactive strength index, and rate of force development are critical determinants of explosive movement patterns (Markovic & Mikulic, 2010; Suchomel et al., 2016). Conversely, HIIT protocols induce superior adaptations in metabolic capacity, anaerobic power output, and neuromuscular efficiency through repeated exposure to high-intensity efforts that closely mimic the physiological demands of sprint performance (Buchheit & Laursen, 2013; Laursen & Jenkins, 2002). The marginally superior performance gains observed in the HIITG explained by HIIT's unique capacity to simultaneously enhance both the phosphocreatine energy system and glycolytic power, while also improving neuromuscular recruitment patterns and intermuscular coordination specific to high-velocity movements (Gibala et al., 2012; Sloth et al., 2013). Furthermore, HIIT's specificity to sprint training demands characterized by repeated bouts of maximal or near-maximal intensity efforts provides a more direct training stimulus that translates to enhanced sprint performance and change-of-direction speed (Iaia & Bangsbo, 2010), explaining the slightly greater improvements observed in the HIITG compared to the PTG despite both modalities producing statistically significant enhancements in athletic performance measures.

The PTG's improvements in sprint and agility performance align with established research demonstrating that plyometric exercises enhance neuromuscular coordination, reactive strength index, and rate of force development are critical determinants of explosive movement patterns (Markovic & Mikulic, 2010; Suchomel et al., 2016). Conversely, HIIT protocols induce superior adaptations in metabolic capacity, anaerobic power output, and neuromuscular efficiency through repeated exposure to high-intensity efforts that closely mimic the physiological demands of sprint performance (Buchheit & Laursen, 2013; Laursen & Jenkins, 2002). The marginally superior performance gains observed in the HIITG explained

by HIIT's unique capacity to simultaneously enhance both the phosphocreatine energy system and glycolytic power, while also improving neuromuscular recruitment patterns and intermuscular coordination specific to high-velocity movements (Gibala et al., 2012; Sloth et al., 2013). Furthermore, HIIT's specificity to sprint training demands characterized by repeated bouts of maximal or near-maximal intensity efforts provides a more direct training stimulus that translates to enhanced sprint performance and change-of-direction speed (Iaia & Bangsbo, 2010), explaining the slightly greater improvements observed in the HIITG compared to the PTG despite both modalities producing statistically significant enhancements in athletic performance measures. Similarly, both training modalities demonstrated significant improvements in standing jump performance variables, like Standing Jump Height, Standing Jump Force, Standing Jump Velocity, and Standing Jump Power with the differential responses reflecting the unique biomechanical and physiological adaptations associated with each intervention. The PTG's superior performance in Standing Jump Height and Standing Jump Velocity attributed to plyometric training's established efficacy in enhancing vertical jump performance through improved stretch-shortening cycle utilization, motor unit synchronization, and elastic energy storage-release mechanisms (Kons et al., 2023; Markovic & Mikulic, 2010). Meta-analytical evidence demonstrates that plyometric training produces moderate to large effects on vertical jump height, with improvements ranging from 4.7% to 8.7% across different jump variations, primarily through enhanced neuromuscular coordination and reactive strength development (Villarreal et al., 2009; Kons et al., 2023). The superior Standing Jump Height and Standing Jump Velocity outcomes in the PTG align with research indicating that plyometric exercises specifically target the fast-twitch muscle fibers responsible for explosive vertical movement patterns and optimize the stretch-shortening cycle mechanics essential for maximal jump velocity generation (Suchomel et al., 2016). Conversely, the HIITG's marginally superior improvements in Standing Jump Force and Standing Jump Power reflect the unique adaptations induced by high-intensity interval protocols, which enhance motor unit recruitment, firing frequency, and force production capabilities through repeated exposure to maximal or near-maximal intensity efforts (Gibala et al., 2012; Laursen & Jenkins, 2002). Recent systematic review evidence demonstrates that HIIT produces moderate effects on jumping performance in athletes ($ES = 0.918$), with particular improvements in Standing Jump Force and Standing Jump Power variables attributed to enhanced neuromuscular recruitment patterns, increased activation of fast-twitch muscle fibers, and improved intermuscular coordination during explosive movements (Sloth et al., 2013; Wang, X. et al., 2025). The differential adaptations observed between training modalities explained by the principle of training specificity, whereby plyometric training's emphasis on rapid stretch-shortening cycle movements preferentially enhances velocity-dependent variables (Standing Jump Height and Standing Jump Velocity), while HIIT's focus on sustained high-intensity efforts promotes force production and power output capabilities (Standing Jump Force and Standing Jump Power) through enhanced neuromuscular drive and metabolic adaptations (Buchheit

& Laursen, 2013; Iaia & Bangsbo, 2010). These findings support the concept that both training modalities induce significant performance improvements through distinct yet complementary physiological pathways, with the specific adaptations reflecting the unique mechanical and metabolic demands imposed by each intervention.

The significant improvements observed in Counter Movement Jump Height, Counter Movement Jump Force, Counter Movement Jump Velocity, and Counter Movement Jump Power in both HIITG and PTG attributed to distinct yet complementary neuromuscular adaptations that enhance explosive performance capabilities. The superior Counter Movement Jump Height and Counter Movement Jump Velocity improvements in HIITG align with previous research demonstrating that high-intensity interval protocols enhance muscle fiber synchronization and neural recruitment patterns, leading to more powerful and coordinated muscle contractions essential for explosive vertical movements (Buchan et al., 2013; Milanović et al., 2015). The marginally better Counter Movement Jump Force performance in PTG supports established literature indicating that plyometric exercises specifically target the stretch-shortening cycle mechanism, enhancing eccentric-concentric coupling and maximizing force production during the countermovement phase (Villarreal et al., 2009; Markovic & Mikulic, 2010). Both training modalities demonstrated equivalent improvements in Counter Movement Jump Power, suggesting that while HIIT optimizes velocity components through enhanced anaerobic power and neuromuscular efficiency (Laursen & Jenkins, 2002), and plyometric training maximizes force output through improved stretch reflex sensitivity and elastic energy utilization (Bobbert et al., 1996; Komi, 2000), their combined effects on the power equation result in similar overall power enhancement. The physiological mechanisms underlying these adaptations include HIIT-induced improvements in phosphocreatine system efficiency, motor unit recruitment, and intermuscular coordination (Gibala et al., 2006), while plyometric training enhances tendon stiffness, pre-activation patterns, and reactive strength capabilities (Chimera et al., 2004; Turner & Jeffreys, 2010). These findings corroborate meta-analytical evidence demonstrating that both training methodologies effectively improve vertical jump performance through distinct pathways, with HIIT primarily enhancing velocity-related components and plyometric training optimizing force-generating capacity, ultimately converging to produce comparable power outputs in trained athletes.

Limitation and Future Research

Despite the methodological rigor, several limitations should be acknowledged. First, the sample was restricted to a specific age group and performance level, which may limit the generalizability of the findings to broader athletic populations or different age categories. Second, although objective tools such as force plates and timing gates were used, external factors like athlete motivation, surface conditions, and circadian rhythms could have influenced performance. Additionally, the training intervention duration was limited to 12 weeks, which may not capture long-term physiological or neuromuscular adaptations. Finally, dietary intake and psychological variables were not controlled, which may have

impacted athletic output and recovery. Future studies could extend the intervention period and include longitudinal follow-ups to examine the sustainability of training effects. Comparative studies across multiple sports or performance levels (e.g., elite vs. recreational) may provide broader insights into sport-specific adaptations. Including female athletes or youth populations can enhance demographic diversity. Moreover, integrating physiological markers (e.g., lactate threshold, hormonal profiles) and neuromuscular assessments (e.g., electromyography) would enrich the understanding of underlying adaptation mechanisms. Investigating the combined effect of strength training with recovery strategies, such as sleep hygiene and nutrition protocols, is also recommended.

Practical Application

The results of this study provide actionable insights for coaches, strength and conditioning professionals, and sport scientists. The use of validated and reliable tests (SJ, CMJ, sprint, and agility) offers practical tools for monitoring athletic performance and training progress. The study highlights the importance of periodized, sport-specific conditioning programs to enhance explosive power, speed, and agility. Implementing these protocols during pre-season or in-season phases can help optimize training outcomes, reduce injury risk, and support talent development in competitive sports. Regular testing can also guide individualized training modifications, ensuring athletes meet performance benchmarks safely and effectively.

Conclusions

This study demonstrated that a structured 12-week high-intensity interval training (HIIT) and plyometric training (PT) protocol significantly improved key performance indicators such as lower-limb explosive power, sprint speed, and agility in young athletes. The inclusion of sport-specific and neuromuscular-focused training modalities contributed to notable enhancements in Squat Jump and Countermovement Jump heights, as well as sprint and agility outcomes. These findings support the integration of HIIT and plyometric elements into regular training routines for optimizing athletic performance. Overall, the study underscores the effectiveness of targeted, periodized conditioning programs in enhancing functional abilities critical to competitive sports performance.

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Conflict of Interest

Authors have no conflict of interest.

References

Wang, J., Qin, Z., Zhang, Q., & Wang, J. (2025). Lower limb dynamic balance, strength, explosive power, agility, and

injuries in volleyball players. *Journal of Orthopaedic Surgery and Research*, 20, 211.

<https://doi.org/10.1186/s13018-025-05566-w>

Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. *Sports Medicine*, 48(1), 111-135.

<https://doi.org/10.1007/s40279-017-0794-z>

McGill, S.M., Chaimberg, J.D., Frost, D.M., & Fenwick, C.M. J. (2010). Evidence of a double peak in muscle activation to enhance strike speed and force: An example with elite mixed martial arts fighters. *Journal of Strength and Conditioning Research*, 24(2), 348-357.

<https://doi.org/10.1519/JSC.0b013e3181cc23d5>

Miller, M.G., Herniman, J.J., Ricard, M.D., Cheatham, C.C., & Michael, T.J. (2006). The effects of a 6-week plyometric training program on agility. *Journal of Sports Science & Medicine*, 5(3), 459-465.

Laursen, P., & Buchheit, M. (Eds.). (2019). *Science and application of high-intensity interval training: Solutions to the programming puzzle*. Human Kinetics.

Ramirez-Campillo, R., Sortwell, A., Moran, J., Afonso, J., Clemente, F.M., Lloyd, R.S., Oliver, J.L., Pedley, J., & Granacher, U. (2023). Plyometric-Jump Training Effects on Physical Fitness and Sport-Specific Performance According to Maturity: A Systematic Review with Meta-analysis. *Sports Medicine - Open*, 9(1), 23.

<https://doi.org/10.1186/s40798-023-00568-6>

Atakan, M.M., Li, Y., Koşar, Ş. N., Turnagöl, H.H., & Yan, X. (2021). Evidence-Based Effects of High-Intensity Interval Training on Exercise Capacity and Health: A Review with Historical Perspective. *International Journal of Environmental Research and Public Health*, 18(13), 7201.

<https://doi.org/10.3390/ijerph18137201>

Helgerud, J., Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., Simonsen, T., Helgesen, C., Hjorth, N., Bach, R., & Hoff, J. (2007). Aerobic high-intensity intervals improve VO₂max more than moderate training. *Medicine and Science in Sports and Exercise*, 39(4), 665-671.

<https://doi.org/10.1249/mss.0b013e3180304570>

Buchheit, M., & Laursen, P.B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Medicine (Auckland, N.Z.)*, 43(5), 313-338.

<https://doi.org/10.1007/s40279-013-0029-x>

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of High-Intensity Interval Training (HIT) and Continuous Endurance Training for VO₂max Improvements: A Systematic Review and Meta-Analysis of Controlled Trials. *Sports Medicine*, 45(10), 1469-1481.

<https://doi.org/10.1007/s40279-015-0365-0>

Coates, A.M., Joyner, M.J., Little, J.P., Jones, A.M., & Gibala, M.J. (2023). A Perspective on High-Intensity Interval Training for Performance and Health. *Sports Medicine (Auckland, N.Z.)*, 53(Suppl 1), 85-96.

<https://doi.org/10.1007/s40279-023-01938-6>

Hung, C.-H., Su, C.-H., & Wang, D. (2025). The Role of High-Intensity Interval Training (HIIT) in Neuromuscular Adaptations: Implications for Strength and Power Development—A Review. *Life*, 15(4), 657.

<https://doi.org/10.3390/life15040657>

- Skelly, L.E., Gillen, J.B., Frankish, B.P., MacInnis, M.J., Godkin, F.E., Tarnopolsky, M.A., Murphy, R.M., & Gibala, M.J. (2021). Human skeletal muscle fiber type-specific responses to sprint interval and moderate-intensity continuous exercise: Acute and training-induced changes. *Journal of Applied Physiology*, 130(4), 1001-1014. <https://doi.org/10.1152/jappphysiol.00862.2020>
- Torma, F., Gombos, Z., Jokai, M., Takeda, M., Mimura, T., & Radak, Z. (2019). High intensity interval training and molecular adaptive response of skeletal muscle. *Sports Medicine and Health Science*, 1(1), 24-32. <https://doi.org/10.1016/j.smhs.2019.08.003>
- Beato, M., Bigby, A.E. J., De Keijzer, K.L., Nakamura, F.Y., Coratella, G., & McErlain-Naylor, S.A. (2019). Post-activation potentiation effect of eccentric overload and traditional weightlifting exercise on jumping and sprinting performance in male athletes. *PloS One*, 14(9), e0222466. <https://doi.org/10.1371/journal.pone.0222466>
- Clemente, F.M., & Sarmiento, H. (2021). Combining small-sided soccer games and running-based methods: A systematic review. *Biology of Sport*, 38(4), 617-627. <https://doi.org/10.5114/biolsport.2021.102932>
- Davies, G., Riemann, B.L., & Manske, R. (2015). Current concepts of plyometric exercise. *International Journal of Sports Physical Therapy*, 10(6), 760-786.
- Abdel-Rahman, A. (2013). The role of biomechanical parameters and muscle activity during eccentric and concentric contractions in vertical jump performance. *Journal of Physical Education and Sport*, 13(3), 430-437. <https://doi.org/10.7752/jpes.2013.03069>
- Aboodarda, S.J., Page, P.A., & Behm, D.G. (2015). Eccentric and concentric jumping performance during augmented jumps with elastic resistance: a meta-analysis. *International Journal of Sports Physical Therapy*, 10(6), 839-849.
- Markovic, G., & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Medicine (Auckland, N.Z.)*, 40(10), 859-895. <https://doi.org/10.2165/11318370-000000000-00000>
- Ramírez-Campillo, R., Burgos, C. H., Henríquez-Olguín, C., Andrade, D. C., Martínez, C., Álvarez, C., Castro-Sepúlveda, M., Marques, M. C., & Izquierdo, M. (2015). Effect of unilateral, bilateral, and combined plyometric training on explosive and endurance performance of young soccer players. *Journal of Strength and Conditioning Research*, 29(5), 1317-1328. <https://doi.org/10.1519/JSC.0000000000000762>
- Ramírez-Campillo, R., Sortwell, A., Moran, J., Afonso, J., Clemente, F. M., Lloyd, R. S., Oliver, J. L., Pedley, J., & Granacher, U. (2023). Plyometric-Jump Training Effects on Physical Fitness and Sport-Specific Performance According to Maturity: A Systematic Review with Meta-analysis. *Sports Medicine - Open*, 9(1), 23. <https://doi.org/10.1186/s40798-023-00568-6>
- Moran, C.G., Lecky, F., Bouamra, O., Lawrence, T., Edwards, A., Woodford, M., Willett, K., & Coats, T.J. (2018). Changing the System—Major Trauma Patients and Their Outcomes in the NHS (England) 2008-17. *EClinicalMedicine*, 2-3, 13-21. <https://doi.org/10.1016/j.eclinm.2018.07.001>
- Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F.B., & Chéour, F. (2016). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics*, 53, 231-247. <https://doi.org/10.1515/hukin-2016-0026>
- Matavulj, D., Kukolj, M., Ugarkovic, D., Tihanyi, J., & Jaric, S. (2001). Effects of plyometric training on jumping performance in junior basketball players. *The Journal of Sports Medicine and Physical Fitness*, 41(2), 159-164.
- Foster, C., Farland, C.V., Guidotti, F., Harbin, M., Roberts, B., Schuette, J., Tuuri, A., Doberstein, S.T., & Porcari, J.P. (2015). The Effects of High Intensity Interval Training vs Steady State Training on Aerobic and Anaerobic Capacity. *Journal of Sports Science & Medicine*, 14(4), 747-755. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4657417/>
- Jagsz, S., & Sikora, M. (2025). The Effectiveness of High-Intensity Interval Training vs. Cardio Training for Weight Loss in Patients with Obesity: A Systematic Review. *Journal of Clinical Medicine*, 14(4), Article 4. <https://doi.org/10.3390/jcm14041282>
- Tuttor, M., von Stengel, S., Kohl, M., Lell, M., Scharf, M., Uder, M., Wittke, A., & Kemmler, W. (2020). High Intensity Resistance Exercise Training vs. High Intensity (Endurance) Interval Training to Fight Cardiometabolic Risk Factors in Overweight Men 30–50 Years Old. *Frontiers in Sports and Active Living*, 2, 68. <https://doi.org/10.3389/fspor.2020.00068>
- Oliver, J.L., Ramachandran, A.K., Singh, U., Ramirez-Campillo, R., & Lloyd, R.S. (2024). The Effects of Strength, Plyometric and Combined Training on Strength, Power and Speed Characteristics in High-Level, Highly Trained Male Youth Soccer Players: A Systematic Review and Meta-Analysis. *Sports Medicine*, 54(3), 623-643. <https://doi.org/10.1007/s40279-023-01944-8>
- Yang, G., Chen, W., Qi, D., Zhang, J., & Men, Z. (2024). The Effects of a 6-Week Plyometric and Sprint Interval Training Intervention on Soccer Player's Physical Performance. *Journal of Sports Science & Medicine*, 23(3), 526-536. <https://doi.org/10.52082/jssm.2024.526>
- Cronin, J.B., & Hansen, K.T. (2005). Strength and power predictors of sports speed. *Journal of Strength and Conditioning Research*, 19(2), 349-357. <https://doi.org/10.1519/14323.1>
- Pauole, K., Madole, K., Garhammer, J., Lacourse, M., & Rozenek, R. (2000). Reliability and Validity of the T-Test as a Measure of Agility, Leg Power, and Leg Speed in College-Aged Men and Women. *Journal of Strength and Conditioning Research*, 14(4), 443-450. <https://doi.org/10.1519/00124278-200011000-00012>
- Hammami, M., Gaamouri, N., Shephard, R.J., & Chelly, M.S. (2019). Effects of Contrast Strength vs. Plyometric Training on Lower-Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. *Journal of Strength and Conditioning Research*, 33(8), 2094-2103. <https://doi.org/10.1519/JSC.0000000000002425>
- Razali, M.N., & Yap, B. (2011). Power Comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling Tests. *J. Stat. Model. Analytics*, 2(1), 21-33.
- Field, A. (2013). *Discovering statistics using IBM SPSS statistics: And sex and drugs and rock "n" roll (4th edition)*. Sage.
- Cohen, J. (2013). *Statistical Power Analysis for the Behavioral Sciences*. Routledge. <https://doi.org/10.4324/9780203771587>

- Hasan, S. (2023). Effects of plyometric vs. strength training on strength, sprint, and functional performance in soccer players: A randomized controlled trial. *Scientific Reports*, 13(1), 4256. <https://doi.org/10.1038/s41598-023-31375-4>
- Kons, R.L., Orssatto, L.B. R., Ache-Dias, J., De Pauw, K., Meeusen, R., Trajano, G.S., Dal Pupo, J., & Detanico, D. (2023). Effects of Plyometric Training on Physical Performance: An Umbrella Review. *Sports Medicine - Open*, 9, 4. <https://doi.org/10.1186/s40798-022-00550-8>
- Suchomel, T.J., Nimphius, S., & Stone, M.H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine (Auckland, N.Z.)*, 46(10), Article 10. <https://doi.org/10.1007/s40279-016-0486-0>
- Laursen, P.B., & Jenkins, D.G. (2002). The scientific basis for high-intensity interval training: Optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine (Auckland, N.Z.)*, 32(1), 53-73. <https://doi.org/10.2165/00007256-200232010-00003>
- Gibala, M.J., Little, J.P., Macdonald, M.J., & Hawley, J.A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *The Journal of Physiology*, 590(5), 1077-1084. <https://doi.org/10.1113/jphysiol.2011.224725>
- Sloth, M., Sloth, D., Overgaard, K., & Dalgas, U. (2013). Effects of sprint interval training on VO₂max and aerobic exercise performance: A systematic review and meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*, 23(6), e341-352. <https://doi.org/10.1111/sms.12092>
- Iaia, F.M., & Bangsbo, J. (2010). Speed endurance training is a powerful stimulus for physiological adaptations and performance improvements of athletes. *Scandinavian Journal of Medicine & Science in Sports*, 20(Suppl 2), 11-23. <https://doi.org/10.1111/j.1600-0838.2010.01193.x>
- Villarreal, E.S.-S., Kellis, E., Kraemer, W.J., & Izquierdo, M. (2009). Determining Variables of Plyometric Training for Improving Vertical Jump Height Performance: A Meta-Analysis. *The Journal of Strength & Conditioning Research*, 23(2), 495. <https://doi.org/10.1519/JSC.0b013e318196b7c6>
- Buchheit, M., & Laursen, P.B. (2013b). High-Intensity Interval Training, Solutions to the Programming Puzzle: Part I: Cardiopulmonary Emphasis. *Sports Medicine*, 43(5), 313-338. <https://doi.org/10.1007/s40279-013-0029-x>
- Wang, X., Soh, K. G., Samsudin, S., Li, L., Liu, C., Sun, M., & Ma, S. (2025). Effects of high-intensity training on jumping performance among athletes: A systematic review with meta-analysis. *Scientific Reports*, 15(1), 1763. <https://doi.org/10.1038/s41598-024-83161-5>
- Buchan, D.S., Ollis, S., Young, J.D., Cooper, S.-M., Shield, J.P. H., & Baker, J.S. (2013). High intensity interval running enhances measures of physical fitness but not metabolic measures of cardiovascular disease risk in healthy adolescents. *BMC Public Health*, 13, 498. <https://doi.org/10.1186/1471-2458-13-498>
- Bobbert, M.F., Gerritsen, K.G., Litjens, M.C., & Van Soest, A.J. (1996). Why is countermovement jump height greater than squat jump height? *Medicine and Science in Sports and Exercise*, 28(11), 1402-1412. <https://doi.org/10.1097/00005768-199611000-00009>
- Komi, P.V. (2000). Stretch-shortening cycle: A powerful model to study normal and fatigued muscle. *Journal of Biomechanics*, 33(10), 1197-1206. [https://doi.org/10.1016/s0021-9290\(00\)00064-6](https://doi.org/10.1016/s0021-9290(00)00064-6)
- Gibala, M.J., Little, J.P., Van Essen, M., Wilkin, G.P., Burgomaster, K.A., Safdar, A., Raha, S., & Tarnopolsky, M.A. (2006). Short-term sprint interval versus traditional endurance training: Similar initial adaptations in human skeletal muscle and exercise performance. *The Journal of Physiology*, 575(3), 901-911. <https://doi.org/10.1113/jphysiol.2006.112094>
- Chimera, N.J., Swanik, K.A., Swanik, C.B., & Straub, S.J. (2004). Effects of Plyometric Training on Muscle-Activation Strategies and Performance in Female Athletes. *Journal of Athletic Training*, 39(1), 24-31.
- Turner, A.N., & Jeffreys, I. (2010). The Stretch-Shortening Cycle: Proposed Mechanisms and Methods for Enhancement. *Strength & Conditioning Journal*, 32(4), 87. <https://doi.org/10.1519/SSC.0b013e3181e928f9>

Визначення впливу високоінтенсивного інтервального тренування та пліометричного тренування на швидкість, спритність та вибухову результативність нижніх кінцівок у чоловіків-баскетболістів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 13 с., 3 табл., 3 рис., 52 джерела.

Історія питання. Високоінтенсивне інтервальне тренування (ВІТ) та пліометричне тренування (ПТ) широко використовуються для підвищення спортивної результативності у видах спорту, що вимагають швидкості, спритності та вибухової потужності нижніх кінцівок, як-от баскетбол. Попри покращення нервово-м'язових та фізіологічних можливостей обома методами, питання їхньої порівняльної ефективності щодо конкретних рухових здібностей залишається нез'ясованим.

Мета дослідження. Мета цього дослідження полягала в оцінці та порівнянні впливу ВІТ та ПТ на швидкість, спритність і вибухову результативність нижніх кінцівок у чоловіків-баскетболістів.

Матеріали та методи. Загалом 22 чоловіки-баскетболісти (середній вік 21.27 ± 1.34 роки) було розподілено за методом рандомізації на дві інтервенційні групи: група високоінтенсивного інтервального тренування (ВІТ, $n = 8$) та група пліометричного тренування (ПТ, $n = 14$). Обидві групи проходили відповідні тренувальні програми протягом визначеного періоду інтервенції. Ключові показники результативності, зокрема швидкість, спритність, стрибок у присіді (ПС) та стрибок із контррухом (КРС), оцінювались перед та після проведення тренування. З метою визначення ефектів взаємодії між часом (перед та після інтервенції) та групою (ВІТ проти ПТ) за всіма показниками результатів було застосовано двофакторний дисперсійний аналіз із повторними вимірами (2×2).

Результати. Як група ВІТ, так і група ПТ продемонстрували істотне поліпшення результатів у часі спринту, спритності, висоті стрибка, швидкості, потужності та співвідношенні потужності до маси тіла (усі показники $p < .001$). Виразених змін у показниках сили ПС виявлено не було. Двофакторний дисперсійний аналіз показав суттєвий вплив часу на всі змінні ($p < .001$) без значних групових або взаємодійних ефектів ($p > .05$), що свідчить про порівняльні поліпшення в рамках обох інтервенцій.

Висновки. Отримані результати підтвердили, що як високоінтенсивне інтервальне тренування, так і пліометричне тренування є ефективними у підвищенні швидкості, спритності та вибухової результативності нижніх кінцівок серед чоловіків-баскетболістів. Відсутність істотних відмінностей між групами свідчить про ефективність впровадження будь-якого із зазначених методів тренування у програми підвищення результативності залежно від уподобань спортсменів, тренувального контексту або доступності ресурсів.

Ключові слова: нервово-м'язова адаптація, анаеробна працездатність, вибухова сила, механіка стрибка, баскетболісти.

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The Influence of Chronotype on Strength Variables in Female University Students at different times of day: A Cross-Sectional Study

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Abstract

Background. Chronotype influences physical performance through circadian rhythms that vary across the day. Strength and power often peak in the evening, suggesting timing impacts training outcomes. This study explores these effects in female university students, a group which is underrepresented in chronobiological research.

Objectives. This study aimed to examine how chronotype influences strength performance in female university students at different times of day. Specifically, it compared maximal strength, explosive power, and hand muscle strength between morning-type and evening-type individuals to identify optimal training or performance times based on chronobiological preference.

Materials and methods. The Horne and Ostberg Morningness–Eveningness Questionnaire was used to classify 56 Indian female university students (mean age = 22.2 years; weight = 56 ± 4.31 kg; height = 158 ± 5 cm; BMI = 21 ± 1.5 kg/m²). Strength performance was assessed using three measures: one-repetition maximum (1RM) for maximal strength; countermovement jump (CMJ) for explosive power; and handgrip dynamometry for muscle strength. Testing was conducted under standardized conditions at each participant's chronotype-aligned time (morning or evening). Independent samples t-tests were used for analysis, with the Shapiro–Wilk and Levene's tests confirming the assumptions of normality and homogeneity.

Results. It was observed that the evening-type individuals expressed much better scores on all variables of being tested than morning types. The evening group produced greater values in 1RM squat (78.3 ± 2.63 kg vs. 72.1 ± 3.11 kg; $t_{(54)} = -8.08$, $p < .001$, $d = 2.16$), CMJ (30.1 ± 2.32 cm vs. 26.1 ± 2.32 cm; $t_{(54)} = -6.46$, $p < .001$, $d = 1$).

Conclusions. The findings of this study indicate that evening-type female university students have enhanced strength performance during evening hours, underscoring the need to consider chronotype when planning training and performance assessments in female athletes.

Keywords: chronotype, morningness – eveningness, maximum strength, explosive power, hand muscle strength.

Introduction

Chronotype is the natural inclination to sleep at a certain time, reflecting deeper links between individual

biology and social time. Some people, called morning-types, wake early and function best in daylight, whereas evening-types tend to turn on mentally and physically later and often enjoy late-night work or leisure (Das et al., 2024). Such tendencies closely related with the body's circadian rhythm that coordinates many physical, mental and behavioural processes on a rough day-long schedule. That helps to maintain sleep and wakefulness, adjusts hormone levels,

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raises or lowers body temperature and modulates strength, focus, mood and energy. Individuals chronotype can be identified through self-report the Morningness-Eveningness Questionnaire (MEQ) or the Munich Chronotype Questionnaire (MCTQ) (Roenneberg et al., 2019). These Questionnaires ask about usual bed and rise times, changes in energy through the day, and how readily someone can perform work or study early, late or around the noon peak. Its expression arises from a blend of genetic predispositions, life-history events and current living conditions (Adan et al., 2012). Whether someone naturally rises early or stays up late therefore influences daily peaks and troughs in physical and mental performance (Morrow & Roenneberg, 2003). Among the many biological and mental factors that sway human performance, circadian rhythms stand out as especially powerful. In recent years, the idea of chronotype-preferred hours for exercise, competition or recovery-has drawn increasing interest in sport and exercise science.

Researchers typically classify people into three main chronotypes: morning-type (MT), evening-type (ET), and intermediate-type (IT), with each group showing distinct peak times for physical and mental performance (Adan et al., 2012). Evidence indicates that chronotype influences athletic ability, especially in tasks demanding high force, explosive power and sustained endurance (Chtourou & Souissi, 2012). Morning-types tend to reach their best results early in the day, while evening-types shine later, often in the late afternoon or evening (Vitale & Weydahl, 2017). These time-dependent patterns are thought to follow daily changes in core body temperature, circulating hormones and the efficiency of neuromuscular pathways. Although interest in sex-related differences has grown, studies on chronotype and strength in young adult women remain surprisingly scarce. Moreover, most fitness tests and practices scheduled at fixed times, which can disadvantage students whose peak periods lie outside those slots (Facer-Childs & Brandstaetter, 2015).

General strength reinforces everyday tasks and protects the body by improving joint stability and muscular control, reducing the odds of minor or major injuries while moving (Garber et al., 2011). Explosive strength, sometimes called power, describes the body's knack for producing as much force as possible in the shortest possible phase, a quality that matters whenever a person sprints, jumps or throws an object with noticeable speed (Cormie et al., 2011). At the other end of the spectrum, muscular endurance is the ability to keep repeating a movement or to hold a position without early fatigue. However, it is essential in sustained physical work such as cycling, rowing or manual labour. Gains in any form of strength depend on size of the muscles recruited and consistently the nerves fire (Sale, 1988). A well-designed resistance program often recommended as the most straightforward way to increase both strength and power. Key training principles such as progressive overload, task specificity, and adequate recovery guide progress in athletes and rehabilitation clients alike (Kraemer & Ratamess, 2004). Personal factors, including age, biological sex, and even daily hormone cycles, can further shape how much and how quickly strength improves. However, factors such as chronological age, sex and even the timing of workouts relative to daily rhythms can shift how easily muscle strength is built and expressed. Numerous studies confirm that men tend to display higher absolute strength than women (Miller

et al., 1993). Understanding these circumferences, the present study will explore the influence of chronotype on strength variables in university female students at different times of day. The results will help create a better training schedule for both academic and athletic tasks that fits with each person's circadian rhythms.

Materials and Methods

Participants

Out of 100 university female students assessed using the Morningness-Eveningness Questionnaire, 28 morning-type and 28 evening-type students were selected through randomization, meeting the predefined inclusion criteria. These participants were then assigned to the morning group ($n = 28$) and the evening group ($n = 28$) for the study with a mean age of 22 ± 2 years, weight of 56 ± 4.31 Kg and height of 158 ± 5 cm, and BMI of 21 ± 1.5 kg/m². The subjects maximum strength performance was measured by the 1 RM squat test, explosive power was measured by the counter movement jump test, and hand muscle strength performance was measured by the hand grip dynamometer.

The present study used a priori power analysis for the selection of sample size with the help of G*Power 3.1.9.7 software with an alpha level = 0.05, power = 0.83, and an effect size of 0.80 for an independent samples t-test. It was determined that a minimum of 28 athletes should be included in each group. The study received approval from the departmental committee of Visva-Bharati University, West Bengal. Further Informed consent was obtained from all participants before they were included in the study and all procedures were conducted by the ethical guidelines of the latest version of the Helsinki Declaration. The tests were done under standardized conditions, either in the morning or in the evening sessions for each participant at their chronotype-aligned time of day. Before starting, they were given a brief explanation and demonstration of the categorized exercise test protocol. Testing took place at the gymnasium and the laboratory of the Department of Physical Education and Sport Science, Visva-Bharati University, Santiniketan, West Bengal in India.

Study Design

In this work, a randomized cross-sectional, comparative research design was used as a way to examine the impact of chronotype on the strength-related physical performance of female university-level students. The participants were divided into two groups: morning type and evening type. Every group went through a single testing exercise where the maximum strength was indicated in the one-repetition maximum squat (1RM) test, explosive power was determined through the countermovement jump (CMJ), and the hand muscle strength was evaluated according to a handgrip dynamometer.

Inclusion and Exclusion Criteria

The subjects were university female participants between the ages of 18 and 25 years, having regular undergraduate or post graduate classes, and a more or less regular sleep-wake

pattern. Participants were chosen without musculoskeletal injuries or medical conditions that can impair physical performance. Those who were already intermediate-type were not included in the study. Those with a history of neurological, cardiovascular, and orthopaedic disorders were also excluded. Participants using performance-enhancing substances, involved in competitive sports or strength training in the past three months, or with irregular menstrual cycles or hormonal disorders were excluded to ensure uniformity in strength performance measurements.

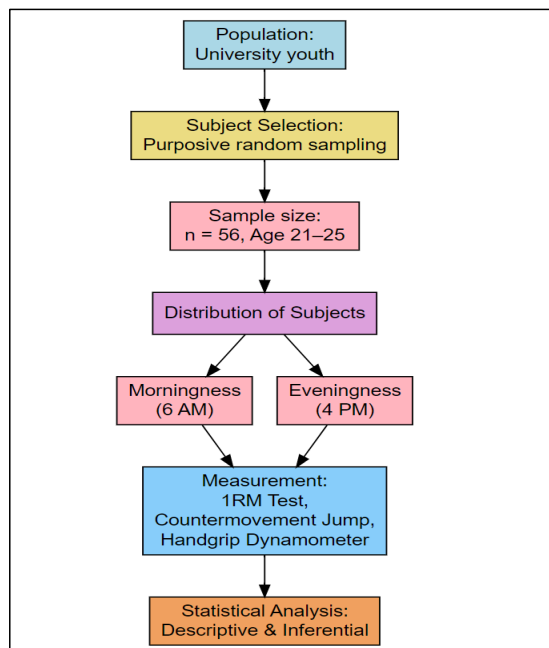


Fig 1. Flow diagram outlining the Study Design

Testing Protocol

The researcher used Horne and Ostberg's Morningness and Eveningness Questionnaires (MEQs) to identify the different chronotypes of the individual and MEQ scores ranging from 16 to 86. Scores range 42 to 58 imply "intermediate type," while scores below 41 and below imply "evening type." Scores of 59 and above imply a morning type (Khan et al., 2023).

Maximal Repetition Squat Test (1-RM): All participants performed a dynamic warm-up before the 1-RM squat test. They selected their starting weights, with guidance to begin at 30–40% of body weight to minimize injury risk. Using free squats, weights were progressively increased in 2.5-5 kg increments based on perceived difficulty until no further repetitions could be performed. Results were recorded in kilograms. Each group completed the test on separate days with 72 hours of rest between sessions. The test used free weights, following the protocol of İlbak et al. (2024).

Countermovement jumps (CMJ): Before and after each set of the half-squat test, participants performed two maximal countermovement jumps (CMJs) on a contact platform (Newtest Oy, Finland) with a 3–7 second delay after squatting. Jumps were performed from an extended position to 90° knee flexion, with a 4-second gap between

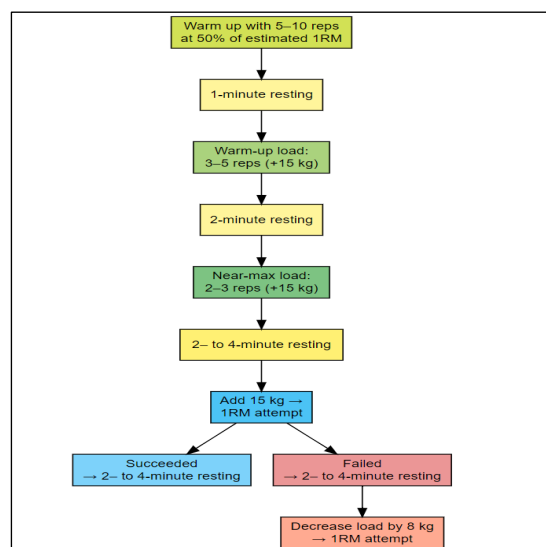


Fig. 2. The test protocol of the 1 RM test

jumps. Flight time was used to calculate jump height, and the higher of the two jumps was used for analysis (Izquierdo et al., 2002).

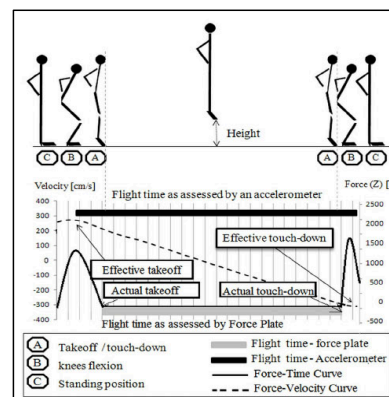


Fig 3. The test protocol of Countermovement jumps (CMJ)

Grip Strength (Dynamometry): Using a calibrated handgrip dynamometer (Takei TTK 5001, Takei Scientific Instruments Co. Ltd., Niigata, Japan), three maximal voluntary isometric contractions were measured to determine grip strength with the right and left hands, respectively. To measure this correctly, the participants had to stand with their arms parallel to their bodies, with their hands in a neutral position (Jurado-Castro et al., 2022).



Fig. 4. The test protocol of Grip Strength (Dynamometry)

Statistical Analysis

All statistical analyses were performed using Jamovi software (Version 2.4) to examine the impact of chronotype (Morningness vs. Eveningness) on maximum strength (1RM squat), explosive power (CMJ), and hand muscle strength (grip test). Descriptive statistics (mean, SD, SE) were calculated for each group to summarize performance levels and variability. The Shapiro-Wilk test confirmed normal distribution ($p > 0.05$), supporting the use of parametric tests. Levene's test showed no significant differences in variance between groups ($p > 0.05$). Independent samples t-tests were used to compare performance across chronotypes, with statistical significance set at $p < 0.05$.

Results

All performance variables were analyzed descriptively and inferentially between morning and evening chronotype groups. The evening group showed higher mean scores in 1RM squat ($M = 78.3 \pm 2.63$ kg) compared to the morning group ($M = 72.1 \pm 3.11$ kg), in CMJ ($M = 30.1 \pm 2.32$ cm vs. $M = 26.1 \pm 2.32$ cm), and in grip strength ($M = 29.7 \pm 1.55$ kg vs. $M = 27.5 \pm 2.04$ kg). The Shapiro-Wilk test confirmed normal distribution for all variables ($p > .05$), and Levene's test confirmed homogeneity of variances ($p > .05$).

Independent samples t-tests revealed statistically significant differences favoring the evening group in all strength variables: 1RM squat ($t_{(54)} = -8.08$, $p < .001$, $d = 2.16$), CMJ ($t_{(54)} = -6.46$, $p < .001$, $d = 1.73$), and grip strength ($t_{(54)} = -4.48$, $p < .001$, $d = 1.20$). These results suggest that evening-type individuals demonstrate superior performance, likely influenced by circadian rhythm effects.

Table 1. Descriptive Statistics for Performance Tests

Test	Group	n	Mean	SD	SE
1RM Squat (kg)	Morning	28	72.1	3.11	0.587
1RM Squat (kg)	Evening	28	78.3	2.63	0.496
CMJ (cm)	Morning	28	26.1	2.32	0.439
CMJ (cm)	Evening	28	30.1	2.32	0.439
Grip Strength (kg)	Morning	28	27.5	2.04	0.385
Grip Strength (kg)	Evening	28	29.7	1.55	0.292

Fig. 5, Fig. 6, Fig. 7, a raincloud plot that shows respectively the distribution of 1RM, CMJ, and hand grip strength between the Morning and Evening groups. The visualization combines a violin plot, a box plot, and jittered raw data points to deliver a full picture of the performance variance of the time of day.

Table 2. Independent Samples t-Test Results

Variable	t	df	p-value	Mean Difference	SE Difference	Cohen's d
1RM Squat (kg)	-8.08	54	< .001	-6.21	0.769	-2.16
CMJ (cm)	-6.46	54	< .001	-4.01	0.621	-1.73
Grip Strength (kg)	-4.48	54	< .001	-2.16	0.483	-1.20

Note. A negative mean difference indicates superior performance in the evening-type group. Statistical significance was determined at $p < .05$. Hypothesis tested: $H_a: \mu_{\text{morning}} \neq \mu_{\text{evening}}$.

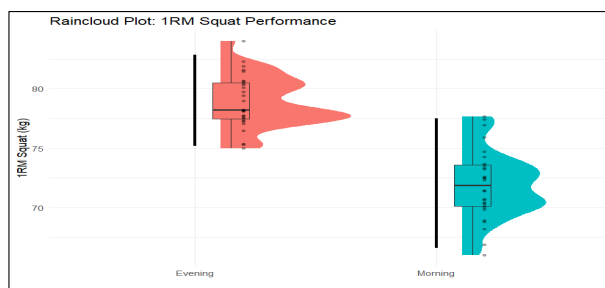


Fig 5. 1RM Squat Performance

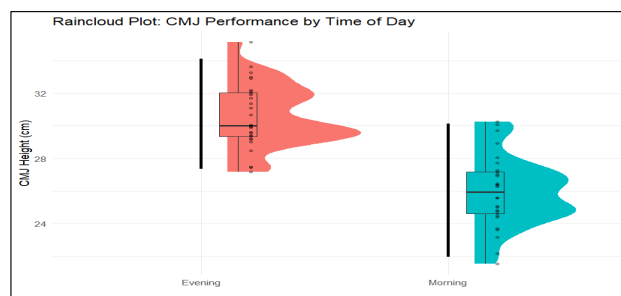


Fig 6. CMJ Performance by Time of Day

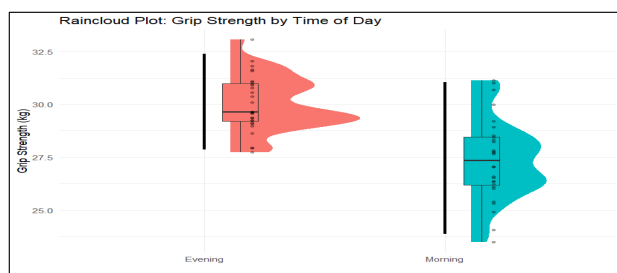


Fig 7. Grip Strength by Time of Day

Discussion

The study examined the influence of test timing on strength measures in a group of female university students and findings consistently favour to evening sessions groups. Participants recorded higher scores in one-repetition maximum squats, countermovement jumps, and grip strength when assessed in the evening compared with morning testing. It is well known that core temperature of the body peaks in afternoon session which promotes greater muscle pliability, faster enzyme reaction times and improved nerve conduction. All the factors positively contribute to increased force production. Study of Souissi et al. (2022) and Thun et al., (2022) also express that raised body temperature

correlates strongly with enhanced outcomes in both strength and endurance tasks (Souissi et al., 2022; Thun et al., 2022).

The late-afternoon to evening training window generally coincides with favorable endocrine and metabolic dynamics, marked by elevated serum growth hormone concentrations, muted cortisol release and refined blood glucose and lactate profiles that can bolster energy availability during high-intensity exertions (Fernandes et al., 2014). Repeated workouts during this time might facilitate greater hypertrophic response than morning sessions, probably because muscular and systemic temperatures tend to be higher and the coinciding hormonal milieu promotes protein synthesis (Küusmaa et al., 2016). De Hoyo et al. (2016) observed consistently greater absolute strength levels in evening trials. Another study by İlbağ et al. (2024) stated that athletes attain significantly higher 1RM squat scores after sunset. Evening training also benefits from naturally elevated core temperature, which enhances musculotendinous elasticity, speeds nerve conduction, and accelerates enzymatic turnover, collectively translating to improved explosive power and vertical-jump metrics (Heishman et al., 2017; Zelenović et al., 2018).

Muscle strength and power, as assessed by neuromuscular tests like the countermovement jump (CMJ), tend to show diurnal variation that peaks in the late afternoon or early evening (López-Samanes et al., 2017). This oscillation appears to stem from the interplay of circadian alterations in muscle temperature, hormone secretion and ion handling within fibres (Harrison et al., 2024). Evening sessions typically occur after a full day of eating, providing higher circulating carbohydrates and amino acids and often coincide with reduced plasma cortisol, both of which favour contractile capacity (Heishman et al., 2017). Reinforcing this pattern, recent investigations in both male and female athletes report significant increases in CMJ height and velocity when tests are moved from the morning to a later time slot, underscoring the role of timing in explosive strength assessment (Robles-González et al., 2023). Thus, the current findings agree with the wider literature, confirming that circadian timing can meaningfully influence performance metrics in sports science.

A recent observational study by Heishman et al. (2017) concluded that collegiate basketball players recorded higher countermovement-jump scores during afternoon practice sessions than in morning workouts. Similarly, elite male handball players displayed substantial gains in short-term jump height and sprint speed when activities were postponed until the evening (Pavlović et al., 2018). A larger investigation of team sport athletes confirmed that both countermovement-jump performance and agility tended to peak later in the day, supporting previous recommendations (Martín-López et al., 2024).

Hand gGrip strength also follows a diurnal pattern, usually peaking in the evening compared with the early morning, and several linked physiological factors have been identified. Elevated core body temperature later in the day appears to enhance muscle elasticity, improve blood flow, and speed up neural conduction—and these changes together fine-tune the strength-endurance balance required for stable, precise gripping. Neuromuscular recruitment tends to become more efficient as the day advances, producing smoother coordination and stronger contractions in skeletal muscles (López-Samanes et al., 2017). Morning cortisol concentrations, a well-documented stress marker, may temporarily impede muscular output, while evening levels

drop significantly, creating a more favourable endocrine profile for strength tasks (Heishman et al., 2017). Relatedly, grip strength exhibits a clear diurnal pattern, generally peaking in the evening and falling to lower morning measures (Patel et al., 2004; Reinberg et al., 1994). Recent work on Brazilian Jiu-Jitsu athletes likewise reported higher scores during late-day assessments, reinforcing the notion of time-of-day effects in combat sports (Kons et al., 2025).

Exercise performed during the evening, when core body temperature is elevated, tends to improve muscle flexibility, accelerate nerve conduction velocity, and boost enzyme activity, collectively increasing neuromuscular efficiency and power output (López-Samanes et al., 2017; Heishman et al., 2017). Nighttime training is also associated with lower evening cortisol levels, which reduces neural inhibition; concurrently, anabolic hormones such as growth hormone become more secreted and can positively influence strength adaptations (Heishman et al., 2017). Evening sessions benefit from greater availability of circulating glucose and lactate, providing an extra energy reserve during high-intensity efforts (Fernandes et al., 2014). Taken together, these thermal, hormonal, and metabolic factors create a physiological environment especially favourable for strength and power activities. Over weeks or months, repeatedly training in this window may compound those individual benefits, yielding superior muscle hypertrophy and longterm performance gains (Kuusmaa et al., 2016). Consequently, the time of day an athlete chooses to lift weights emerges as an important yet sometimes overlooked variable in pursuit of maximum strength.

A recent investigation involving adolescent soccer athletes indicated that both strength and aerobic endurance were significantly improved during late-afternoon and evening testing windows (Duan et al., 2024). Complementary work has further documented elevated rates of energy expenditure and superior cycling times when efforts are scheduled for the evening, thereby reinforcing the hypothesis that human physiology is better primed for exertion later in the day (Souissi et al., 2022). Beyond the biological realm, psychological variables—specifically heightened alertness, motivation, and arousal—frequently peak in the evening and may amplify motor output even more than synchronised metabolism alone (Teo et al., 2011). Regular diurnal patterns of movement also contribute, as accumulated locomotion pre- or post-office hours can improve joint mobility and lower neural activation thresholds during formal exercise sessions (Chtourou & Souissi, 2012). Combined, these lines of evidence suggest that both explosive and isometric strength—indexed by tests such as the countermovement jump and hand-grip dynamometry—exhibit reliable evening maxima, underscoring the functional relevance of circadian timing for sports performance.

The current observations support earlier reports indicating that muscle force and power production peak later in the day, a pattern attributed to elevated tissue temperature, favourable enzyme kinetics and enhanced neural output (Reilly et al., 2007). An investigation of elite male handball players confirmed that strength, power, and throwing velocity improved more markedly during evening training, with positional role further modulating the magnitude of change (Cherif et al., 2022). Parallel work focused on university women in the Netherlands showed that participants with an evening chronotype scored higher in explosive strength and agility tests, linking circadian

orientation to performance outcomes (Das et al., 2024). A time-of-day study of female sprinters and jumpers also reported significant gains during evening trials compared to morning assessments, emphasising the potential of scheduling workouts later in the day (Klaus-Karwisch et al., 2023). Collectively, these lines of evidence suggest that strength-related training and competition may be optimised if scheduled for the evening hours. According to findings of Saha et al. (2025) matching natural sleep-wake pattern to work schedules can enhance overall performance.

According to the evidence, Strength performance is generally higher in the evening than in the morning, likely due to factors such as increased body temperature and hormonal fluctuations. Aligning training with an individual's circadian rhythm and chronotype may enhance results. Future research should explore how training time affects performance across different genders and sports. Athletes can use this knowledge to better structure their training for optimal strength gains.

Conclusions

The results show that strength performance in female university students peaks in the evening across all measures—1RM squat, CMJ, and grip strength. This supports the role of circadian rhythms in enhancing physical and mental function later in the day. Coaches should consider both chronotype and time of day when planning training and assessments.

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Conflict of Interest

The authors declare no conflicts of interest.

References

- Das, S.C., Singh, S., & Chakraborty, S. (2024). Chronotype and Athletic Performance in Different Time of Day. *ShodhKosh: Journal of Visual and Performing Arts*, 5(6). <https://doi.org/10.29121/shodhkosh.v5.i6.2024.3419>
- Roenneberg, T., Pilz, L.K., Zerbini, G., & Winnebeck, E.C. (2019). Chronotype and social jetlag: A (self-) critical review. *Biology*, 8(3). <https://doi.org/10.3390/biology8030054>
- Adan, A., Archer, S.N., Hidalgo, M.P., Di Milia, L., Natale, V., & Randler, C. (2012). Circadian typology: A comprehensive review. *Chronobiology International*, 29(9), 1153-1175.
- Morrow, M., & Roenneberg, T. (2003). The network of time: Understanding the molecular circadian system. *Current Biology*, 13(5), R198-R207.
- Adan, A., Archer, S. N., Hidalgo, M. P., Di Milia, L., Natale, V., & Randler, C. (2012). Circadian typology: A comprehensive review. *Chronobiology International*, 29(9), 1153-1175. <https://doi.org/10.3109/07420528.2012.719971>
- Chtourou, H., & Souissi, N. (2012). *The Effect of Training at a Specific Time of Day: A Review*. www.nscs.com
- Vitale, J.A., & Weydahl, A. (2017). Chronotype, Physical Activity, and Sport Performance: A Systematic Review. *Sports Medicine*, 47(9), 1859-1868. Springer International Publishing. <https://doi.org/10.1007/s40279-017-0741-z>
- Facer-Childs, E., & Brandstaetter, R. (2015). The impact of circadian phenotype and time since awakening on diurnal performance in athletes. *Current Biology*, 25(4), 518-522. <https://doi.org/10.1016/j.cub.2014.12.036>
- Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-M., Nieman, D. C., & Swain, D. P. (2011). Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise. *Medicine & Science in Sports & Exercise*, 43(7), 1334-1359. <https://doi.org/10.1249/MSS.0b013e318213febf>
- Cormie, P., McGuigan, M.R., & Newton, R.U. (2011). Developing maximal neuromuscular power: Part 1 - Biological basis of maximal power production. *Sports Medicine*, 41(1). <https://doi.org/10.2165/11537690-000000000-00000>
- Sale, D.G. (1988). Neural adaptation to resistance training. *Medicine and Science in Sports and Exercise*, 20(5). <https://doi.org/10.1249/00005768-198810001-00009>
- Kraemer, W.J., & Ratamess, N.A. (2004). Fundamentals of resistance training: Progression and exercise prescription. *Medicine & Science in Sports & Exercise*, 36(4), 674-688.
- Miller, A.E. J., MacDougall, J.D., Tarnopolsky, M.A., & Sale, D.G. (1993). Gender differences in strength and muscle fiber characteristics. *European Journal of Applied Physiology and Occupational Physiology*, 66(3). <https://doi.org/10.1007/BF00235103>
- İlbak, İ., Eken, Ö., Stojanović, S., Joksimović, M., Pavlović, R., & Radulović, N. (2024). Investigation of maximal strength performance in terms of training time routine. *Pedagogy of Physical Culture and Sports*, 28(1), 26-32. <https://doi.org/10.15561/26649837.2024.0103>
- Izquierdo, M., Ibañez, J., González-Badillo, J.J., & Gorostiaga, E.M. (2002). Effects of creatine supplementation on muscle power, endurance, and sprint performance. *Medicine and Science in Sports and Exercise*, 34(2), 332-343. <https://doi.org/10.1097/00005768-200202000-00023>
- Jurado-Castro, J. M., Campos-Pérez, J., Vilches-Redondo, M. Á., Mata, F., Navarrete-Pérez, A., & Ranchal-Sanchez, A. (2022). Morning versus evening intake of creatine in elite female handball players. *International Journal of Environmental Research and Public Health*, 19(1). <https://doi.org/10.3390/ijerph19010393>
- Souissi, W., Hammouda, O., Ammar, A., Ayachi, M., Bardiaa, Y., Daoud, O., Hassen, I. Ben, Souissi, M., & Driss, T. (2022). Higher evening metabolic responses contribute to diurnal variation of self-paced cycling performance. *Biology of Sport*, 39(1). <https://doi.org/10.5114/biolsport.2021.102930>
- Thun, E., Bjorvatn, B., Flo, E., Harris, A., & Pallesen, S. (2015). Sleep, circadian rhythms, and athletic performance. *Sleep Medicine Reviews*, 23. <https://doi.org/10.1016/j.smrv.2014.11.003>
- Fernandes, A.L., Lopes-Silva, J.P., Bertuzzi, R., Casarini, D.E., Arita, D.Y., Bishop, D.J., & Lima-Silva, A.E. (2014). Effect of time of day on performance, hormonal and metabolic response during a 1000-M cycling time trial. *PLoS ONE*, 9(10). <https://doi.org/10.1371/journal.pone.0109954>
- Küüsmaa, M., Schumann, M., Sedlak, M., Kraemer, W. J., Newton, R. U., Malinen, J. P., Nyman, K., Häkkinen, A., & Häkkinen, K. (2016). Effects of morning versus evening combined

- strength and endurance training on physical performance, muscle hypertrophy, and serum hormone concentrations. *Applied Physiology, Nutrition and Metabolism*, 41(12). <https://doi.org/10.1139/apnm-2016-0271>
- De Hoyos, M., Gonzalo-Skok, O., Sanudo, B., Carrascal, C., Plaza-Armas, J. R., Camacho-Candil, F., & Otero-Esquina, C. (2016). Comparative effects of in-season full-back squat, resisted sprint training, and plyometric training on explosive performance in U-19 elite soccer players. *Journal of Strength and Conditioning Research*, 30(2). <https://doi.org/10.1519/JSC.0000000000001094>
- Heishman, A. D., Curtis, M. A., Saliba, E. N., Hornett, R. J., Malin, S. K., & Weltman, A. L. (2017). Comparing performance during morning vs. afternoon training sessions in intercollegiate basketball players. *The Journal of Strength & Conditioning Research*, 31(6), 1557-1562.
- Zelenović, M., Kontro, T., Čaušević, D., Bjelica, B., Aksović, N., & Milanović, Z. (2024). Warm-up is an efficient strategy to prevent diurnal variation of short-term maximal performance in young basketball players. *Chronobiology International*, 41(3). <https://doi.org/10.1080/07420528.2024.2313646>
- López-Samanes, Á., Moreno-Pérez, D., Maté-Muñoz, J. L., Domínguez, R., Pallarés, J. G., Mora-Rodríguez, R., & Ortega, J. F. (2017). Circadian rhythm effect on physical tennis performance in trained male players. *Journal of Sports Sciences*, 35(21). <https://doi.org/10.1080/02640414.2016.1258481>
- Harrison, P.W., James, L.P., Jenkins, D.G., McGuigan, M.R., Holmberg, P.M., & Kelly, V.G. (2024). The Effects of Low-Load Squat Jump and Maximal Isometric Priming Exercise on Muscular Performance and Perceptual State. *Journal of Strength and Conditioning Research*, 38(1). <https://doi.org/10.1519/JSC.0000000000004524>
- Robles-González, L., Ramírez Maldonado, M., Alcalá-Escamilla, J. C., Jurado-Fasoli, L., Miras-Moreno, S., Soriano, M. A., García-Ramos, A., Ruiz, J. R., & Amaro-Gahete, F. J. (2023). Caffeine ingestion attenuates diurnal variation of lower-body ballistic performance in resistance-trained women. *European Journal of Sport Science*, 23(3). <https://doi.org/10.1080/17461391.2022.2038274>
- Pavlović, L., Stojiljković, N., Aksović, N., Stojanović, E., Valdevit, Z., Scanlan, A. T., & Milanović, Z. (2018). Diurnal Variations in Physical Performance: Are There Morning-to-Evening Differences in Elite Male Handball Players? *Journal of Human Kinetics*, 63(1). <https://doi.org/10.2478/hukin-2018-0012>
- Martin-López, J., Pérez-López, A., Varillas-Delgado, D., & López-Samanes, Á. (2024). Influence of time-of-day on neuromuscular performance in team sport athletes: a systematic review and meta-analysis. In *Frontiers in Sports and Active Living*, 6. Frontiers Media SA. <https://doi.org/10.3389/fspor.2024.1466050>
- Patel, A., Adams, J., & Davey, C. (2004). Diurnal Variation in Grip Strength and Hand Dexterity in Healthy Adults. *The British Journal of Hand Therapy*, 9(4). <https://doi.org/10.1177/175899830400900402>
- Reinberg, A.E., Bickova-Rocher, A., Gorceix, A., Ashkenazi, I.E., & Smolensky, M.H. (1994). Placebo effect on the circadian rhythm period τ of temperature and hand-grip strength rhythms: Interindividual and gender-related difference. *Chronobiology International*, 11(1). <https://doi.org/10.3109/07420529409057230>
- Kons, R., Santos, G., Borges, M. L. B., Cintra de Sousa, P. H., & Detanico, D. (2025). Time-of-day effects on physical performance and perceptual responses in Brazilian Jiu-Jitsu athletes. *Chronobiology international*, 42(1), 147-154.
- Küüsmaa, M., Schumann, M., Sedliak, M., Kraemer, W. J., Newton, R. U., Malinen, J. P., Nyman, K., Häkkinen, A., & Häkkinen, K. (2016). Effects of morning versus evening combined strength and endurance training on physical performance, muscle hypertrophy, and serum hormone concentrations. *Applied Physiology, Nutrition and Metabolism*, 41(12). <https://doi.org/10.1139/apnm-2016-0271>
- Duan, C., Kim, Y., & Park, Y. (2024). Effects of speed-agility-quickness training and sprint interval training on physiological and physical performance, and sports enjoyment in young soccer players. *Journal of Men's Health*, 20(7), 59-69. <https://doi.org/10.22514/jomh.2024.110>
- Teo, W., Newton, M.J., & McGuigan, M.R. (2011). Circadian rhythms in exercise performance: Implications for hormonal and muscular adaptation. *Journal of Sports Science and Medicine*, 10.
- Reilly, T., Atkinson, G., Edwards, B., Waterhouse, J., Farrelly, K., & Fairhurst, E. (2007). Diurnal variation in temperature, mental and physical performance, and tasks specifically related to football (soccer). *Chronobiology International*, 24(3). <https://doi.org/10.1080/07420520701420709>
- Cherif, M., Said, M.A., Ben Chaifa, M., & Kotb, A.A. H. (2022). Position-dependent morning-to-evening variability in physical performances in elite male handball players. *Biological Rhythm Research*, 53(10), 1496-1508. <https://doi.org/10.1080/09291016.2021.1967574>
- Klaus-Karwisch, S., Merkle, A., Werner, S., Ruf, L., Woll, A., Härtel, S., & Altmann, S. (2023). Sprint and jump performances of female athletes are enhanced in the evening but not associated with individual chronotype. *Chronobiology International*, 40(10). <https://doi.org/10.1080/07420528.2023.2267659>
- Saha, G. C., Orhan, B. E., Hazra, S., Biswas, S., Karak, P. K., Mondal, S., ... & Gaur, M. P. (2025). Effect of diurnal variations on cognitive and physical performance among female athletes. *Retos: nuevas tendencias en educación física, deporte y recreación*, (68), 874-888. <https://doi.org/10.47197/retos.v>

Вплив хронотипу на силові показники студенток університету в різний час доби: Поперечне дослідження

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

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Історія питання. Хронотип впливає на фізичну результативність через циркадні ритми, що змінюються протягом дня. Пік сили та потужності часто спостерігається ввечері, що свідчить про вплив часу на результати тренувань. У цій науковій роботі вивчається вплив зазначених факторів на студенток університету — групи, яка недостатньо представлена в хронобіологічних дослідженнях.

Мета дослідження. Мета дослідження полягала у вивченні впливу хронотипу на силову працездатність студенток університету в різний час доби. Зокрема, проведено порівняльний аналіз показників максимальної сили, вибухової потужності та м'язової сили кистей між особами ранкового та вечірнього типу з метою визначення оптимального часу для проведення тренувань або продуктивної діяльності на основі хронобіологічних переваг.

Матеріали та методи. Для класифікації 56 індійських студенток (середній вік = 22.2 роки; вага = 56 ± 4.31 кг; зріст = 158 ± 5 см; $IMT = 21 \pm 1.5$ кг/м²) було застосовано опитувальник Хорна–Остберга щодо визначення схильності до ранкової або вечірньої активності ("The Horne and Ostberg Morningness–Eveningness Questionnaire"). Оцінка силових працездатності проводилася за допомогою трьох вимірювань: одне повторення з максимальною вагою (1ПМ) для визначення максимальної сили; стрибок із контрпрухом (КРС) для вибухової потужності; динамометрія кистьового хвату для оцінки м'язової сили. Тестування проводилося в стандартних умовах, в узгоджений час відповідно до хронотипу кожної учасниці (ранок або вечір). З метою аналізу використовувалися t-критерії для незалежних вибірок, а також критерії Шапіро-Вілка та Левене, що підтверджують припущення про нормальність та однорідність.

Результати. Відзначено, що особи вечірнього типу продемонстрували значно кращі результати за всіма досліджуваними показниками, ніж особи ранкового типу. Група вечірнього типу досягла значніших показників у присіданні з 1ПМ (78.3 ± 2.63 кг проти 72.1 ± 3.11 кг; $t(54) = -8.08$, $p < .001$, $d = 2.16$), КРС (30.1 ± 2.32 см проти 26.1 ± 2.32 см; $t(54) = -6.46$, $p < .001$, $d = 1$).

Висновки. Результати цього дослідження показують, що студентки вечірнього типу мають підвищену силову працездатність у вечірні години, що підкреслює необхідність враховувати хронотип при плануванні тренувань та оцінюванні результативності спортсменок.

Ключові слова: хронотип, ранкова – вечірня активність, максимальна сила, вибухова потужність, м'язова сила кистей.

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The Effects of an Eight-Week Small-Sided Game-Based High-Intensity Interval Training Intervention and Traditional High-Intensity Interval Training Intervention on Physical Fitness in Youth Female Soccer Players

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Abstract

Objectives. The study aimed to compare the outcomes of an eight-week Small-Sided Game-based High-Intensity Interval Training (SSG-HIIT) and Traditional High-Intensity Interval Training (THIIT) on parameters of physical fitness in youth female soccer players. Specifically, it assessed changes in anaerobic power, explosive strength, sprint speed, agility, and flexibility.

Materials and Methods. Twenty-seven female soccer players aged 14 to 17 years playing at a competitive level (>2 years) were randomly assigned to three conditions: SSG-HIIT (n = 9), THIIT (n = 9) and Active Control Group (ACG, n = 9). The intervention took a period of eight weeks, with three sessions per week on the experimental groups. SSG-HIIT sessions included 3v3 to 5v5 soccer games with progressive intensity, while THIIT involved structured sprint intervals. Pre- and post-intervention assessments comprised the Running-Based Anaerobic Sprint Test (RAST), standing broad jump, 50-m sprint, Illinois agility test, and sit-and-reach flexibility test.

Results. There was a huge improvement in all variables in both SSG-HIIT and THIIT groups ($p < 0.05$), whereas ACG showed negligible changes. SSG-HIIT led to superior gains in explosive power (8.69%), flexibility (11.3%), anaerobic power (RAST: -8.58%), sprint speed (-3.97%), and agility (-4.37%) compared to THIIT. Post hoc analysis confirmed significantly greater improvements in explosive power and flexibility in the SSG-HIIT group ($p < 0.05$), though sprint and agility gains were statistically similar between the two interventions.

Conclusions. According to the findings, SSG-HIIT proved more effective than THIIT in enhancing multiple physical fitness parameters, especially explosive power and flexibility. Incorporating game-based training within high-intensity protocols offers a practical and sport-specific approach to conditioning youth female soccer players.

Keywords: small-sided games, high-intensity interval training, youth soccer, anaerobic power, physical fitness.

Introduction

The most popular sport in the world, soccer, is an intense competitive activity with significant physical and physiological requirements on players, requiring optimal

development of multiple fitness components including aerobic capacity, explosive power, speed, agility, and flexibility (Datson et al., 2014). The contemporary sport has become more competitive and quicker than ever, and as a result, highly advanced training strategies are required in order to maximize performance outcomes and minimize injury potential. High-intensity interval training (HIIT) has become an important component of modern soccer conditioning program, which has shown to greatly enhance

aerobic and anaerobic performance measures (Buchheit & Laursen, 2013). The traditional protocols in HIIT are developed around alternating blocks of intense activity and recovery or a lower level of effort (Kumar et al., 2023), and have been well-validated in improving cardiovascular health, power and metabolism in soccer players (Helgerud et al., 2001). However, the integration of soccer-specific movements and decision-making processes within training has led to the development of small-sided games (SSGs) as an alternative training modality. SSGs combine the physiological benefits of HIIT with technical and tactical skill development, offering a more holistic approach to soccer conditioning (Hill-Haas et al., 2011).

Recent studies have established that SSG and HIIT effectively improved aerobic performance, and both types were significantly better than the control groups (Arslan et al., 2020). Moreover, both SSG and HIIT have been shown to enhance vertical and horizontal jump performance, agility or change-of-direction ability, as well as aerobic fitness as assessed through progressive and intermittent multistage testing in youth soccer players (Andersson et al., 2010; Arslan et al., 2020). The physiological responses to SSG-based training have been shown to elicit similar cardiovascular adaptations to traditional HIIT (THIIT) while providing additional benefits related to sport-specific skill development (F. M. Clemente et al., 2020). Comparative studies have revealed that SSG training creates substantial improvements in 20-meter sprint performance, agility, and anaerobic power in youth soccer players as measured by Running-based Anaerobic Sprint Test (RAST) (Hammami et al., 2018). RAST has become a standard assessment tool for evaluating anaerobic power and fatigue index in soccer players, providing valuable insights into explosive power capabilities and repeated sprint performance (Zacharogiannis et al., 2004). In recent years, RAST has shown high reliability and validity in measuring the anaerobic performance of young soccer players, with significant correlations between RAST parameters and traditional anaerobic testing methods (Jastrzębska, 2023; Köklü et al., 2011). Complementary fitness components including sprint speed, agility, and flexibility are equally crucial for optimal soccer performance, as they directly influence players' ability to execute technical skills under pressure and adapt to the dynamic nature of match play (Stølen et al., 2005). Training focused on speed, agility, and quickness (SAQ) has demonstrated notable enhancements in sprinting ability and directional change performance among youth soccer athletes (Jovanovic et al., 2011; Milanović et al., 2013).

The development of female soccer has experienced unprecedented growth globally, with increasing participation rates and elevated competitive standards demanding evidence-based training approaches specifically tailored to female athletes (Datson et al., 2014). Over the past decade, there has been a notable increase in female soccer participation, accompanied by greater financial investment from governing organizations. This growth places a growing responsibility on researchers and sports medicine professionals to deepen their understanding of the physical profiles, performance demands, and health requirements specific to female soccer players. The young female soccer players encounter physiological and biomechanical particularities that make them different

not only with their male peers, but also with adult female players. Biological factors unique to female athletes can influence both game tempo and overall work capacity, highlighting the need for tailored training interventions that consider these physiological distinctions (Datson et al., 2014). Adolescence is a pivotal stage in athletic development, during which well-designed training programs can optimize performance improvements and reduce the likelihood of injury (Lloyd & Oliver, 2012). Research has shown that 15-year-old female soccer players demonstrate significant improvements in sprint performance (10m and 20m) and agility when exposed to structured training interventions, with pre-post improvements of 0.08 seconds in 10m sprint and 0.11 seconds in 20m sprint performance (Milanović et al., 2013). In female soccer players, strength training is chiefly associated with improvements in physical fitness components such as muscular strength, power, and speed, as well as increased bone mineral density. However, evidence regarding its role in injury prevention among female athletes remains comparatively limited (Darragi et al., 2024). Establishing structured and consistent training programs during the developmental years is especially important for female athletes, as studies have shown notable increases in body weight and fat percentage from the end of preseason through the postseason and into the transition phase, underscoring the necessity for ongoing, well-regulated training interventions (Parpa et al., 2024). The specificity of training adaptations in female soccer players is further emphasized by the distinct physical demands of women's soccer. The physical demands encountered by female soccer players during competition are influenced by the level of play, with match intensity and workload varying accordingly. These demands necessitate training programs that address the multifaceted nature of soccer performance while considering the unique physiological characteristics of female athletes.

Despite the growing body of research on HIIT and SSG interventions in soccer, several limitations persist in the current literature, including the predominant focus on male soccer players creating a substantial knowledge gap regarding female athlete responses (Mujika et al., 2009), limited intervention durations (typically 4-8 weeks) that may not adequately capture full training adaptations in youth athletes, challenges in standardizing SSG protocols due to numerous variables affecting training outcomes (Halouani et al., 2014), methodological difficulties in assessing training load during SSG sessions, seasonal variations in performance, and psychological differences between training modalities where HIIT produces mood disturbance while SSG ensures mood balance. Therefore, the primary objective of this study was to compare the effects of an eight-week SSG based HIIT (SSG-HIIT) intervention versus THIIT on physical fitness parameters in youth female soccer players, specifically evaluating the comparative effects on anaerobic power and fatigue index as measured by RAST, assessing differential impacts on explosive power development, determining relative effectiveness in enhancing sprint speed performance, comparing effects on agility and change-of-direction capabilities, examining influence on flexibility parameters, and providing evidence-based recommendations for optimal training prescription in youth female soccer players. The findings will contribute

to the limited body of research on female soccer training methodologies and provide practical insights for coaches, strength and conditioning professionals, and sports scientists working with this underrepresented population in sports science literature.

Materials and Methods

Study Design

In the study, a three-arm, parallel group randomized, and controlled trial was planned to study the effects of SSG-HIIT and THIIIT on different physical fitness parameters in adolescent female soccer players. The study was ethically approved by DSS Academy, Ormanjhi, Ranchi, India (Ref. No.: DSSA/2025/007) and was undertaken in accordance with the principles in the Declaration of Helsinki (World Medical Association, 2013). All the participants and their legal guardians provided written informed consent before participation.

Participants

The participants of the study were adolescent soccer-playing females aged between 14 and 17 years. Eligibility requirements were two years playing experience at competitive level and the active involvement in organized soccer trainings not less than three times a week. The participants had to give medical clearance of being able to perform high-intensity exercise and had never had musculoskeletal injuries within the three months prior to the study. Individuals were excluded if they had a known history of cardiovascular, respiratory, or metabolic conditions; were currently using performance-enhancing substances or medications influencing physical performance; were involved in additional structured training programs outside of their regular soccer regimen; or were un-

able to complete baseline fitness assessments due to illness or injury. The study took place at DSS Academy, Ormanjhi, Ranchi, India, over an eight-week period from April 14 to June 9, 2025. Sample size estimation was performed using G*Power software (version 3.1.9.7), referencing effect sizes reported in prior studies on HIIT among youth athletes (Saha et al., 2025). Given $\alpha = 0.05$, a statistical power of 0.80, and an estimated effect size of 0.25 on the primary outcome (anaerobic power), a minimum needed sample size of eight subjects per group was estimated to be achieved. In anticipation of 20% dropout rate, nine participants per group were recruited, and the final sample size became 27 athletes. Participants were randomly assigned to one of three intervention arms using a computer-generated randomization sequence: (1) SSG-HIIT ($n = 9$), (2) THHT group ($n = 9$), or (3) Active Control group (ACG, $n = 9$). The processing of randomization was stratified by age and baseline fitness scores to ensure balanced distribution. The allocation concealment was assured by using sequentially numbered opaque and sealed envelopes.

Table 1. Demographic Values for Participants

Variables	SSG-HIIT	THIIT	ACG
Age	15.44 $\pm$ 1.01	15.11 $\pm$.92	15.77 $\pm$.97
Experience	2.55 $\pm$.52	2.77 $\pm$.66	2.88 $\pm$.60
Height	148.77 $\pm$ 4.46	146.77 $\pm$ 3.19	148.11 $\pm$ 2.42
Weight	49.66 $\pm$ 2.59	48.44 $\pm$ 3.35	48.22 $\pm$ 1.92
BMI	22.53 $\pm$ 2.30	22.55 $\pm$ 2.29	21.98 $\pm$.90

Intervention Protocol

The Table 2 SSG-HIIT protocol was implemented over eight weeks with progressive adjustments in session duration, intensity, and tactical complexity. Participants trained three

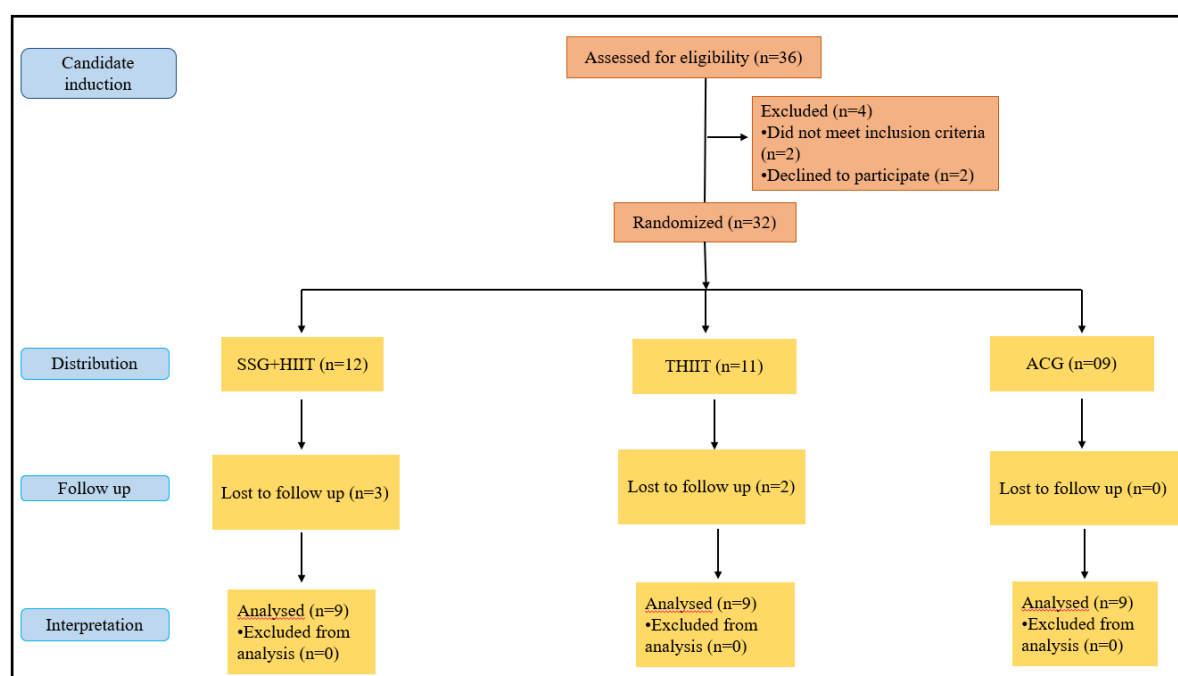


Fig. 1. CONSORT-Compliant Flow Diagram Illustrating the Process of Participant Enrollment, Group Allocation, Follow-Up, and Data Analysis

Table 2. SSG-HIIT Protocol Over an 8-Week Period

Week	Sessions/Week	Duration/Session	Intensity	Work-to-Rest Ratio	Training Content
1-2	3	30-35 min	85-90% HRmax / RPE 7-8	2:1 (2-min game: 1-min rest)	3v3 or 4v4 SSGs on 30x20m pitch, focusing on attacking/defensive transitions
3-4	3	35-40 min	88-92% HRmax / RPE 8-9	2:1	4v4 SSGs with limited touches, mini-goals, or directional play
5-6	3	40-45 min	90-93% HRmax / RPE 8-9	3:1	5v5 games with tactical constraints, such as possession or overloads
7-8	3	45-50 min	90-95% HRmax / RPE 9	3:1	Mixed format SSGs: 4v4 + 2 neutral players, focused on high tempo and decision-making

Table 3. THIIT Protocol (Running-Based) Across an 8-Week Period

Week	Sessions/Week	Duration/Session	Intensity	Work-to-Rest Ratio	Training Content
1-2	3	25-30 min	85-90% HRmax / RPE 7-8	1:1 (30s run: 30s rest)	10-12 reps of 100m shuttle runs or 15s sprint intervals
3-4	3	30-35 min	88-92% HRmax / RPE 8	2:1	6 x 200m intervals 90% effort with 60-90s passive recovery
5-6	3	35-40 min	90-93% HRmax / RPE 8-9	3:1	8 x 30s sprint runs with 15s recovery (tabata-style format introduced)
7-8	3	40-45 min	90-95% HRmax / RPE 9	3:1	10-12 x 20s maximal effort sprints with 10s jog/walk recovery

times per week, starting with 30-35-minute sessions at 85-90% HRmax using 3v3 or 4v4 formats focused on transitions. Intensity and volume increased gradually across the weeks, with sessions extending to 45-50 minutes at 90-95% HRmax by Weeks 7-8. Training formats evolved from limited-touch 4v4 games with directional play to 5v5 games involving tactical constraints (e.g., possession, overloads), culminating in mixed-format 4v4+2 games emphasizing tempo and decision-making. The work-to-rest ratio progressed from 2:1 to 3:1, maintaining high physiological load while targeting game-specific skills.

The THIIT protocol in Table 3 was carried out over eight weeks with three sessions per week, progressively increasing in duration, intensity, and complexity. Training began with 25-30-minute sessions at 85-90% HRmax, using 1:1 work-rest ratios (e.g., 100m shuttle runs or 15s sprints). From Weeks 3-4, intensity rose to 88-92% HRmax with 200m intervals at a 2:1 work-rest ratio. In Weeks 5-6, Tabata-style sprints (8 x 30s with 15s recovery) were introduced, increasing intensity to 90-93% HRmax and a 3:1 ratio. The final phase (Weeks 7-8) featured 10-12 bouts of 20s maximal sprints with 10s jog/walk recovery, pushing intensity to 90-95% HRmax. This progressive format ensured overload while targeting speed, endurance, and anaerobic capacity.

The ACG continued working on their routine soccer activities with no further interventions. Training logs were maintained to monitor habitual activity levels throughout the study period.

Outcome Assessments

RAST: Used to evaluate anaerobic endurance, and has demonstrated strong validity ($r = 0.897$) and high test-retest reliability ($r = 0.919$) in previous research (Saha et al., 2025).

Explosive Power: Standing broad jump distance was measured using a standardized protocol as described by Castro-Piñero et al. (2010). Participants performed three maximal efforts with 2-minute recovery between attempts. The best performance was recorded to the nearest centimetre.

Sprint Speed: 50-meter sprint performance was assessed using electronic timing gates following the protocol established by Haugen & Buchheit (2016). Participants performed two maximal sprints with 5-minute recovery, and the best time was recorded to the nearest 0.01 seconds.

Agility: The Illinois Agility Test was conducted following standardized procedures as described by Liu et al. (2025). Participants completed two trials with 5-minute recovery, and the best time was recorded to the nearest 0.01 seconds.

Flexibility: Sit-and-reach test was performed using a standardized sit-and-reach box according to the protocol described by Khati et al. (2025). Three attempts were made with 30-second intervals, and the best score was recorded to the nearest 0.1 cm.

Data Collection Procedures

All performance assessments were carried out at two time points: baseline (week 0) and immediately following the intervention period (week 9). Testing was conducted in a controlled laboratory environment at a consistent time of day (± 2 hours) to minimize the influence of circadian variations. Participants were advised to refrain from engaging in intense physical activity for at least 48 hours prior to testing and were instructed to maintain stable hydration and nutritional routines. The sequence of assessments was standardized for all participants to ensure consistency:

(1) anthropometric measurements, (2) flexibility evaluation, (3) assessment of explosive power, (4) sprint speed testing, (5) agility testing, and (6) anaerobic power evaluation using the RAST. A minimum rest period of five minutes was provided between each test to facilitate adequate recovery. All testing procedures were conducted indoors under controlled environmental conditions (temperature: 20-22°C; humidity: 50-60%) on a standardized natural grass surface to simulate soccer-specific settings. To minimize assessment bias, outcome evaluators were blinded to participants' group assignments, and participants were instructed not to disclose their training group to the assessors throughout the study duration.

Statistical Analysis.

The analysis of all data was performed with the help of IBM SPSS Statistics software. Descriptive data were expressed as mean values and respective standard deviations (mean $\pm$ SD). The assessment of the outcomes of the interventions was performed using the mixed-model analysis of variance (ANOVA) with two within-level time points (pre- and post-intervention) and three-between-level groups (SSG-HIIT, THIIIT, and ACG). The Bonferonni-adjusted post hoc pairwise comparison was also used to figure out fundamental group $\times$ time interaction effects. Effect sizes for the ANOVA were determined using partial eta-squared (η^2p), with thresholds defined as small (<0.06), moderate ($\geq 0.06-0.13$), and large (≥ 0.14), as suggested by Saha et al. (2025). A statistical level of significance was set at $p < 0.05$.

Results

Table 4 presents the pre- and post-test statistical analysis of physical fitness outcomes across three groups: SSG-HIIT, THIIIT, and the ACG. Significant improvements were observed in all variables for the experimental groups, with the SSG-HIIT group demonstrating the greatest percentage

changes. In the RAST, SSG-HIIT showed an 8.58% improvement, while THIIIT and ACG improved by 4.64% and 1.89%, respectively ($p = 0.000$, $\eta^2p = .52$). Explosive power increased most notably in the SSG-HIIT group (8.69%), followed by THIIIT (6.37%) and minimally in ACG (0.39%), with a large effect size ($p = 0.000$, $\eta^2p = .93$). Sprint speed and agility also improved significantly in both experimental groups, with SSG-HIIT again showing the highest gains (3.97% and 4.37%, respectively), supported by significant F-values and medium to large effect sizes ($p < 0.005$, $\eta^2p = .35$ and .46). Flexibility improvements followed a similar trend, with SSG-HIIT leading at 11.30% improvement, THIIIT at 6.50%, and negligible change in ACG ($p = 0.000$, $\eta^2p = .58$). Overall, both interventions enhanced physical fitness, with SSG-HIIT consistently producing superior outcomes.

Table 5. Post Hoc Statistical Profiling of Physical Fitness Transformations across Varied Training Groups

Variables	(I) Group	(J) Group	Mean Difference (I-J)	p
RAST	SSG-HIIT	HIIT	-.27	1.000
		ACG	.22	1.000
	THIIIT	ACG	.50	0.940
Explosive Power	SSG-HIIT	HIIT	2.33	0.015*
		ACG	8.44	0.000*
	THIIIT	ACG	6.11	0.000*
Sprint Speed	SSG-HIIT	HIIT	.02	1.000
		ACG	-.07	1.000
	THIIIT	ACG	-.09	1.000
Agility	SSG-HIIT	HIIT	.12	1.000
		ACG	-.24	1.000
	THIIIT	ACG	-.37	1.000
Flexibility	SSG-HIIT	HIIT	1.31	.019*
		ACG	1.35	.015*
	THIIIT	ACG	.04	1.000

Table 4. Pre-Post Statistical Investigation of Physical Fitness Gains in Diverse Training Cohorts

Variables	Groups	Pre data	Post data	(%)	SS	F	p	η^2p
RAST	SSG-HIIT	36.22 $\pm$ 1.09	33.11 $\pm$ 1.16	-8.58				
	THIIIT	35.77 $\pm$.66	34.11 $\pm$ 1.05	-4.64	13.59	13.10	0.000*	.52
	ACG	34.77 $\pm$ 1.48	34.11 $\pm$ 1.26	-1.89				
Explosive Power	SSG-HIIT	171.22 $\pm$ 1.64	186.11 $\pm$ 1.83	8.69				
	THIIIT	170.88 $\pm$ 2.20	181.77 $\pm$ 1.71	6.37	484.14	171.43	0.000*	.93
	ACG	169.88 $\pm$ 1.76	170.55 $\pm$ 1.66	0.39				
Sprint Speed	SSG-HIIT	8.30 $\pm$.72	7.97 $\pm$.59	-3.97				
	THIIIT	8.21 $\pm$.76	8.02 $\pm$.75	-2.31	.21	6.70	0.005*	.35
	ACG	8.22 $\pm$.56	8.20 $\pm$.55	-0.24				
Agility	SSG-HIIT	17.35 $\pm$ 1.14	16.60 $\pm$.77	-4.37				
	THIIIT	17.11 $\pm$.89	16.59 $\pm$.95	-3.03	1.20	10.59	0.001*	.46
	ACG	17.24 $\pm$ 1.09	17.21 $\pm$ 1.06	-0.17				
Flexibility	SSG-HIIT	25.74 $\pm$ 1.12	28.65 $\pm$.79	11.30				
	THIIIT	25.07 $\pm$.69	26.70 $\pm$ 1.09	6.50	17.34	16.65	0.000*	.58
	ACG	25.77 $\pm$ 1.19	25.91 $\pm$ 1.33	0.54				

Table 5 presents the post hoc analysis of physical fitness outcomes comparing the SSG-HIIT, THIT, and ACG. Significant differences were observed primarily in explosive power and flexibility. The SSG-HIIT group showed significantly greater gains in explosive power compared to both THIT (mean difference = 2.33, $p = 0.015$) and ACG (8.44, $p = 0.000$), while THIT also outperformed ACG (6.11, $p = 0.000$). In terms of flexibility, SSG-HIIT demonstrated significantly greater improvements than both THIT (1.31, $p = 0.019$) and ACG (1.35, $p = 0.015$). Nevertheless, there were no significant differences between the groups for RAST, sprint speed, or agility, as all p -values exceeded 0.940, indicating similar improvements or minimal differences among groups for these variables. These findings suggest that while both interventions were effective, SSG-HIIT had a more pronounced impact on explosive power and flexibility.

Discussion

The notable findings of this work are that SSG-HIIT and THIT were crucial in enhancing different components of physical fitness in young women soccer players. Nonetheless, the SSG-HIIT protocol led to consistently greater enhancements across all assessed variables, with especially notable gains observed in explosive power and flexibility when compared to both the THIT and ACG. The observed enhancements in anaerobic endurance, assessed through the RAST, are consistent with earlier studies supporting the efficacy of high-intensity training methods in improving anaerobic performance among youth soccer athletes (Sperlich et al., 2010). The superior gains observed in the SSG-HIIT group can be attributed to the combined physiological stress imposed by both game-specific movements and structured interval training. SSG naturally involve successive bouts of high-intensity activity interspersed with limited recovery, thereby replicating the physiological and metabolic demands encountered during actual match play (F. M. Clemente et al., 2020). This finding is consistent with recent work by Clemente & Sarmiento (2020), who reported that combining different training modalities can produce synergistic effects on anaerobic capacity in youth athletes. The superior anaerobic performance observed in both intervention groups relative to the control aligns with the principle of training specificity, suggesting that repeated high-intensity exercise is necessary to elicit physiological adaptations within the phosphocreatine and glycolytic pathways (Buchheit & Laursen, 2013). The SSG-HIIT protocol likely provided additional neuromuscular recruitment patterns and metabolic stress through the varied movement demands inherent in SSG, contributing to the observed superior adaptations.

The substantial improvements in explosive power, particularly in the SSG-HIIT group, represent one of the most significant findings of this investigation. Explosive power is a critical performance determinant in soccer, directly influencing jumping, sprinting, and change of direction capabilities (Faude et al., 2012). The superior gains in the SSG-HIIT group can be explained by the multidirectional movement patterns, rapid acceleration and deceleration phases, and sport-specific power demands embedded within SSG (Dellal et al., 2008). Previous research has established that plyometric and power-based training interventions can

enhance explosive power in youth soccer players (Ramírez-Campillo et al., 2016). The current findings extend this knowledge by demonstrating that integrating SSG with THIT can produce even greater adaptations than HIIT alone. This suggests that the variable movement patterns, reactive strength demands, and sport-specific power applications within SSG provide additional neuromuscular stimuli that enhance explosive power development beyond what is achieved through linear running-based training alone.

Both experimental groups demonstrated meaningful improvements in sprint speed and agility performance, with the SSG-HIIT group showing marginally superior gains. These improvements are consistent with the established relationship between HIIT and neuromuscular adaptations that enhance speed and agility performance (Lockie et al., 2015). The absence of statistically significant differences between groups for these variables indicates that each training approach delivers a sufficient stimulus to enhance these physical attributes in adolescent female soccer players. The observed gains in agility across both intervention groups are consistent with earlier findings that highlight the efficacy of HIIT strategies in improving change-of-direction performance (Milanović et al., 2013). The SSG-HIIT protocol's incorporation of reactive and unpredictable movement patterns may have provided additional cognitive and neuromuscular challenges that contributed to the observed improvements, although the differences were not statistically significant compared to THIT. The significant improvements in flexibility, with the SSG-HIIT group demonstrating superior gains, represent an interesting and practically important finding. Flexibility is crucial for injury prevention and optimal movement efficiency in soccer players (Witvrouw et al., 2004). The enhanced flexibility improvements in the SSG-HIIT group may be attributed to the varied movement patterns, dynamic stretching components, and multidirectional demands inherent in SSG. THIT protocols typically involve linear movement patterns with limited range of motion demands, whereas SSG require players to execute a variety of movement patterns including cutting, turning, and reaching movements that may contribute to improved flexibility (Hill-Haas et al., 2011). This finding suggests that incorporating game-based training methods may provide additional benefits for maintaining or improving flexibility compared to traditional running-based training alone.

This study has significant implications to the youth soccer training program design. The superior adaptations observed in the SSG-HIIT group suggest that combining game-based training with traditional interval training methods can optimize training efficiency and effectiveness. This approach may be particularly beneficial for youth players as it maintains the specificity and enjoyment of soccer-related activities while still providing the physiological stimulus necessary for performance enhancement (Köklü et al., 2015). From a practical standpoint, the SSG-HIIT protocol offers several advantages over traditional training approaches. First, it provides sport-specific skill development opportunities while simultaneously improving physical fitness components. Second, it may enhance player motivation and engagement compared to repetitive running-based training protocols. Third, it allows for more efficient use of training

time by addressing multiple performance components simultaneously (Sanchez-Sanchez et al., 2017). Although this study offers meaningful contributions regarding the comparative impact of distinct training modalities, certain limitations should be considered. The duration of the intervention was relatively brief, potentially restricting the ability to capture long-term physiological adaptations that may arise from prolonged training exposure. Moreover, the participant pool consisted solely of adolescent female soccer players, which may constrain the applicability of the findings to male athletes or individuals from different age categories. To build on these findings, future studies should explore the sustained effects of integrated training protocols over extended periods, determine the most effective balance between SSG and THIT components, and assess their effectiveness across varied age groups and competitive levels. Furthermore, examining the psychological and motivational dimensions of these training methods could yield important insights to inform the design of more holistic youth soccer development programs.

Conclusions

According to the results of the study, both SSG-HIIT and THIT can enhance numerous physical fitness qualities in adolescent female soccer players. Notably, the SSG-HIIT intervention yielded more pronounced improvements, especially in measures of explosive power and flexibility. These results highlight the value of integrating game-based elements within structured HIIT programs. From a practical standpoint, incorporating SSG into conditioning routines may offer coaches an efficient strategy to enhance physical performance while simultaneously reinforcing sport-specific skills.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Datson, N., Hulton, A., Andersson, H., Lewis, T., Weston, M., Drust, B., & Gregson, W. (2014). Applied physiology of female soccer: An update. *Sports Medicine*, 44(9), 1225-1240. <https://doi.org/10.1007/s40279-014-0199-1>
- Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Medicine*, 43(5), 313-338. <https://doi.org/10.1007/s40279-013-0029-x>
- Kumar, G., Pandey, V., Thapa, R. K., Weldon, A., Granacher, U., & Ramirez-Campillo, R. (2023). Effects of Exercise Frequency with Complex Contrast Training on Measures of Physical Fitness in Active Adult Males. *Sports*, 11(1), Article 1. <https://doi.org/10.3390/sports11010011>
- Helgerud, J., Engen, L. C., Wisloff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise*, 33(11), 1925-1931. <https://doi.org/10.1097/00005768-200111000-00019>
- Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: A systematic review. *Sports Medicine*, 41(3), 199-220. <https://doi.org/10.2165/11539740-000000000-00000>
- Arslan, E., Ozer, G. E., & Clemente, F. M. (2020). Running-based high-intensity interval training vs. small-sided game training programs: Effects on the physical performance, psychophysiological responses and technical skills in young soccer players. *Biology of Sport*, 37(2), 165-173. <https://doi.org/10.5114/biolsport.2020.94237>
- Andersson, H. Å., Randers, M. B., Heiner-Møller, A., Krusturup, P., & Mohr, M. (2010). Elite Female Soccer Players Perform More High-Intensity Running When Playing in International Games Compared With Domestic League Games. *Journal of Strength and Conditioning Research*, 24(4), 912-919. <https://doi.org/10.1519/JSC.0b013e3181d09f21>
- Clemente, F. M., Afonso, J., Castillo, D., Arcos, A. L., Silva, A. F., & Sarmiento, H. (2020). The effects of small-sided soccer games on tactical behavior and collective dynamics: A systematic review. *Chaos, Solitons & Fractals*, 134, 109710. <https://doi.org/10.1016/j.chaos.2020.109710>
- Hammami, A., Gabbett, T. J., Slimani, M., & Bouhlel, E. (2018). Does small-sided games training improve physical fitness and team-sport-specific skills? A systematic review and meta-analysis. *The Journal of Sports Medicine and Physical Fitness*, 58(10), 1446-1455. <https://doi.org/10.23736/S0022-4707.17.07420-5>
- Zacharogiannis, E., Paradisis, G., & Tziortzis, S. (2004). An Evaluation of Tests of Anaerobic Power and Capacity. *Medicine & Science in Sports & Exercise*, 36, S116. <https://doi.org/10.1249/00005768-200405001-00549>
- Jastrzębska, A. D. (2023). Comparison of usefulness of two tests measuring anaerobic performance of untrained and soccer-training girls U12. *Scientific Reports*, 13(1), 19498. <https://doi.org/10.1038/s41598-023-46825-2>
- Köklü, Y., Alemdaroğlu, U., Kocak, F., Erol, A., & Findikoglu, G. (2011). Comparison of Chosen Physical Fitness Characteristics of Turkish Professional Basketball Players by Division and Playing Position. *Journal of Human Kinetics*, 30, 99-106. <https://doi.org/10.2478/v10078-011-0077-y>
- Stølen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer: An update. *Sports Medicine*, 35(6), 501-536. <https://doi.org/10.2165/00007256-200535060-00004>
- Jovanovic, M., Sporis, G., Omrcen, D., & Fiorentini, F. (2011). Effects of speed, agility, quickness training method on power performance in elite soccer players. *Journal of Strength and Conditioning Research*, 25(5), 1285-1292. <https://doi.org/10.1519/JSC.0b013e3181d67c65>
- Milanović, Z., Sporiš, G., Trajković, N., James, N., & Samija, K. (2013). Effects of a 12 Week SAQ Training Programme on Agility with and without the Ball among Young Soccer Players. *Journal of Sports Science & Medicine*, 12(1), 97-103.
- Lloyd, R. S., & Oliver, J. L. (2012). The Youth Physical Development Model: A New Approach to Long-Term Athletic Development. *Strength & Conditioning Journal*, 34(3), 61-72. <https://doi.org/10.1519/SSC.0b013e31825760ea>
- Darragi, M., Zouhal, H., Bousselmi, M., Karamti, H. M., Clark, C. C. T., Laher, I., Hackney, A. C., Granacher, U.,

- & Zouita, A. B. M. (2024). Effects of In-Season Strength Training on Physical Fitness and Injury Prevention in North African Elite Young Female Soccer Players. *Sports Medicine - Open*, 10, 94. <https://doi.org/10.1186/s40798-024-00762-0>
- Parpa, K., Katanic, B., & Michaelides, M. (2024). Seasonal Variation and the Effect of the Transition Period on Physical Fitness Parameters in Youth Female Soccer Players. *Sports*, 12(3), 84. <https://doi.org/10.3390/sports12030084>
- Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *Journal of Sports Sciences*, 27(2), 107-114. <https://doi.org/10.1080/02640410802428071>
- Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: A brief review. *Journal of Strength and Conditioning Research*, 28(12), 3594-3618. <https://doi.org/10.1519/JSC.0000000000000564>
- World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, 310(20), 2191-2194. <https://doi.org/10.1001/jama.2013.281053>
- Castro-Piñero, J., Ortega, F. B., Artero, E. G., Girela-Rejón, M. J., Mora, J., Sjöström, M., & Ruiz, J. R. (2010). Assessing Muscular Strength in Youth: Usefulness of Standing Long Jump as a General Index of Muscular Fitness. *Journal of Strength and Conditioning Research*, 24(7), 1810-1817. <https://doi.org/10.1519/jsc.0b013e3181ddb03d>
- Haugen, T., & Buchheit, M. (2016). Sprint Running Performance Monitoring: Methodological and Practical Considerations. *Sports Medicine*, 46(5), 641-656. <https://doi.org/10.1007/s40279-015-0446-0>
- Liu, X., Shao, Y., Saha, S., Zhao, Z., & Karmakar, D. (2025). Maximizing sprint performance among adolescent sprinters: A controlled evaluation of functional, traditional, and combined training approaches. *Frontiers in Public Health*, 13. <https://doi.org/10.3389/fpubh.2025.1596381>
- Khati, A., Saibya, R., Bhutia, N., Khatun, J., Mohit, Singh, H., & Saha, S. (2025). Exploring the Acute Benefits of Manual Soft Tissue Mobilization and Myofascial Release on Dynamic Athletic Performance in National Level Soccer Players. *Physical Education Theory and Methodology*, 25(4), 800-807. <https://doi.org/10.17309/tmfv.2025.4.07>
- Saha, S., Obhrai, S., Vishwakarma, R., Mondal, P., Nagesh, Prasad, B., Upadhyay, K., & Singh, D. K. (2025). Clarifying the Impact of Small-Sided Games and HIIT on Anaerobic Endurance in Adolescent Hockey Players. *Physical Education Theory and Methodology*, 25(3), 660-667. <https://doi.org/10.17309/tmfv.2025.3.23>
- Sperlich, B., Zinner, C., Heilemann, I., Kjendlie, P.-L., Holmberg, H.-C., & Mester, J. (2010). High-intensity interval training improves VO(2peak), maximal lactate accumulation, time trial and competition performance in 9-11-year-old swimmers. *European Journal of Applied Physiology*, 110(5), 1029-1036. <https://doi.org/10.1007/s00421-010-1586-4>
- Clemente, F., & Sarmiento, H. (2020). The effects of small-sided soccer games on technical actions and skills: A systematic review. *Human Movement*, 21, 100-119. <https://doi.org/10.5114/hm.2020.93014>
- Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, 30(7), 625-631. <https://doi.org/10.1080/02640414.2012.665940>
- Dellal, A., Chamari, K., Pintus, A., Girard, O., Cotte, T., & Keller, D. (2008). Heart rate responses during small-sided games and short intermittent running training in elite soccer players: A comparative study. *Journal of Strength and Conditioning Research*, 22(5), 1449-1457. <https://doi.org/10.1519/JSC.0b013e31817398c6>
- Ramírez-Campillo, R., Vergara-Pedrerros, M., Henríquez-Olguín, C., Martínez-Salazar, C., Alvarez, C., Nakamura, F. Y., De La Fuente, C. I., Caniuqueo, A., Alonso-Martinez, A. M., & Izquierdo, M. (2016). Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players. *Journal of Sports Sciences*, 34(8), 687-693. <https://doi.org/10.1080/02640414.2015.1068439>
- Lockie, R., Schultz, A., Callaghan, S., Jordan, C., Luczo, T., & Jeffriess, M. (2015). A preliminary investigation into the relationship between functional movement screen scores and athletic physical performance in female team sport athletes. *Biology of Sport*, 32(1), 41-51. <https://doi.org/10.5604/20831862.1127281>
- Witvrouw, E., Mahieu, N., Danneels, L., & McNair, P. (2004). Stretching and injury prevention: An obscure relationship. *Sports Medicine*, 34(7), 443-449. <https://doi.org/10.2165/00007256-200434070-00003>
- Köklü, Y., Alemdaroğlu, U., Özkan, A., Koz, M., & Ersöz, G. (2015). The relationship between sprint ability, agility and vertical jump performance in young soccer players. *Science & Sports*, 30(1), e1-e5. <https://doi.org/10.1016/j.scispo.2013.04.006>
- Sanchez-Sanchez, J., Hernández, D., Casamichana, D., Martínez-Salazar, C., Ramirez-Campillo, R., & Sampaio, J. (2017). Heart Rate, Technical Performance, and Session-RPE in Elite Youth Soccer Small-Sided Games Played With Wildcard Players. *Journal of Strength and Conditioning Research*, 31(10), 2678-2685. <https://doi.org/10.1519/JSC.0000000000001736>

Вплив восьмитижневої інтервенції з високоінтенсивного інтервального тренування на основі ігор неповними складами та традиційної інтервенції з високоінтенсивного інтервального тренування на фізичну підготовленість юних футболісток

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 5 табл., 1 рис., 35 джерел.

Мета дослідження. Дослідження мало на меті порівняти результати восьмитижневого високоінтенсивного інтервального тренування на основі ігор неповними складами (ІНС-ВІІТ) та традиційного високоінтенсивного інтервального тренування (ТВІІТ) за параметрами фізичної підготовленості у юних футболісток. Зокрема, проведено оцінку змін в анаеробній потужності, вибуховій силі, швидкості спринту, спритності та гнучкості.

Матеріали та методи. Двадцять сім футболісток віком від 14 до 17 років, які грають на змагальному рівні (>2 роки), було розподілено за методом рандомізації на три групи, що виконували наступні програми: ІНС-ВІІТ (n = 9), ТВІІТ (n = 9) та активна контрольна група (АКГ, n = 9). Тривалість інтервенції становила вісім тижнів, з трьома сесіями на тиждень для експериментальних груп. Сесії ІНС-ВІІТ включали футбольні матчі 3v3 до 5v5 з прогресивною інтенсивністю, тоді як ТВІІТ передбачало структуровані спринтерські інтервали. Оцінювання результатів перед- та постінтервенційного етапів включало анаеробний спринт-тест на основі бігу (RAST), стрибок у довжину з місця, спринт на 50 м, Іллінойський тест на спритність та тест на вимірювання загальної гнучкості тіла при згинанні тулуба вперед, сидячи на підлозі з витягнутими вперед руками.

Результати. У групах ІНС-ВІІТ і ТВІІТ спостерігалось значне поліпшення всіх показників (p<0.05), тоді як у АКГ зміни були незначними. Застосування методики ІНС-ВІІТ призвело до суттєвого підвищення показників у вибуховій потужності (8.69 %), гнучкості (11.3 %), анаеробній потужності (RAST: -8.58%), швидкості спринту (-3.97 %) та спритності (-4.37%) порівняно з ТВІІТ. Post hoc аналіз підтвердив значніші покращення вибухової потужності та гнучкості в групі ІНС-ВІІТ (p < 0.05), однак зростання показників спринту та спритності виявилось статистично подібним між двома інтервенціями.

Висновки. Згідно з результатами дослідження, методика ІНС-ВІІТ виявилася ефективнішою за ТВІІТ у покращенні багатьох показників фізичної підготовленості, особливо вибухової потужності та гнучкості. Впровадження тренувань на основі ігор в рамках високоінтенсивних протоколів пропонує практичний та специфічний для спорту підхід до підготовки юних футболісток.

Ключові слова: ігри неповними складами, високоінтенсивне інтервальне тренування, юнацький футбол, анаеробна потужність, фізична підготовленість.

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The Acute Fatigue Effects of Small-Sided Games on Lower Limb Strength, Inter-Limb Asymmetry and Landing Technique in Young Under-15 Female Soccer Players

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Abstract

Background. The increase in young female soccer players requires understanding the adaptations determined by sport-specific exercises both to enable improvements in sports performance and to reduce injury risk in women's soccer.

Objectives. This study aimed to analyze the acute effects of Small-Sided Games (SSG) on landing technique control, lower limb strength and lower limb functional asymmetry in Under-15 female soccer players.

Materials and Methods. A total of 18 young female soccer players (age: 14.04 ± 0.26 years, weight: 51.56 ± 2.9 kg; height: 146.9 ± 3.22 cm) randomly performed hop test, Landing Error Scoring System assessment and vertical jump at the end of warm-up (pre-fatigue condition) and post SSG (3vs3, 4×4 min on field $24.5\text{m} \times 24.5$ m, post-fatigue condition). The inter-limb asymmetry value was calculated by comparing the two hop tests (left and right) using the formula: $(\text{highest performing limb} - \text{lowest performing limb} / \text{highest performing limb}) \times 100$.

Results. The hop test and vertical jump results in the pre vs. post-SSG comparing showed a significant performance decrease ($p < 0.001$, ES: 1.43 and 1.43, respectively). The inter-limb asymmetry value significantly increased ($p < 0.001$, ES: 1.18) from $9.07 \pm 2.67\%$ to $13.42 \pm 7.49\%$. The landing control value has undergone a substantial decrease from 5.72 ± 0.67 to 7.83 ± 0.86 ($p < 0.001$, ES: 1.29).

Conclusions. The findings indicate that high-intensity soccer drills have an impact on the landing control quality, decrease explosive strength performance, and increase inter-limb asymmetry value. Soccer-specific exercises must be carefully modulated within the training session.

Keywords: small-sided games, jump, inter-limb asymmetry, young female soccer player, high-intensity drill.

Introduction

The growing interest for soccer practice in Italy among female population has been attracting research attention: reports from the Italian Football Federation (FIGC) indicate that there were nearly 18.000 young female soccer players in the 2023-24 season, an increase of about 23.3% from the previous season and about 49.5% from the 2021-22 soccer season (FIGC Report, 2024).

The increase in young female soccer players requires understanding the adaptations determined by sport-specific exercises both to enable improvements in sports

performance (Crossley et al., 2020) and to reduce injury risk in women's soccer (Crossley et al., 2020; Darragi et al., 2024; Randell et al., 2021).

Epidemiological studies point out a different incidence of non-contact Anterior Cruciate Ligament (ACL) injuries between male and female soccer players (Fortington & Finch, 2016; Lucarno et al., 2021). This relevant difference requires careful consideration on the pre-conditions of young female soccer players, as well as the selection of training drills and its overall organization.

It is well known which movements determine a high risk to the integrity ACL in young female soccer player's, including sudden changes of direction, landing and body control during unilateral task (Lucarno et al., 2021; Mancino et al., 2024).

These observations should be taken into account since these movements are commonly performed during an official match and training session (Randell et al., 2021; Lucarno et al., 2021; Mancino et al., 2024).

Besides, the developmental of qualitative control over these movements requires many years. Therefore, it is needed a training programs targeted specifically toward these movement factors in young female soccer players, especially during the early years of sports participation (Angulo-Barroso et al., 2022); in addition, these factors are often affected by the stage of individual maturation (Ramachandra et al., 2024).

To adapt to the demands of the performance model, the drills designed in soccer training are increasing in intensity and volume of sessions. Some drills are adapted and transformed to achieve intensities similar to or even higher than competition intensities (Pražica et al., 2022; Makar et al., 2023; Sannicandro & Cofano, 2023).

In particular, SSGs are widely used in both men and women soccer, in high qualification as well as in youth training (López-Fernández et al., 2018; Farhani et al., 2024).

SSGs are drills with smaller numbers of players and reduced space than competitive matches and it is an effective training method to increase both physical adaptations and technical skills in open skills sports (Sannicandro & Cofano, 2023; Asian-Clemente et al., 2021).

In addition, these exercises can be carried out with several variations and formats to achieve important metabolic and cardiovascular adaptations determined by high exercise intensity (Sannicandro & Cofano, 2023; López-Fernández et al., 2018; Farhani et al., 2024).

In this regard, research has also focused on fatigue induced by SSGs, observed in both men's (Modena & Schena, 2024; Konefal et al., 2023) and women's soccer (López-Fernández et al., 2018 & 2019).

For some authors, exercise-induced fatigue can be described up to many hours after the end of the session: this observation shows that the intensity of these drills is very high (Guard et al., 2022; Luchesi et al., 2023; Calderón Pellegrino et al., 2020).

The same way in which the exercises are scheduled, as well as rest time between sets, may condition performance and acute effects of fatigue (Branquinho et al., 2021).

Acute effects on hamstring fatigue in young soccer players (Sannicandro et al., 2022) and professional soccer players (Madison et al., 2019) engaged in SSG drills are known: following soccer training loads between 12 minutes and 24 minutes, hamstring eccentric force is reduced in the range of approximately 10% to 14% (Sannicandro et al., 2022; Madison et al., 2019).

The effects of acute fatigue resulting from high-intensity drills in female soccer players is a current topic in the literature: in fact, fatigue alters the control of some sport-specific movements and may represent a risk for non-contact injuries (Sannicandro et al., 2024; Sannicandro & Trotta, 2025; Mancino et al., 2024; Viswanathan et al., 2025).

When assessing the postural control of professional female soccer players performing a drop jump test before and after a high-intensity fatigue-inducing exercise protocol, a significant impairment was observed in hip flexion and ankle dorsiflexion angle (Kamitani et al., 2022).

Furthermore, previous studies evaluating landing control in U15 and U17 female soccer players before and

after high-intensity exercise have reported a considerable deterioration in performance during the post-exercise test (Sannicandro et al., 2024; Sannicandro & Trotta, 2025).

However, the most relevant aspect concerns the comparison between a vertical jump performed and a soccer-specific jump (the athlete jumps vertically to hit a ball). In the soccer-specific jump, players adapt and modify some kinematic parameters such as the ankle dorsoflexion angle or the knee bend angle during the landing phase (Mancini et al., 2022).

Based on these observations, deficits in jumping and landing technique represent risk factors for non-contact ACL injuries (Mancini et al., 2022).

Therefore, further studies are needed in the literature aimed in the analysis on high-intensity acute effects and on sport-specific drills in young female soccer players.

So far, the effects of general high-intensity drills on landing technique in young female soccer players (Sannicandro et al., 2024) or the effects of a functional agility-oriented training protocol (Sannicandro & Trotta, 2025) have been investigated.

The LESS evaluation in the post-warm-up and post-functional agility short-term fatigue protocol showed a value of 5.44 ± 0.46 and 8.66 ± 0.97 ($p > 0.001$, ES: 1.44), respectively. The LESS assessment for the post-RSA protocol condition showed a value of 8.91 ± 0.42 ; this value was statistically significant ($p > 0.001$, ES: 1.56) compared with the post-warm-up condition (Sannicandro & Trotta, 2025).

Besides, this deterioration in the control of landing technique through jump assessment is even more evident in young female soccer players (Westbrook et al., 2020).

However, soccer training is not exclusively based on high-intensity running drills but includes structured training sessions with sport-specific drills such as Large Side Games (Cofano et al., 2021; Sannicandro et al., 2021), transitional games (Asian-Clemente et al., 2024), SSGs with unbalanced (Nunes et al., 2020) and high inferiority teams (Nunes et al., 2020; Asian-Clemente et al., 2022).

Additionally, in recent years, the popularity and use of these soccer-specific drills to structure high-intensity training sessions have increased (Nunes et al., 2020; Asian-Clemente et al., 2022). In contrast, there is a lack of studies analyzing the influence of some key-skills on control, that may provide valuable insights for designing preventive programs in female soccer players (Sannicandro et al., 2024; Sannicandro & Trotta, 2025).

The effects of acute fatigue resulting from these exercises could also influence lower limb strength and strength asymmetry, as was observed in men's soccer (Sannicandro et al., 2022; Dello Iacono et al., 2023; Heil et al., 2020).

Decreased lower limb strength and increased lower limb functional asymmetry could describe a complex scenario that leads athlete to non-contact injury risk in sports and soccer (Aldhabi et al., 2024; Bromley et al., 2021; Bishop et al., 2019).

Lower limb strength asymmetries are sensitive to fatigue (Bromley et al., 2021) and this increase observed after intense soccer-specific exercise should not be underestimated. It is necessary to implement studies in women's soccer as well to provide professionals with more information on performance and injury risk (Bromley et al., 2021; Bishop et al., 2019).

Therefore, further research is needed to understand the effects of soccer-specific drills on movement control, strength and inter-limb asymmetries in young female soccer players involved in both competitive and recreational sports.

The purpose of this study is to analyze the acute effects of Small-side Games on landing technique control, lower limb strength and lower limb functional asymmetry in Under-15 female soccer players.

Material and Methods

Study Participants

18 young female soccer players (average age: 14.04 ± 0.26 years, weight: 51.56 ± 2.9 kg; height: 146.9 ± 3.22 cm) playing in first level clubs in Italy were involved in the study.

Inclusion criteria in the study focused on: a) age between 13 and 14 years, b) having a training background of at least 3 years, c) having no injuries or training suspension in the past 3 months, d) not having taken any medications in the last week.

The study was approved by the club's manager, by FIGC regional ethics committee. The study was performed according to the principles expressed in the Declaration of Helsinki. The written informed consent was obtained from the parents, while the young female soccer players have signed the informed assents.

Study Organization

Assessments aimed at testing the effects of acute fatigue were organized into two different training sessions placed at the same time (4 p.m.) and interspersed 48 hours apart to reduce the effects of inter-session fatigue.

In the two sessions, the same warm-up consisting of 3 minutes of self-activation, 5 minutes of running at 60-65% of HRmax, 5 minutes of dynamic stretching and joint mobility exercises and 5 minutes characterized by soccer-specific runs and submaximal sprints (3x15 meters, rec. 50sec) was presented for a total duration of about 18 minutes.

In the first session, three strength and conditioning soccer coaches with at least 8 years of training experience conducted the tests at the end of the warm-up (pre-fatigue condition). The participants performed the evaluation tests in a random form.

In the second session, the evaluation tests were performed in random form after SSG (3vs3), with 4 x 4min (2min recovery) in a field on measuring 24.5 x 24.5 m (López-Fernández et al., 2018).

To verify if the exercises were performed at high intensity, SSG were monitored with heart rate monitor (Polar Team Pro, Kempele, Finland) and rate of perceived exertion (RPE) was registered through Borg Scale (CR-10) at the end of the same exercises (López-Fernández et al., 2018).

The Landing Error Scoring System (LESS) was performed to assess the landing control: a jump over a landing zone is required from a 30-cm box at a distance equal to 50 percent of the young player's height, followed by a maximum vertical jump (Beese et al., 2015).

LESS protocol requires the detector to evaluate the landing through 17 indicators that consider the execution of movement in the sagittal and frontal plane: errors are

detected through two video cameras that capture the area of execution of the test. Test execution should be videotaped, ensuring that the two cameras are positioned to detect movement in the frontal and sagittal planes (Liveris et al., 2021)..

The cameras (Sony HDR-P675) were placed approximately 4 meters forward and lateral to the box. In agreement with other similar studies, the height of the camera lens was placed about 130 cm above the floor. Higher scores correspond to a greater number of errors and thus to worse performance technique. In agreement with previous research (Beese et al., 2015; Sannicandro et al., 2024), LESS scores are graded for the specific population observed and are defined as excellent (0-3 points), good (4-5 points), moderate (6 points) and poor (>7 points).

The hop test (i.e. horizontal unilateral long jump) was used to assess the explosive strength of the single lower limb (Wiprich et al., 2024; Fox et al., 2023). Single hop test (HT) was performed with free arms and each participant executed two trials for each limb. The best trial was recorded (Fox et al., 2023).

To determine inter-limb asymmetry (ILA), the index was calculated using the formula already adopted in other similar research (Read et al., 2017; Fort-Vanmeerhaeghe et al., 2020):

(Highest performing limb – Lowest performing limb / Highest performing limb) $\times 100$ (Fort-Vanmeerhaeghe et al., 2020).

For the assessment of explosive strength (vertical component), a Countermovement Jump (CMJ) was used (Fort-Vanmeerhaeghe et al., 2020): the jump was performed with hands at the hips on a conductance platform (Globus, Italy) that measures the elevation value of the center of gravity in cm; each participant performed two tests and the best was recorded.

Statistical Analysis

Data are presented as mean and standard deviations (mean $\pm$ DS). Normality of data distribution was checked using Shapiro Wilk Test. A paired samples t-test was used to examine differences pre-post differences in young female soccer players. If data did not present a normal distribution, Wilcoxon signed-rank test was used to analyze the exercise-induced change observed. The evaluation of the effect prior to and post- short-term fatigue protocol for the tested hypothesis was estimated using the Cohen's d method: as for the effect size index (Effect Size), after calculating the δ index it is possible to convert it into Effect Size: ≤ 0.20 small; 0.50 average; ≥ 0.80 large.

All statistical analysis carried out employing Jasp software (version 0.19.2, Amsterdam, The Netherlands) with level of significance set to $p < 0.05$.

Results

Comparison of pre SSG and post SSG CMJ values (Fig.1) showed a significant decrease in vertical jump performance (25.91 ± 2.91 cm vs 21.19 ± 2.28 cm, $p < 0.001$, ES:1.47).

Left and right hop test values (Figg. 2 and 3) showed a significant decrease when comparing pre SSG and post SSG (119.72 ± 5.79 cm vs 96.94 ± 6.31 cm, for left limb and 119.44

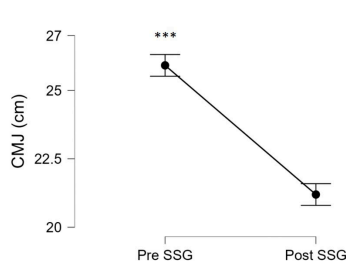


Fig. 1. CMJ values in pre-fatigue and post-fatigue conditions

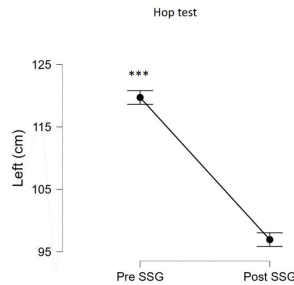


Fig. 2. Left hop test values in pre-fatigue and post-fatigue conditions

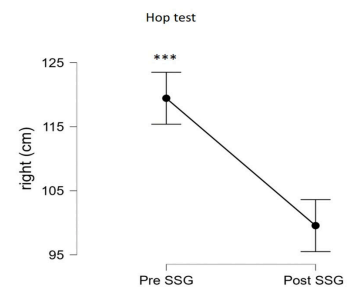


Fig. 3. Right hop test values in pre-fatigue and post-fatigue conditions

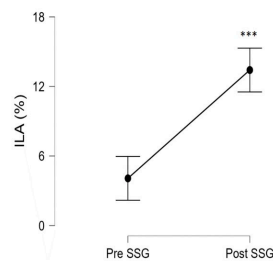


Fig. 4. Inter-limb asymmetry values in pre-fatigue and post-fatigue conditions

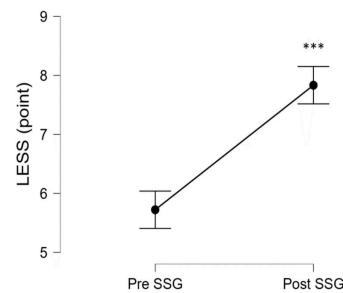


Fig. 5. Landing Error Scoring System (LESS) values in pre-fatigue and post-fatigue conditions

± 6.27 cm vs 99.56 ± 12.21 cm for right limb, $p < 0.001$, ES:1,36).

The value of functional asymmetry (Fig.4) increased significantly when comparing pre SSG and post SSG values ($9.07 \pm 2.67\%$ vs $13.42 \pm 7.49\%$, $p < 0.001$, ES:1,18).

Landing technique evaluations obtained through the LESS showed a significant decrease in the control of this movement (Fig.5) when comparing pre SSG and post SSG values (5.72 ± 0.67 vs 7.83 ± 0.86 , $p < 0.001$, ES:1,29).

Evaluation of exercise intensity showed an average heart rate of 192.5 ± 5.6 bpm corresponding to approximately $93.81 \pm 4.12\%$ of the maximum heart rate; The RPE value recorded at the end of SSGs was 7.5 ± 0.7 u.a.

Discussion

The aim of the study was to investigate the effects of acute fatigue following SSGs on strength, inter-limb asymmetries and single-leg explosive strength values in Under-15 female soccer players.

To the best of our knowledge, this is the first study that have investigated the acute effects of soccer-specific drills on the parameters of vertical jump strength, single-leg jump strength, lower limb strength asymmetry and landing technique.

Researchers have focused both on performance-enhancing aspects (Esposito et al., 2024; D'Isanto et al., 2022; D'Elia, 2023) and on studies aimed at the protecting health and maturation process in young soccer players (Raiola et al., 2022; Esposito et al., 2020).

To date, in women's soccer, the importance of performance-enhancing exercises - also oriented in terms of injury prevention - has been considered a central themes in research both in youth (Sannicandro et al., 2024; Mancino et al., 2022; Esposito et al., 2024) and professional soccer environments (Dello Iacono et al., 2023; Beese et al., 2015). The high incidence of injuries in women's soccer is a major and current issue in the literature (Silvers-Granelli, 2021; Horan et al., 2022) and some recent reviews have addressed the analysis of anterior cruciate ligament injury mechanisms in female soccer players (D'Onofrio et al., 2025).

The performance decrease in vertical jump of about 18.3% seems to indicate that the specific-sport load assigned to young female soccer players determine a significant acute fatigue condition.

In similar studies that have investigated the acute effects of SSGs-based training sessions in young elite female soccer players, no significant differences in horizontal jump strength values between pre- and post-exercise were observed (Castillo et al., 2021). Likely, the gender and sports competitive level of the study conducted with young soccer players may have determined these differences.

The performance decrease observed in single-leg jumping for left limb (approximately -19.1%) and right limb (approximately -16.77%) is consistent with that reported in bilateral jumping. Explosive strength capacity appears to be strongly affected by sport-specific exercises in young female soccer players.

This scenario is in agreement with a previous study conducted with Under 23 female soccer players, where a

functional relationship between vertical and horizontal jumping performance was found (Roso-Moliner et al., 2023).

Repeated accelerations and decelerations performed during SSGs likely constitute a significant overload for young female soccer players, as previously observed for some strength-related performance parameters in both young (Hidalgo de Mora et al., 2025) and professional soccer players (Rumpf et al., 2025; Rowell et al., 2018; Hietamo et al., 2021).

Lower limb strength asymmetry values show an increase of approximately 47%, indicating a significant negative impact in preventive terms. The literature suggests that the cut-off of 15% discriminates an athlete at risk of knee injury due to non-contact trauma (Hietamo et al., 2021; Warren et al., 2020; Guan et al., 2022).

The increase of this outcome constitutes a factor that may predispose to the likelihood increased of injury to the ACL due to the soccer-specific skills performed during SSGs and that represent movements predisposing to the injury risk (D'Onofrio et al., 2025).

It is noteworthy that the main characteristic of SSGs is the execution of continuous pressing and re-aggressing movements by the defending team. Marking, intercepting, cutting maneuvers and side-step cuts to reach and to retrieve the ball are performed at high intensity, thus posing a high risk of lower limb injury in the female soccer player (Jones et al., 2016; Della Villa et al., 2021; Della Villa et al., 2025).

The full-field collective and individual pressing required by the technical staff determine in abnormal postures that are occurred due to the qualitative decrease in movement control (D'Onofrio et al., 2025).

Inter-limb asymmetry values identified in this study are much higher than those described in previous studies with male athletes (Bishop et al., 2021), even when different assessments (Ascenzi et al., 2022) were used and the same age range as our sample (Bouafif et al., 2024) was involved.

This aspect highlights to a greater extent the importance of load dosage with young female soccer players subelite: likely, female population need to be approached carefully and progressively to soccer-specific loads, as the literature suggests for the youth context (Mainer-Pardos et al., 2024; Kale et al., 2023; Villanueva-Guerrero et al., 2023).

The worsening in landing control of about 36% confirms that the monitored soccer-specific load may result in altered skills at risk for young female soccer player.

Indeed, previous studies have shown the effects of acute fatigue following high-intensity exercise and Repetead Sprint Ability session in Under 13 female soccer players. The LESS test performed post high-intensity protocol determined a performance decrease of approximately 28%, while the LESS post RSA session produced a decrease in landing control of about 25% (Sannicandro et al., 2024).

The Heart Rate measured during the exercises, as well as the RPE value obtained, indicate that SSGs constitute high intensity exercise. These findings are consistent with other studies that have reported similar decrease in LESS performance tests in young female soccer players (Sannicandro et al., 2024; Sannicandro & Trotta, 2025).

This study contributes to the knowledge available to coaching staff who train young female soccer players at both elite and sub-elite levels. The acute effects of soccer-specific post-exercise fatigue should induce staff to carefully plan and to implement these exercises.

The introduction of SSGs must consider the cardiorespiratory demands elicited in young female soccer players and must be carefully placed within training session, as specified in the literature (Sanchez-Sanchez et al., 2018).

The scheduling of training sessions must adapt to the age, gender and sports competitive level of the participants (Esposito & Raiola, 2020).

Although this study provides interesting insights on training load in young female soccer players, some limitations should be considered: firstly, training age soccer specific to the participants was not detected. Indeed, this factor could affect the strength values of young female soccer players and, as a result, the intensity observed during SSGs. Secondly, there were no familiarization sessions with the proposed and monitored drills: this aspect may have conditioned the performance and intensity of the exercise proposed. Finally, a maximal aerobic test was not presented, which would have allowed more accurate measurement of each participant's FCmax value.

Further studies may investigate the effects of different volumes of soccer-specific exercises in order to provide information on the most suitable duration for young female soccer players. In addition, the assessment of CMJ through force platforms will be able to supplement the data obtained in this study with values for peak strength, muscle power, and ground reaction force in the landing phase.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

- Report calcio FIGC (2024). FIGC-ReportCalcio2024-BD_Alta.pdf
- Crossley, K. M., Patterson, B. E., Culvenor, A. G., Bruder, A. M., Mosler, A. B., & Mentiplay, B. F. (2020). Making football safer for women: a systematic review and meta-analysis of injury prevention programmes in 11 773 female football (soccer) players. *British journal of sports medicine*, 54(18), 1089-1098. <https://doi.org/10.1136/bjsports-2019-101587>
- Darragi, M., Zouhal, H., Bousselmi, M., Karamti, H. M., Clark, C. C. T., Laher, I., Hackney, A. C., Granacher, U., & Zouita, A. B. M. (2024). Effects of In-Season Strength Training on Physical Fitness and Injury Prevention in North African Elite Young Female Soccer Players. *Sports medicine - open*, 10(1), 94. <https://doi.org/10.1186/s40798-024-00762-0>
- Randell, R. K., Clifford, T., Drust, B., Moss, S. L., Unnithan, V. B., De Ste Croix, M. B. A., Datson, N., Martin, D., Mayho, H., Carter, J. M., & Rollo, I. (2021). Physiological Characteristics of Female Soccer Players and Health and Performance Considerations: A Narrative Review. *Sports medicine*, 51(7), 1377-1399. <https://doi.org/10.1007/s40279-021-01458-1>
- Fortington, L. V., & Finch, C. F. (2016). Priorities for injury prevention in women's Australian football: a compilation of national data from different sources. *BMJ open sport & exercise medicine*, 2(1), e000101. <https://doi.org/10.1136/bmjsem-2015-000101>
- Lucarno, S., Zago, M., Buckthorpe, M., Grassi, A., Tosarelli, F., Smith, R., & Della Villa, F. (2021). Systematic Video Analysis of Anterior Cruciate Ligament Injuries in Professional Female Soccer Players. *The American journal*

- of sports medicine, 49(7), 1794-1802.
<https://doi.org/10.1177/03635465211008169>.
- Mancino, F., Kayani, B., Gabr, A., Fontalis, A., Plastow, R., & Haddad, F. S. (2024). Anterior cruciate ligament injuries in female athletes: risk factors and strategies for prevention. *Bone & joint open*, 5(2), 94-100.
<https://doi.org/10.1302/2633-1462.52.BJO-2023-0166>
- Angulo-Barroso, R., Ferrer-Uris, B., Jubany, J., & Busquets, A. (2022). Children's strategies in drop-landing. *Frontiers in psychology*, 13, 982467.
<https://doi.org/10.3389/fpsyg.2022.982467>
- Ramachandran, A. K., Pedley, J. S., Moeskops, S., Oliver, J. L., Myer, G. D., & Lloyd, R. S. (2024). Changes in Lower Limb Biomechanics Across Various Stages of Maturation and Implications for ACL Injury Risk in Female Athletes: a Systematic Review. *Sports medicine*, 54(7), 1851-1876.
<https://doi.org/10.1007/s40279-024-02022-3>
- Praça, G. M., Chagas, M. H., Bredt, S. D. G. T., & de Andrade, A. G. P. (2022). Small-Sided Soccer Games with Larger Relative Areas Result in Higher Physical and Physiological Responses: a Systematic and Meta-Analytical Review. *Journal of human kinetics*, 81, 163-176.
<https://doi.org/10.2478/hukin-2022-0013>
- Makar, P., Silva, A. F., Kawczyński, A., Akyildiz, Z., Yıldız, M., Praça, G., & Clemente, F. M. (2023). Variability of peak speed and sprinting actions during the same small-sided games: within- and between-player variations inspected over four consecutive weeks. *Biology of sport*, 40(4), 959-965.
<https://doi.org/10.5114/biolport.2023.124846>
- Sannicandro, I., & Cofano, G. (2023). Large Sided Games and Sport-Specific Training: Parameters of High Intensity in Professional Soccer Players. *Physical Education Theory and Methodology*, 23(1), 124-132.
<https://doi.org/10.17309/tmfv.2023.1.18>
- López-Fernández, J., Sánchez-Sánchez, J., Rodríguez-Cañamero, S., Ubago-Guisado, E., Colino, E., & Gallardo, L. (2018). Physiological responses, fatigue and perception of female soccer players in small-sided games with different pitch size and sport surfaces. *Biology of sport*, 35(3), 291-299.
<https://doi.org/10.5114/biolport.2018.77829>
- Farhani, Z., Amara, S., Aissa, M. B., Guelmami, N., Bouassida, A., & Dergaa, I. (2024). The variability of physical enjoyment, physiological responses, and technical-tactical performance according to the bout duration of small-sided games: a comparative study between female and male soccer players. *BMC sports science, medicine & rehabilitation*, 16(1), 77.
<https://doi.org/10.1186/s13102-023-00794-1>
- Asian-Clemente, J., Rabano-Muñoz, A., Muñoz, B., Franco, J., & Suarez-Arrones, L. (2021). Can Small-side Games Provide Adequate High-speed Training in Professional Soccer? *International journal of sports medicine*, 42(6), 523-528.
<https://doi.org/10.1055/a-1293-8471>
- Modena, R., & Schena, F. (2024). External training load and performance recovery after small-sided games in soccer: Insights for return-to-play management. *AIMS public health*, 11(1), 315-329.
<https://doi.org/10.3934/publichealth.2024016>
- Konefał, M., Chmura, J., Zacharko, M., Zajac, T., & Chmura, P. (2023). The Relationship Among Acceleration, Deceleration and Changes of Direction in Repeated Small Sided Games. *Journal of human kinetics*, 85, 96-103.
<https://doi.org/10.2478/hukin-2022-0113>
- López-Fernández, J., Gallardo, L., Fernández-Luna, Á., Villacañas, V., García-Unanue, J., & Sánchez-Sánchez, J. (2019). Pitch Size and Game Surface in Different Small-Sided Games. Global Indicators, Activity Profile, and Acceleration of Female Soccer Players. *Journal of strength and conditioning research*, 33(3), 831-838.
<https://doi.org/10.1519/JSC.0000000000002090>
- Guard, A., McMillan, K., & MacFarlane, N. (2022). Influence of game format and team strategy on physical and perceptual intensity in soccer small-sided games. *International Journal of Sports Science & Coaching*, 17(5), 1109-1118.
<https://doi.org/10.1177/17479541211056399>
- Luchesi, M. S., Couto, B. P., Gabbett, T. J., Praça, G. M., Oliveira, M. P., & Sayers, M. G. L. (2023). The influence of the field orientation on physical demands in soccer small-sided games. *International Journal of Sports Science & Coaching*, 18(1), 143-151.
<https://doi.org/10.1177/17479541211068830>
- Calderón Pellegrino, G., Paredes-Hernández, V., Sánchez-Sánchez, J., García-Unanue, J., & Gallardo, L. (2020). Effect of the Fatigue on the Physical Performance in Different Small-Sided Games in Elite Football Players. *Journal of strength and conditioning research*, 34(8), 2338-2346.
<https://doi.org/10.1519/JSC.0000000000002858>
- Branquinho, L., Ferraz, R., Travassos, B., Marinho, D. A., & Marques, M. C. (2021). Effects of Different Recovery Times on Internal and External Load During Small-Sided Games in Soccer. *Sports health*, 13(4), 324-331.
<https://doi.org/10.1177/1941738121995469>
- Sannicandro, I., Cofano, G., & Raiola, G. (2022). The acute effects of Small-sided games on hamstring strength in young soccer players. *Physical Education Theory and Methodology*, 22(1), 77-84.
<https://doi.org/10.17309/tmfv.2022.1.11>
- Madison, G., Patterson, S. D., Read, P., Howe, L., & Waldron, M. (2019). Effects of Small-Sided Game Variation on Changes in Hamstring Strength. *Journal of strength and conditioning research*, 33(3), 839-845.
<https://doi.org/10.1519/JSC.0000000000002955>
- Sannicandro, I., Esposito, G., D'Onofrio, R., & Giacomo, C. (2024). The Effects of Fatigue on Landing Performance in Young Female Soccer Players. *Physical Education Theory and Methodology*, 24(2), 254-262.
<https://doi.org/10.17309/tmfv.2024.2.09>
- Sannicandro, I., & Trotta, N. (2025). High-Intensity Exercise and Landing Technique in Under-15 Subelite Female Soccer Players. *Advances in Physical Education*, 15, 132-147.
<https://doi.org/10.4236/ape.2025.151010>
- Viswanathan, V. K., Vaishya, R., Iyengar, K. P., Jain, V. K., & Vaish, A. (2025). Strategies for preventing anterior cruciate ligament injuries in athletes: Insights from a scoping review. *Journal of orthopaedics*, 67, 101-110.
<https://doi.org/10.1016/j.jor.2025.01.001>
- Kamitani, A., Hara, K., Fujii, Y., & Yoshida, S. (2023). Landing Posture in Elite Female Athletes During a Drop Vertical Jump Before and After a High-Intensity Ergometer Fatigue Protocol: A Study of 20 Japanese Women's Soccer League Players. *Orthopaedic journal of sports medicine*, 11(6), 23259671231171859.
<https://doi.org/10.1177/23259671231171859>
- Mancini, S., Dickin, D. C., Hankemeier, D., Ashton, C., Welch, J., & Wang, H. (2022). Effects of a soccer-specific vertical jump on lower extremity landing kinematics. *Sports*

- medicine and health science*, 4(3), 209-214.
<https://doi.org/10.1016/j.smhs.2022.07.003>
- Westbrook, A. E., Taylor, J. B., Nguyen, A. D., Paterno, M. V., & Ford, K. R. (2020). Effects of maturation on knee biomechanics during cutting and landing in young female soccer players. *PloS one*, 15(5), e0233701.
<https://doi.org/10.1371/journal.pone.0233701>
- Cofano, G., D'Elia, F., Piccinno, A., & Sannicandro, I. (2021). Analysis of the External and Internal Load in 5vs5 Large Sided Games: Differences Between Different Sized Fields. *Physical Education Theory and Methodology*, 21(4), 337–342. <https://doi.org/10.17309/tmf.2021.4.08>
- Sannicandro, I., Piccinno, A., Rosa A.R., Cofano G. (2021). Analysis of the External and Internal Load in 4vs4 Large Sided Games: Differences between Fields of Different Sizes. *International Journal of Human Movement and Sports Sciences*, 9(6), 1470 - 1476.
<https://doi.org/10.13189/saj.2021.090644>
- Asian-Clemente, J. A., Rabano-Muñoz, A., Suarez-Arrones, L., & Requena, B. (2024). Analysis of Differences in Running Demands between Official Matches and Transition Games of Young Professional Soccer Players according to the Playing Position. *Journal of human kinetics*, 92, 121-131. <https://doi.org/10.5114/jhk/175339>
- Nunes NA, Gonçalves B, Coutinho D and Travassos B (2020) How Numerical Unbalance Constraints Physical and Tactical Individual Demands of Ball Possession Small-Sided Soccer Games. *Front. Psychol.*, 11:1464.
<https://doi.org/10.3389/fpsyg.2020.01464>
- Asian-Clemente, J. A., Rabano-Muñoz, A., Requena, B., & Suarez-Arrones, L. (2022). High-speed Training in a Specific Context in Soccer: Transition Games. *International journal of sports medicine*, 43(10), 881-888.
<https://doi.org/10.1055/a-1794-9567>
- Dello Iacono, A., McLaren, S. J., Macpherson, T. W., Beato, M., Weston, M., Unnithan, V. B., & Shushan, T. (2023). Quantifying Exposure and Intra-Individual Reliability of High-Speed and Sprint Running During Sided-Games Training in Soccer Players: A Systematic Review and Meta-analysis. *Sports medicine*, 53(2), 371-413.
<https://doi.org/10.1007/s40279-022-01773-1>
- Heil, J., Loffing, F., & Büsch, D. (2020). The Influence of Exercise-Induced Fatigue on Inter-Limb Asymmetries: a Systematic Review. *Sports medicine - open*, 6(1), 39.
<https://doi.org/10.1186/s40798-020-00270-x>
- Aldhabi, R., Albadi, M., Alzahrani, A., Almasari, A., Alorabi, F., Alsobhi, M., Gmmash, A., Othman, R., Almaddah, M., & Khalil, A. A. (2024). The effect of post-match fatigue on physical performance in adolescent soccer players. *The Journal of sports medicine and physical fitness*, 64(11), 1165-1171. <https://doi.org/10.23736/S0022-4707.24.16061-6>
- Bromley, T., Turner, A., Read, P., Lake, J., Maloney, S., Chavda, S., & Bishop, C. (2021). Effects of a Competitive Soccer Match on Jump Performance and Interlimb Asymmetries in Elite Academy Soccer Players. *Journal of strength and conditioning research*, 35(6), 1707-1714.
<https://doi.org/10.1519/JSC.0000000000002951>
- Bishop, C., Turner, A., Maloney, S., Lake, J., Loturco, I., Bromley, T., & Read, P. (2019). Drop Jump Asymmetry is Associated with Reduced Sprint and Change-of-Direction Speed Performance in Adult Female Soccer Players. *Sports*, 7(1), 29. <https://doi.org/10.3390/sports7010029>
- López-Fernández, J., Sánchez-Sánchez, J., Rodríguez-Cañamero, S., Ubago-Guisado, E., Colino, E., & Gallardo, L. (2018). Physiological responses, fatigue and perception of female soccer players in small-sided games with different pitch size and sport surfaces. *Biology of sport*, 35(3), 291-299.
<https://doi.org/10.5114/biolsport.2018.77829>
- Beese, M. E., Joy, E., Switzler, C. L., & Hicks-Little, C. A. (2015). Landing Error Scoring System Differences Between Single-Sport and Multi-Sport Female High School-Aged Athletes. *Journal of athletic training*, 50(8), 806-811. <https://doi.org/10.4085/1062-6050-50.7.01>
- Liveris, N. I., Tsarbou, C., Tsimeas, P. D., Papageorgiou, G., Xergia, S. A., & Tsiokanos, A. (2021). Evaluating the Effects of Match-Induced Fatigue on Landing Ability; the Case of the Basketball Game. *International journal of exercise science*, 14(6), 768-778.
- Wiprich, M. T., Eberle, E. F., Balbinot, G. F., Cecconi, M. P., Binotti, F., Tadiello, G. S., & Bonetti, L. V. (2024). Evaluation of muscular and functional inter-limb asymmetries during mid-season in young male soccer athletes. *Journal of bodywork and movement therapies*, 38, 605-614. <https://doi.org/10.1016/j.jbmt.2024.03.067>
- Fox, K. T., Pearson, L. T., & Hicks, K. M. (2023). The effect of lower inter-limb asymmetries on athletic performance: A systematic review and meta-analysis. *PloS one*, 18(6), e0286942. <https://doi.org/10.1371/journal.pone.0286942>
- Read, P.J., Oliver, J.L., Myer, G.D., De Ste Croix, M.B.A., Lloyd, R.S. (2017). The Effects of Maturation on Measures of Asymmetry During Neuromuscular Control Tests in Elite Male Youth Soccer Players. *Pediatr Exerc Sci*, 30,168–75.
- Fort-Vanmeerhaeghe, A., Bishop, C., Buscà, B., Aguilera-Castells, J., Vicens-Bordas, J., & Gonzalo Skok, O. (2020) Inter-limb asymmetries are associated with decrements in physical performance in youth elite team sports athletes. *PLoS ONE* 15(3), e0229440.
<https://doi.org/10.1371/journal.pone.0229440>
- Esposito, G., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Ecological-Dynamic Approach vs. Traditional Prescriptive Approach in Improving Technical Skills of Young Soccer Players. *Journal of functional morphology and kinesiology*, 9(3), 162. <https://doi.org/10.3390/jfmk9030162>
- D'Isanto T., Altavilla G., Esposito G., D'Elia F., Raiola G. (2022). Heuristic Learning and Sport: Theoretical Lines and Operational Proposals. *Encyclopaideia*, 26, 69-80.
<https://doi.org/10.6092/issn.1825-8670/14237>
- D'Elia F. (2023). External loading in football to discriminate the different performance model. *Journal of Physical Education and Sport*, 23(4), 1050-1055.
<https://doi.org/10.7752/jpes.2023.04131>
- Raiola, G., D'Isanto, T., Di Domenico, F., & D'Elia, F. (2022). Effect of Teaching Methods on Motor Efficiency, Perceptions and Awareness in Children. *International journal of environmental research and public health*, 19(16), 10287. <https://doi.org/10.3390/ijerph191610287>
- Esposito, G., D'Elia, F., & Raiola, G. (2020). A Method to Promote the Development of Intelligence and Game Skills in Youth Football. *Physical Education Theory and Methodology*, 20(3), 142-148.
<https://doi.org/10.17309/tmf.2020.3.03>
- Esposito, G., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Ecological-Dynamic Approach vs. Traditional Prescriptive

- Approach in Improving Technical Skills of Young Soccer Players. *Journal of Functional Morphology and Kinesiology*, 9(3), 162. <https://doi.org/10.3390/jfmk9030162>
- Silvers-Granelli H. (2021). Why Female Athletes Injure Their ACLs More Frequently? What can we do to mitigate their risk?. *International journal of sports physical therapy*, 16(4), 971-977. <https://doi.org/10.26603/001c.25467>
- Horan, D., Blake, C., Häggglund, M., Kelly, S., Roe, M., & Delahunt, E. (2022). Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League. *Scandinavian journal of medicine & science in sports*, 32(1), 177-190. <https://doi.org/10.1111/sms.14062>
- D'Onofrio, R., Pompa, D., Savoia, C., Masucci, M., Laterza, F., & Manzi, V. (2025). Pressing, pressure and re-aggressing as tactical movement of anterior cruciate ligament injuries in women's soccer. *The Journal of sports medicine and physical fitness*, 65(5), 657-664. <https://doi.org/10.23736/S0022-4707.24.16402-X>.
- Castillo, D., Rodríguez-Fernández, A., Nakamura, F. Y., Sanchez-Sanchez, J., Ramirez-Campillo, R., Yanci, J., Zubillaga, A., & Raya-González, J. (2021). Influence of Different Small-Sided Game Formats on Physical and Physiological Demands and Physical Performance in Young Soccer Players. *Journal of strength and conditioning research*, 35(8), 2287-2293. <https://doi.org/10.1519/JSC.0000000000003114>
- Roso-Moliner, A., Lozano, D., Nobari, H., Bishop, C., Carton-Llorente, A., & Mainer-Pardos, E. (2023). Horizontal jump asymmetries are associated with reduced range of motion and vertical jump performance in female soccer players. *BMC sports science, medicine & rehabilitation*, 15(1), 80. <https://doi.org/10.1186/s13102-023-00697-1>
- Hidalgo de Mora, J., Cornejo-Daza, P. J., Sánchez-Valdepeñas, J., Rodiles Guerrero, L., Riscart-López, J., Campos Vázquez, M. Ángel., & Pareja-Blanco, F. (2025). Effects of pitch size and set configuration on mechanical responses and fatigue induced by different small sided games in soccer. *Retos*, 63, 377-386. <https://doi.org/10.47197/retos.v63.109184>
- Rowell, A. E., Aughey, R. J., Hopkins, W. G., Esmaeili, A., Lazarus, B. H., & Cormack, S. J. (2018). Effects of Training and Competition Load on Neuromuscular Recovery, Testosterone, Cortisol, and Match Performance During a Season of Professional Football. *Front Physiol*, 9, 668. <https://doi.org/10.3389/fphys.2018.00668>
- Rumpf, M.C., Jäger, J., Clemente, F.M., Altmann, S., & Lochmann, M. (2025). The effect of relative pitch size on physiological, physical, technical and tactical variables in small-sided games: a literature review and practical guide. *Front. Sports Act. Living*, 7:1592536. <https://doi.org/10.3389/fspor.2025.1592536>
- Hietamo, J., Pasanen, K., Leppänen, M., Steffen, K., Kannus, P., Heinonen, A., Mattila, Vm., & Parkkari, J. (2021). Association between lower extremity muscle strength and acute ankle injury in youth team-sports athletes. *Physical therapy in sport: Official journal of the Association of Chartered Physiotherapists in Sports Medicine*, 48, 188-195. <https://doi.org/10.1016/j.ptsp.2021.01.007>
- Warren, M., Lininger, M.R., Smith, C.A., Copp, A.J., Chimera, N.J. (2020). Association of Functional Screening Tests and Noncontact Injuries in Division I Women Student-Athletes. *J. Strength Cond. Res.*, 34, 2302-2311
- Guan, Y., Bredin, S. S. D., Taunton, J., Jiang, Q., Wu, N., & Warburton, D. E. R. (2022). Association between Inter-Limb Asymmetries in Lower-Limb Functional Performance and Sport Injury: A Systematic Review of Prospective Cohort Studies. *Journal of clinical medicine*, 11(2), 360. <https://doi.org/10.3390/jcm11020360>
- Jones, P. A., Herrington, L. C., & Graham-Smith, P. (2016). Technique determinants of knee abduction moments during pivoting in female soccer players. *Clinical biomechanics (Bristol, Avon)*, 31, 107-112. <https://doi.org/10.1016/j.clinbiomech.2015.09.012>
- Della Villa, F., Häggglund, M., Della Villa, S., Ekstrand, J., & Waldén, M. (2021). High rate of second ACL injury following ACL reconstruction in male professional footballers: an updated longitudinal analysis from 118 players in the UEFA Elite Club Injury Study. *British journal of sports medicine*, 55(23), 1350-1356. <https://doi.org/10.1136/bjsports-2020-103555>
- Della Villa, F., Stride, M., Bortolami, A., Williams, A., Davison, M., & Buckthorpe, M. (2025). Systematic Video Analysis of ACL Injuries in Male Professional English Soccer Players: A Study of 124 Cases. *Orthopaedic journal of sports medicine*, 13(2), 23259671251314642. <https://doi.org/10.1177/23259671251314642>
- Bishop, C., Coratella, G., & Beato, M. (2021). Intra- and Inter-Limb Strength Asymmetry in Soccer: A Comparison of Professional and Under-18 Players. *Sports*, 9(9), 129. <https://doi.org/10.3390/sports9090129>
- Ascenzi, G., Filetti, C., Di Salvo, V., Nuñez, F. J., Suarez-Arrones, L., Ruscello, B., Francioni, F. M., & Villanueva, A. M. (2022). Inter-limb asymmetry in youth elite soccer players: Effect of loading conditions. *PloS one*, 17(6), e0269695. <https://doi.org/10.1371/journal.pone.0269695>
- Bouafif, N., Hammami, R., Mahmoudi, A., Jiménez-Martínez, P., Alix-Fages, C., Garcia-Ramos, A., Juesas, A., Gene-Morales, J., Gaied-Chortane, S., & Colado, J. C. (2024). Reliability of single-leg maximal dynamic strength performance and inter-limb asymmetries in pre-pubertal soccer players. The influence of maturity in asymmetries. *Heliyon*, 10(19), e38716. <https://doi.org/10.1016/j.heliyon.2024.e38716>
- Mainer-Pardos, E., Kaniş, O., Oliveira, R., & Nobari, H. (2024). Effect of additional short sprint training on physical performance in adolescent male soccer players: a systematic review and meta-analysis. *Acta Kinesiologica*, 18(3), 41-52. <https://doi.org/10.51371/issn.1840-2976.2024.18.3.07>
- Kale, M., Yol, Y., Tolali, A.B., Ayaz, E. (2023). Effects of repetitive different jump pre-conditioning activities on post activity performance enhancement: Effects of repetitive different jump preloads. *Acta Kinesiologica*, 17(3), 55-61. <https://doi.org/10.51371/issn.1840-2976.2023.17.2.9>
- Villanueva-Guerrero, O., Mainer-Pardos, E., Nobari, H., Lozano, D., Arjol-Serrano, J.L., Roso-Moliner, A. (2023). Analysis of the effects of the transitional period on performance parameters in young soccer players. *Acta Kinesiologica*, 17(2), 4-11. <https://doi.org/10.51371/issn.1840-2976.2023.17.2.1>
- Sanchez-Sanchez, J., Ramirez-Campillo, R., Carretero, M., Martín, V., Hernández, D., & Nakamura, F. Y. (2018). Soccer Small-Sided Games Activities Vary According to the Interval Regime and their Order of Presentation within the Session. *Journal of human kinetics*, 62, 167-175. <https://doi.org/10.1515/hukin-2017-0168>
- Esposito, G., & Raiola, G. (2020). Monitoring the performance and technique consolidation in youth football players. *Trends in Sport Sciences*, 27(2), 93-100.

Вплив проявів гострої втоми при використанні ігор неповними складами на силу нижніх кінцівок, асиметрію між кінцівками та техніку приземлення у юних футболісток вікової категорії до 15 років

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 рис., 75 джерел.

Історія питання. Зростання кількості юних футболісток вимагає розуміння адаптаційних процесів, що визначаються специфічними для цього виду спорту вправами як для покращення спортивної результативності, так і з метою зменшення ризику травматизму у жіночому футболі.

Мета дослідження. Мета цього дослідження полягала в проведенні аналізу безпосереднього впливу ігор неповними складами (ІНС) на контроль техніки приземлення, силу нижніх кінцівок та функціональну асиметрію нижніх кінцівок у футболісток віком до 15 років.

Матеріали та методи. Загалом 18 юних футболісток (вік: 14.04 ± 0.26 років, вага: 51.56 ± 2.9 кг; зріст: 146.9 ± 3.22 см) рандомізовано виконували комплекс тестів зі стрибків на одній нозі, використовуючи систему оцінювання помилок приземлення (Landing Error Scoring System) та вертикальний стрибок наприкінці розминки (у стані перед втомою) та після проведення ІНС (3 на 3, 4 × 4 хв на полі 24,5 м × 24,5 м, стан після втоми). Значення асиметрії між кінцівками було розраховано шляхом порівняння двох тестів зі стрибків на одній нозі (лівою та правою кінцівками) за формулою: (кінцівка з найвищим показником результативності – кінцівка з найнижчим показником/кінцівка з найвищим показником) × 100.

Результати. Результати тестів з виконання стрибків на одній нозі та вертикального стрибка на етапах порівняльного аналізу перед та після проведення ІНС показали значне зниження результативності ($p < 0.001$, ES: 1.43 та 1.43 відповідно). Значення асиметрії між кінцівками суттєво підвищилися ($p < 0.001$, ES: 1.18) з $9.07 \pm 2.67\%$ до $13.42 \pm 7.49\%$. Значення контролю приземлення зазнало істотного зниження показників з 5.72 ± 0.67 до 7.83 ± 0.86 ($p < 0.001$, ES: 1.29).

Висновки. Результати дослідження свідчать про вплив високоінтенсивних футбольних тренувань на якість контролю приземлення, зниження результативності вибухової сили та підвищення значення асиметрії між кінцівками. Специфічні футбольні вправи мають бути ретельно модульовані в рамках тренувального заняття.

Ключові слова: ігри неповними складами, стрибок, асиметрія між кінцівками, юна футболістка, тренування високої інтенсивності.

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The Role of Physical Activity, Sensation Seeking, and Boredom in Shaping Adolescent Learning Styles

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Abstract

Objectives. This study aimed to examine the relationship between physical activity, boredom proneness, sensation seeking, and learning styles among high school students in the Czech Republic.

Materials and Methods. The study involved 476 students aged 15–18 years (292 girls and 184 boys), attending general and sports grammar schools. Standardized instruments were used to measure boredom (Boredom Proneness Scale), sensation seeking (Sensation Seeking Scale V), learning styles (Learning Styles Inventory), and physical activity levels (International Physical Activity Questionnaire). The study employed non-parametric tests, correlation analysis, and regression modeling.

Results. The results indicated that older students reported lower physical activity, higher boredom proneness, and reduced intrinsic motivation. Boys in general grammar schools showed higher physical activity and a preference for silence and movement during learning, but lower persistence compared to their peers. Girls in general grammar schools expressed a stronger tendency to seek new sensory experiences. Weak associations were observed between sensation seeking, persistence, and social learning preferences. Regression models moderately predicted student age and gender based on psychological and behavioral variables.

Conclusions. The findings demonstrated that factors such as age, gender, and physical activity significantly influence adolescent learning preferences and motivation. Implementing differentiated teaching strategies and experiential, movement-based learning may enhance engagement, particularly in students prone to boredom or high in sensation seeking.

Keywords: secondary education, psychological factors, school engagement, student's well-being, individual differences.

Introduction

The experience of boredom, the tendency to seek extraordinary sensations, and students' levels of physical activity interact and shape learning preferences and motivation. While boredom is often seen as negative, it may also encourage students to seek new experiences and adapt their learning approaches. Sensation seeking — a preference for novelty and intensity — also influences how students engage with educational tasks.

By examining these psychological factors alongside learning styles and physical activity, this study aims to provide insights to help educators and policymakers design more effective learning environments for secondary-level students.

Boredom, its manifestations, functions and relation to the educational process

Recent research highlights the impact of school boredom on student well-being. A study on 2,331 California students introduces the School Boredom Mindset (SBM), identifying high-risk students with negative school attitudes and lower well-being (Furlong et al., 2021).

Boredom is primarily described as a state in which an individual desires to do something other than their current activity (Csikszentmihalyi, 2000; Fahlman et al., 2013; Mikulas & Vodanovich, 1993; Todman, 2003; Van Tilburg & Igou, 2012). It is an unpleasant experience that represents a failure to interact with the immediate environment, regardless of the individual's motivation to make the interaction successful (Danckert & Merrifield, 2018; Eastwood et al., 2012). Students of any gender may experience difficulty concentrating and sustaining attention (Eastwood et al., 2012; Harris, 2000; Hartl et al., 2010; Wallace et al., 2003), which can negatively affect the educational process.

A significant number of authors point to the potential positives of experiencing states of boredom. For example through its unintentional scanning may lead to creativity and problem solving (Belton & Priyadharshini, 2007). It allows for contemplation, daydreaming and imagining alternatives, and can be an important part of creative work (Gasper & Middlewood, 2014; Harris, 2000; Mann & Cadman, 2014). On the other hand, Elpidorou (2018) points out that boredom as a trait does not predict creativity. Overall, boredom can promote the restoration of the perceived meaningfulness of activities aligned with one's interests (Bench & Lench, 2013; Elpidorou, 2014, 2015; Smith et al., 2009; Van Tilburg & Igou, 2011, 2012). This insight may help address motivational processes in schooling for students who experience boredom.

Sensation seeking tendency, physical activity and sport as a part of the student's experience

The experience of boredom is linked to the sensation seeking tendency (SST). In this study, SST refers to a preference for new, powerful, and exceptional experiences, as first described by Zuckerman (Zuckerman, 1978). SST is influenced by genetic and external factors (Zuckerman, 1994) and is highly related to risk-taking (Zuckerman, 2001). Individuals with high SST have greater central nervous system arousal, and this tendency typically peaks during adolescence (Neary and Zuckerman, 1976, Zuckerman, 1994). Although research has shown that, on average, male respondents report higher SST scores (Psychology Today Staff, 2004; Zuckerman, 2005), such findings should be interpreted as statistical tendencies rather than categorical distinctions, considering individual and contextual variability. Heredity explains 34–69% of SST variation (Eysenck, 1983; Fulker et al., 1980; Hur & Bouchard, Jr., 1997; Koopmans et al., 1995), but environmental influences, such as family dynamics, socioeconomic status, and cognitive ability, also contribute (Zuckerman, 1994; Feij & Taris, 2010; Henry & Moffitt, 1997). SST is linked to openness, aversion to structured situations, adventure seeking, proneness to boredom, and lower inhibitions (Galloway & Lopez, 1999). High SST is associated with impulsivity, antisocial behavior (Zuckerman & Link, 1968), social dominance (Zuckerman, 2005), "grit" (Muris, 2009), and possible delinquency during adolescence (Harden et al., 2012). These traits can have both positive (e.g. rescue workers) and negative (e.g. addiction) effects and they may influence students' engagement in learning.

In terms of SST and physical activity (PA) or sporting activities, research is inconsistent. Often, SST is linked to risky or extreme sports (Zuckerman, 1979). Potgieter and Bisschoff (1990) reported positive correlations with high/moderate-risk sports but negative with low-risk sports. Contact sport athletes show higher SST than those in non-contact sports (Schroth, 1995). In the Czech Republic, Kuban (2006) found slightly higher SST among sports students than non-sports students, though not statistically significant. Similarly, Franken et al. (Franken et al., 1994) and Jack and Ronan (Jack & Ronan, 1998) also found SST to be related to general sports involvement.

Research on SST in the educational domain remains limited. Bösselmann et al. (2021) demonstrated that adolescents with higher levels of physical activity reported

less boredom and lower fear of COVID-19 during the pandemic, suggesting that physical engagement may buffer against negative emotional states in school-age populations.

Educational process from the perspective of experiencing boredom and sensation seeking tendency

Boredom and sensation seeking should be viewed as complex psychological phenomena that demand a nuanced, well-informed educational approach. Reducing them to simplistic explanations overlooks their significant impact on learning and creativity. In schools, boredom often stems from unengaging content, monotonous instruction, rigid structures, or teaching perceived as irrelevant. Students may respond by daydreaming, becoming distracted, disengaging, or even skipping school (Průcha et al., 2009). At the same time, boredom can prompt reflection and motivate students to seek meaningful and stimulating activities (Bench & Lench, 2013; Elpidorou, 2015; Smith et al., 2009; Van Tilburg & Igou, 2011, 2012). Negative emotions and experiences are a natural part of learning. Although unpleasant, they can be instructive and contribute to personal growth. Even within positive, supportive learning environments, such emotions have an important role (Baumeister et al., 2001; Diener & Seligman, 2002). Acknowledging and constructively addressing these experiences may lead to improvements in student motivation, as well as in teaching practices, learning environments, and curricular design.

Learning styles, experiencing boredom, sensation seeking tendency in sport oriented grammar school students

When discussing boredom and SST in the educational process, learning style (LS) is one of the important variables. For this research, Dunn's (Dunn, 2000) concept of LS was chosen, which focuses on preferences for certain types of social interaction and learning environments, less on information processing, and least on personality traits. It describes LS in relation to multiple variables, helping to retain knowledge that might otherwise be lost through overgeneralization. Dunn et al. (Dunn, Rita et al., 1989) define LS as biologically and developmentally determined characteristics that influence student learning. Each learner has an LS, and it is important to identify individual strengths and weaknesses in this area. They relate to 21 factors that influence the learning process itself and are divided into four groups: environmental influences, emotionality, social needs and physical needs (Dunn, Rita et al., 1989).

To examine the relationship between these variables, this study surveyed sports and general grammar school students. Previous research shows that individuals in sports tend to have higher SST (Franken et al., 1994; Jack & Ronan, 1998; Kuban, 2006). Differences in preferred LS have been identified between students in general grammar schools and those in sports-oriented schools (e.g. sports students are less persistent) (Culková, 2017). Girls in sports-focused programs tend to prefer learning in the morning, whereas those in general programs prefer evenings; boys in sports classes also differ in their preferences (e.g., they prefer evenings) (Culková, 2013). A statistically significant correlation between SST and the preference for experiential learning was observed. SST is also linked to boredom, and

gender-related differences are frequently observed (Culková, 2013; Zuckerman, 2005).

For grammar school students, learning styles are typically developed and can be reliably assessed, offering value to both students and teachers. Recognizing sensation seeking and boredom proneness helps adapt learning strategies, as these factors influence learning behavior and attitudes toward lifelong education. This study focuses on Czech students from both sports-oriented and general grammar schools.

Materials and Methods

The research is based on a non-interventional questionnaire survey, part of the research design is quantitative, part comparative, part correlational and part exploratory.

Study Participants

The sample consisted of 476 students (292 girls and 184 boys) from general and sports-oriented four-year grammar schools in the Czech Republic. These students were in grades 1 to 3, representing typical Czech secondary education. Specifically, 54 female and 107 male students attended the sports-oriented grammar school, and 130 female and 185 male students attended the general grammar school. All participants completed the survey, resulting in a 100% response rate.

Study Organization

Questionnaires were distributed in hard copy. Data were transcribed into a database, and scores were calculated algorithmically (summative for scales and subscales). The standardized questionnaire used was the Sensation Seeking Scale form V (SSS-V), standardized in Czech by Kuban (2006) from Zuckerman's original version (1978). The total score reflects the tendency to seek new and strong experiences (Kuban, 2006). The second questionnaire used was the Boredom Proneness Scale (BPS), which measures trait boredom and assesses how connected individuals feel to their environment and their ability to adapt (Farmer & Sundberg, 1986). Higher scores indicate a lower tendency to experience boredom. The third questionnaire is Learning Style Inventory (LSI) questionnaire (Dunn, Rita et al., 1989), also a standardized and adapted to Czech by Pýchová, Kantorová and Mareš (Mareš & Skalská, 1994). The fourth questionnaire is the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003; Hagströmer et al., 2008) measuring self-reported PA in five domains: work/study, transport, housework, recreation/sport, and sitting time.

Statistical Analysis

Data processing was performed in SPSS v24 and JASP 0.16.3.0. Descriptive statistics and error detection were calculated first. The normality of the data distribution was assessed using the Shapiro-Wilk test, known for its rigor. Results ($S-W = 0.885-0.972$, $p \leq 0.03$) indicated non-normal distribution across all scales, so non-parametric

methods were used. Specific statistical methods are reported alongside the results. The research followed the ethical principles of the Declaration of Helsinki (2013). It was approved by the ethics committee of the affiliated university (approval number: 9/2024). Informed consent was obtained from all participants, and participation was voluntary and anonymous.

Results

The study results should be presented in tables and described in a logical sequence.

School-type and age-based differences

Differences between school type - general versus sports grammar schools, were tested and that there is no statistically significant difference between the students of the two types of grammar schools in any of the observed variables.

The method of calculating the correlation coefficient was used to verify the influence of age (represented by the year of study) on the variables studied. Students from 1st to 3rd year were monitored. Results shown in Table 1.

Table 1. Grade associations: Spearman correlation ($n = 476$)

Variable	Rho	p
IPAQ	-0.208	< 0.001
BPS_Summa	-0.112	0.01
SSS_Total	-0.153	< 0.001
SSS_TAS	-0.065	0.16
SSS_ES	-0.121	0.01
SSS_Dis	-0.048	0.29
SSS_BS	-0.098	0.03
LSI_Int.Motivation	-0.163	< 0.001
LSI_Persistence	0.054	0.24
LSI_FoodDrinkCons.	-0.209	< 0.001
LSI_Exper.Learning	-0.097	0.03
LSI_SilencePreference	0.076	0.10
LSI_TactileLearning	-0.293	< 0.001
LSI_LocationChange	0.010	0.83
LSI_LearningW.Friends	0.052	0.26

Note. Conditioned on variables: Gender (man), Group (general x sport).

Most variables show a significant correlation with age (year of study), always in a negative direction, i.e., the older the students, the less PA, SST (specifically ES and BS), LSI intrinsic motivation, consumption while learning, experiential learning, and tactile learning.

The Mann-Whitney test was calculated. The value of W is the sum of the rank of the first sample. The effect size is measured by the rank-biserial correlation ($R-B C$), which indicates the magnitude and direction of the correlation (a positive value means that the first sample tends to be larger and vice versa). Significance is in the p column ($p \leq 0.05$ indicates a statistically significant difference between groups).

Table 2. Gender differences: M-W test (n = 476, ng = 292 girls, nb = 184 boys)

Test/scale	W	p	R-B C	W general	p general	R-B C general	W sport	p Sport	R-B C sport
IPAQ	22391.5	0.002	-0.17	9040.0	< .001	-0.248	2855.5	0.91	-0.01
BPS_Summa	29141.5	0.12	0.09	13087.5	0.18	0.088	3107.5	0.43	0.08
SSS_Total	28544.5	0.25	0.06	13572.0	0.05	0.129	2674.0	0.44	-0.07
SSS_TAS	26646.5	0.88	-0.01	12435.0	0.60	0.034	2622.5	0.33	-0.09
SSS_ES	30599.0	0.01	0.14	14021.5	0.01	0.166	3129.5	0.38	0.08
SSS_Dis	26337.5	0.72	-0.02	12377.5	0.66	0.029	2552.5	0.22	-0.12
SSS_BS	28143.5	0.38	0.05	12904.5	0.26	0.073	2883.0	0.98	-0.00
BPS_Boredom	25865.5	0.49	-0.04	12217.5	0.81	0.016	2670.5	0.43	-0.08
LSI_IntrinsicMotivation	26582.0	0.84	-0.01	11546.5	0.54	-0.040	3045.5	0.57	0.05
LSI_Persistence	24191.5	0.06	-0.10	10943.5	0.16	-0.090	2553.0	0.21	-0.12
LSI_FoodDrinkConsumption	29272.0	0.01	0.09	12717.5	0.38	0.058	3341.0	0.10	0.16
LSI_ExperientialLearning	28744.5	0.20	0.07	12959.0	0.24	0.078	3043.0	0.58	0.05
LSI_SilencePreference	23862.0	0.04	-0.11	10581.0	0.06	-0.120	2613.0	0.31	-0.10
LSI_TactileLearning	26055.5	0.59	-0.03	11461.0	0.48	-0.047	2914.5	0.93	0.01
LSI_LocationChange	23469.5	0.02	-0.13	10537.5	0.06	-0.124	2501.5	0.16	-0.13
LSI_LearningWithFriends	27135.0	0.85	0.01	12495.0	0.54	0.039	2736.0	0.57	-0.05

Note: R-B C = rank biserial correlation

The results reveal significant gender differences in several variables: boys report higher physical activity (IPAQ), girls score higher in sensation seeking – experience seeking (SSS-ES), while boys show a stronger preference for silence and more frequent need to change location while learning. Male students also scored higher in LSI Persistence, indicating lower persistence, though this was at the borderline of significance. These differences appear primarily among students from general grammar schools. In contrast, no significant gender differences were observed among students from sports-oriented grammar schools.

Spearman's rank correlation was used to assess the strength and direction of relationships between variables in a non-normally distributed dataset, with effect sizes interpreted using Cohen's criteria. The correlation matrix included total and subscale scores from the SSS, LSI, IPAQ, and BPS. No significant associations were found between IPAQ or BPS and the other variables.

Statistically significant associations between SSS and LSI variables were found in two cases: SSS_Dis with LSI_Persistence ($\rho = 0.103$, $p = 0.025$) and LSI_Learning with friends with LSI_Persistence ($\rho = -0.090$, $p = 0.048$). These findings suggest that both adherence to social norms and learning in a peer context may support greater persistence. However, the correlation coefficients indicate only weak associations.

Prediction modeling

When we attempted to predict grammar school affiliation by major (general versus sports), logistic regression always excluded all observed variables.

Predicting gender yielded more interesting results. We used a logistic regression model calculation in which gender was predicted and IPAQ, BPS, SSS subscales, and each

LSI type were entered as covariates. The resulting model shows a poor model fit of the characteristics (AIC = 608, BIC = 642, $\Delta X^2 = 1.116$, $p < 0.204$), with a model learning rate of approximately 10 % (McFadden $R^2 = 0.067$, Nagelke $R^2 = 0.116$). As expected (see t-test results above), the computational algorithm included IPAQ as the strongest predictor, SSS_ES and LSI_Persistence and LSI_Location change; LSI_Food drink consumption, LSI_Intrinsic motivation and BPS were also included in the model. The values of the variables in the model suggest that if the results show a combination of increased SSS_ES, BPS, LSI_Food drink consumption and decreased IPAQ, LSI_Location change, LSI_Persistence and LSI_Intrinsic motivation, there is an increased likelihood of being a female student.

Table 3. Prediction of gender: logistic regression (n = 476)

Parameter	Estimate	Standard Error	Z	Wald Statistic	p
(Intercept)	-2.116	1.236	-1.713	2.934	0.087
IPAQ	0.000	0.000	3.164	10.011	0.002
SSS_ES	-0.156	0.057	-2.741	7.514	0.006
BPS_Summa	-0.054	0.025	-2.194	4.813	0.028
LSI_LocationChange	0.149	0.058	2.582	6.668	0.010
LSI_FoodDrinkCons	-0.083	0.030	-2.741	7.511	0.006
LSI_Persistence	0.265	0.106	2.488	6.188	0.013
LSI_Int.Motivation	0.176	0.071	2.494	6.221	0.013

Due to the notable behavior of the variable grade (year of study), we created a linear regression model to predict it using IPAQ, BPS, SSS subscales, and various LSI types as covariates. The model was statistically significant but showed

Table 4. Prediction of grade: linear regression (n = 476)

Model / Items	Unstandard	SE	Standard	T	P	Lower	Upper
(Intercept)	2.953	0.220		13.451	< 0.001	2.522	3.385
IPAQ	-2.164 ^{e-5}	4.398 ^{e-6}	-0.205	-4.921	< 0.001	-3.029 ^{e-5}	-1.300 ^{e-5}
BPS_Summa	-0.02	0.01	-0.10	-2.37	0.02	-0.04	-0.00
SSS_ES	-0.07	0.02	-0.14	-3.38	< 0.001	-0.10	-0.03
LSI_Persistence	0.10	0.03	0.12	2.90	0.00	0.03	0.16
LSI_FoodDrinkCons.	-0.03	0.01	-0.13	-2.85	0.01	-0.05	-0.01
LSI_SilencePrefer.	0.08	0.03	0.14	3.06	0.00	0.03	0.13
LSI_TactileLearning	-0.06	0.01	-0.26	-5.63	< 0.001	-0.09	-0.04
LSI_Learn.W.Friends	0.06	0.03	0.08	1.90	0.06	-0.00	0.11

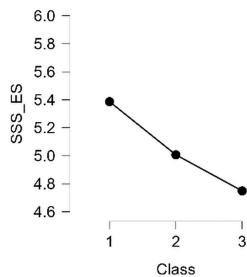


Fig. 1. Grade and SSS_ES

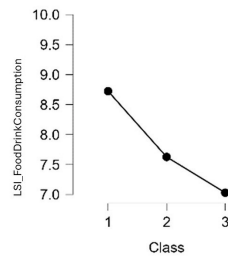


Fig. 2. Grade and LSI_Food drink consumption

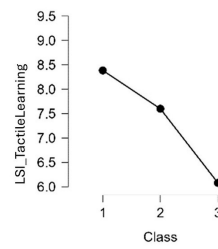


Fig. 3. Grade and LSI_Tactile learning

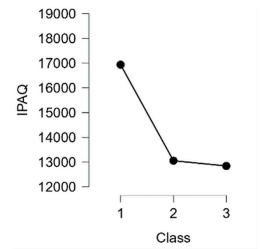


Fig. 4. Grade and IPAQ

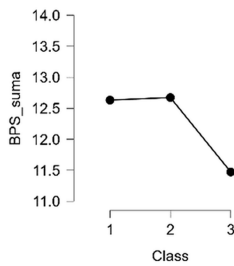


Fig. 5. Grade and BPS

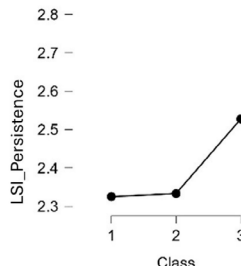


Fig. 6. Grade and LSI_Persistence

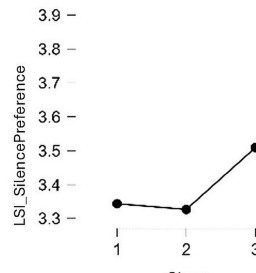


Fig. 7. Grade and LSI_Silence preference

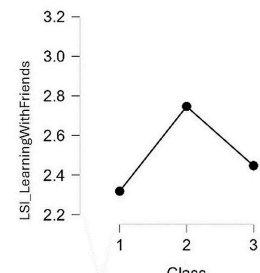


Fig. 8. Grade and LSI_Learning with friends

weak fit ($R=0.444$, $R^2=0.197$, adj. $R^2=0.183$, $RMSE=0.749$), explaining nearly 20% of variance. Predictors included IPAQ, BPS, SSS_ES, LSI_Food and Drink Consumption, LSI_Tactile Learning, as well as LSI_Persistence, LSI_Silence Preference, and LSI_Learning with Friends. Despite modest model fit, the identified relationships were meaningful and worth presenting.

The table shows that higher grade levels (i.e., older students) are predicted by lower scores in IPAQ, BPS, SSS_ES, LSI_Food and Drink Consumption, and LSI_Tactile Learning, along with higher scores in LSI_Persistence (indicating lower persistence), LSI_Silence Preference, and LSI_Learning with Friends.

The graphs show an example of how SSS_ES, LSI_Food drink consumption, and LSI_Tactile learning decrease with grade.

Discussion

The expected close association between BPS and SSS-V was not confirmed. Similarly, no significant differences were

found in SSS-V scores between sports and general grammar school students, consistent with Böselmann et al. (2021). However, some variations emerged, discussed below:

Higher levels of physical activity (IPAQ) correlated with lower boredom proneness (BPS) and higher thrill seeking (SSS_ES), supporting previous findings linking PA to lower boredom and negative emotional states (Böselmann et al., 2021, Furlong et. al. 2021). As PA tends to decline with age, this may increase the risk of boredom and reduced motivation. Schools should thus prioritize maintaining PA to counteract boredom and sustain motivation.

The tendency to seek new sensory experiences (SSS_ES) was more common among female students, while male students boys showed lower persistence and a higher preference for silence and movement. A higher tendency towards boredom (BPS) was linked to lower motivation and a preference for experiential learning (LSI_Experiential Learning), consistent with the idea that boredom can motivate students to seek novelty (Elpidorou, 2014, 2015). This aligns with Culková's (2015), recommendation to incorporate experiential learning opportunities, particularly for students high in SST.

With age, PA, intrinsic motivation, and preference for experiential and tactile learning (LSI_Tactile Learning) decreased. Older students reported higher boredom and preferred quiet or social learning environments, suggesting a shift from sensory-based to more traditional strategies (Elpidorou, 2015). Tailoring teaching methods to age and individual needs is therefore crucial (Culková, 2017).

Male students in general grammar schools showed higher PA but lower persistence, while female students showed a higher preference for sensory experiences (SSS_ES) and greater persistence. This aligns with previous research indicating sex-based differences in boredom proneness and learning styles (Bench & Lench, 2013). Addressing both sex and age differences in teaching methods may enhance motivation and engagement.

The study also found that learning with friends was linked to greater persistence, highlighting the importance of social connections in motivation (Bench & Lench, 2013). Social ties can enhance the meaningfulness of learning, supporting engagement and reducing boredom.

Overall, this study highlights the interplay between physical activity, boredom, and sensation seeking in shaping students' learning. The absence of significant differences between types of grammar schools suggests SST is influenced more by individual factors (Elpidorou, 2015). The link between physical activity and lower boredom (Bösselmann et al., 2021; Furlong et al., 2021) underscores the value of promoting physical activity to enhance engagement.

The relationship between SST, boredom, and learning preferences aligns with theories that see boredom as a motivator for seeking novelty and meaningful experiences (Elpidorou, 2014, 2015; Eastwood et al., 2012). Observed variations across age and gender groups highlight the need for teaching approaches that consider individual and developmental differences (Culková, 2015, 2017). Together, these findings stress the importance of fostering engaging learning environments that address boredom and SST to support students' educational experiences.

Limitations and Practical Directions

This study has limitations. It relies on self-reports, which may introduce bias, and its cross-sectional design limits causal conclusions. The sample, drawn from Czech grammar schools, may restrict generalizability. Future research should use longitudinal designs, include diverse educational and cultural contexts, and integrate qualitative data to better understand how students experience boredom and sensation seeking in learning.

Conclusions

This study provides a psychological perspective on how physical activity, boredom, and sensation seeking influence learning styles among Czech high school students. The findings indicate that gender, age, and physical activity significantly affect motivation and engagement. Older students tend to report lower physical activity, reduced intrinsic motivation, and greater boredom proneness, highlighting the need for age-specific strategies to sustain engagement. Students with high sensation seeking benefit from experiential and movement-based learning, while

differentiated teaching that respects individual preferences can enhance learning outcomes. Integrating physical activity into academic settings, fostering collaboration among educators, and addressing socio-psychological factors can support student well-being and motivation. Future research should explore culturally responsive, tailored educational strategies that address boredom, support social integration, and promote lasting academic engagement.

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Conflict of Interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- Furlong, M., Smith, D., Springer, T., & Dowdy, E. (2021). Bored with school! Bored with life? Well-being characteristics associated with a school boredom mindset. *Journal of Positive School Psychology*, 5, 42-64. <https://doi.org/10.47602/jpsp.v5i1.261>
- Csikszentmihalyi, M. (2000). Beyond boredom and anxiety. Jossey-bass.
- Fahlman, S. A., Mercer-Lynn, K. B., Flora, D. B., & Eastwood, J. D. (2013). Development and Validation of the Multidimensional State Boredom Scale. *Assessment*, 20(1), 68-85. <https://doi.org/10.1177/1073191111421303>
- Mikulas, W. L., & Vodanovich, S. J. (1993). The essence of boredom. *Psychological Record*, 43(1), 3-12.
- Todman, M. (2003). Boredom and Psychotic Disorders: Cognitive and Motivational Issues. *Psychiatry: Interpersonal and Biological Processes*, 66(2), 146-167. <https://doi.org/10.1521/psyc.66.2.146.20623>
- Van Tilburg, W. A. P., & Igou, E. R. (2012). On boredom: Lack of challenge and meaning as distinct boredom experiences. *Motivation and Emotion*, 36(2), 181-194. <https://doi.org/10.1007/s11031-011-9234-9>
- Danckert, J., & Merrifield, C. (2018). Boredom, sustained attention and the default mode network. *Experimental Brain Research*, 236(9), 2507-2518. <https://doi.org/10.1007/s00221-016-4617-5>
- Eastwood, J. D., Frischen, A., Fenske, M. J., & Smilek, D. (2012). The Unengaged Mind: Defining Boredom in Terms of Attention. *Perspectives on Psychological Science*, 7(5), 482-495. <https://doi.org/10.1177/1745691612456044>
- Harris, M. B. (2000). Correlates and Characteristics of Boredom Proneness and Boredom. *Journal of Applied Social Psychology*, 30(3), 576-598. <https://doi.org/10.1111/j.1559-1816.2000.tb02497.x>
- Hartl, P., Hartlová-Císařová, H., & Nepřaš, K. (2010). *Velký psychologický slovník* (Vyd. 4., V Portálu 1). Portál.
- Wallace, J. C., Vodanovich, S. J., & Restino, B. M. (2003). Predicting cognitive failures from boredom proneness and daytime sleepiness scores: An investigation within military and undergraduate samples. *Personality and*

- Individual Differences*, 34(4), 635-644.
[https://doi.org/10.1016/S0191-8869\(02\)00050-8](https://doi.org/10.1016/S0191-8869(02)00050-8)
[https://doi.org/10.1016/S0191-8869\(02\)00050-8](https://doi.org/10.1016/S0191-8869(02)00050-8)
- Belton, T., & Priyadarshini, E. (2007). Boredom and schooling: A cross-disciplinary exploration. *Cambridge Journal of Education*, 37(4), 579-595.
<https://doi.org/10.1080/03057640701706227>
- Gasper, K., & Middlewood, B. L. (2014). Approaching novel thoughts: Understanding why elation and boredom promote associative thought more than distress and relaxation. *Journal of Experimental Social Psychology*, 52, 50-57. <https://doi.org/10.1016/j.jesp.2013.12.007>
- Mann, S., & Cadman, R. (2014). Does Being Bored Make Us More Creative? *Creativity Research Journal*, 26(2), 165-173. <https://doi.org/10.1080/10400419.2014.901073>
- Elpidorou, A. (2014). The bright side of boredom. *Frontiers in Psychology*, 5. <https://doi.org/10.3389/fpsyg.2014.01245>
- Elpidorou, A. (2015). *The quiet alarm* [Blog]. Aeon. <https://aeon.co/essays/life-without-boredom-would-be-a-nightmare>
- Elpidorou, A. (2018). The good of boredom. *Philosophical Psychology*, 31(3), 323-351.
<https://doi.org/10.1080/09515089.2017.1346240>
- Bench, S., & Lench, H. (2013). On the Function of Boredom. *Behavioral Sciences*, 3(3), 459-472.
<https://doi.org/10.3390/bs3030459>
- Smith, J. L., Wagaman, J., & Handley, I. M. (2009). Keeping it dull or making it fun: Task variation as a function of promotion versus prevention focus. *Motivation and Emotion*, 33(2), 150-160.
<https://doi.org/10.1007/s11031-008-9118-9>
- Van Tilburg, W. A. P., & Igou, E. R. (2011). On Boredom and Social Identity: A Pragmatic Meaning-Regulation Approach. *Personality and Social Psychology Bulletin*, 37(12), 1679-1691.
<https://doi.org/10.1177/0146167211418530>
- Zuckerman, M. (1978). *Sensation seeking*. In H. London & J. Exner E. (Eds.), *Dimensions of Personality* (pp. 487-559). Wiley.
- Zuckerman, M. (1994). *Behavioral Expressions and Biosocial Bases of Sensation Seeking*. Cambridge University Press.
- Zuckerman, M. (2001). *Personality and Risk Taking*. Tenth Biennial Meeting of the International Society for the Study of Individual Differences, The University of Edinburgh.
- Neary, R. S., & Zuckerman, M. (1976). Sensation Seeking, Trait and State Anxiety, and the Electrodermal Orienting Response. *Psychophysiology*, 13(3), 205-211.
<https://doi.org/10.1111/j.1469-8986.1976.tb00098.x>
- Psychology Today Staff. (2004). Cupid's Comeuppance Playful Cupid may have met his match in science. PT explores infatuation from neurochemicals to novelty. *Psychology Today*. <https://www.psychologytoday.com/intl/articles/200409/cupids-comeuppance>
- Zuckerman, M. (2005). *Psychobiology of Personality: Problems in the Behavioural Sciences*. Cambridge University Press.
- Eysenck, H. J. (1983). A biometrical-genetical analysis of impulsive and sensation seeking behavior. In M. Zuckerman (Ed.), *Biological bases of sensation seeking, impulsivity, and anxiety* (pp. 1-27). Erlbaum.
- Fulker, D. W., Eysenck, S. B. G., & Zuckerman, M. (1980). A genetic and environmental analysis of sensation seeking. *Journal of Research in Personality*, 14(2), 261-281.
[https://doi.org/10.1016/0092-6566\(80\)90033-1](https://doi.org/10.1016/0092-6566(80)90033-1)
[https://doi.org/10.1016/0092-6566\(80\)90033-1](https://doi.org/10.1016/0092-6566(80)90033-1)
- Hur, Y.-M., & Bouchard, Jr., T. J. (1997). The genetic correlation between impulsivity and sensation seeking traits. *Behavior Genetics*, 27(5), 455-463.
<https://doi.org/10.1023/A:1025674417078>
- Koopmans, J. R., Boomsma, D. I., Heath, A. C., & Van Doornen, L. J. P. (1995). A multivariate genetic analysis of sensation seeking. *Behavior Genetics*, 25(4), 349-356.
<https://doi.org/10.1007/BF02197284>
- Feij, J. A., & Taris, T. W. (2010). Beyond the genetic basis of sensation seeking: The influence of birth order, family size and parenting styles. *Romanian Journal of Applied Psychology*, 12(2), 54-61.
- Henry, B., & Moffitt, T. E. (1997). *Neuropsychological and neuroimaging studies on juvenile delinquency and adult criminal behavior*. In *Handbook of Antisocial Behavior* (pp. 280-288). Wiley and Sons, Inc.
- Galloway, G., & Lopez, K. (1999). Sensation seeking and attitudes to aspects of national parks: A preliminary empirical investigation. *Tourism Management*, 20(6), 665-671. [https://doi.org/10.1016/S0261-5177\(99\)00031-X](https://doi.org/10.1016/S0261-5177(99)00031-X)
- Zuckerman, M., & Link, K. (1968). Construct validity for the Sensation-Seeking Scale. *Journal of Consulting and Clinical Psychology*, 32(4), 420-426.
<https://doi.org/10.1037/h0026047>
- Muris, P. (2009). Fear and Courage in Children: Two Sides of the Same Coin? *Journal of Child and Family Studies*, 18(4), 486-490. <https://doi.org/10.1007/s10826-009-9271-0>
- Harden, K. P., Quinn, P. D., & Tucker-Drob, E. M. (2012). Genetically influenced change in sensation seeking drives the rise of delinquent behavior during adolescence. *Developmental Science*, 15(1), 150-163.
<https://doi.org/10.1111/j.1467-7687.2011.01115.x>
- Zuckerman, M. (1979). *Sensation Seeking: Beyond the Optimal Level of Arousal*. Lawrence Erlbaum.
- Potgieter, J., & Bisschoff, F. (1990). Sensation Seeking among Medium- and Low-Risk Sports Participants. *Perceptual and Motor Skills*, 71(3_suppl), 1203-1206.
<https://doi.org/10.2466/pms.1990.71.3f.1203>
- Schroth, M. L. (1995). A comparison of sensation seeking among different groups of athletes and nonathletes. *Personality and Individual Differences*, 18(2), 219-222.
[https://doi.org/10.1016/0191-8869\(94\)00144-H](https://doi.org/10.1016/0191-8869(94)00144-H)
[https://doi.org/10.1016/0191-8869\(94\)00144-H](https://doi.org/10.1016/0191-8869(94)00144-H)
- Kuban, J. (2006). *Tendence k vyhledávání prožitku a její diagnostika*. Gaudeamus.
- Franken, R. E., Hill, R., & Kierstead, J. (1994). Sport interest as predicted by the personality measures of competitiveness, mastery, instrumentality, expressivity, and sensation seeking. *Personality and Individual Differences*, 17(4), 467-476. [https://doi.org/10.1016/0191-8869\(94\)90084-1](https://doi.org/10.1016/0191-8869(94)90084-1)
[https://doi.org/10.1016/0191-8869\(94\)90084-1](https://doi.org/10.1016/0191-8869(94)90084-1)
- Jack, S. J., & Ronan, K. R. (1998). Sensation seeking among high- and low-risk sports participants. *Personality and Individual Differences*, 25(6), 1063-1083.
[https://doi.org/10.1016/S0191-8869\(98\)00081-6](https://doi.org/10.1016/S0191-8869(98)00081-6)
- Bösselmann, V., Amatriain-Fernández, S., Gronwald, T., Murillo-Rodríguez, E., Machado, S., & Budde, H. (2021). Physical Activity, Boredom and Fear of COVID-19

- Among Adolescents in Germany. *Frontiers in Psychology*, 12, 624206. <https://doi.org/10.3389/fpsyg.2021.624206>
- Průcha, J., Walterová, E., & Mareš, J. (2009). *Pedagogický slovník* (6.). Portál.
- Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is Stronger than Good. *Review of General Psychology*, 5(4), 323-370. <https://doi.org/10.1037/1089-2680.5.4.323>
- Diener, E., & Seligman, M. E. P. (2002). Very Happy People. *Psychological Science*, 13(1), 81-84. <https://doi.org/10.1111/1467-9280.00415>
- Dunn, R. (2000). Learning styles: Theory, research, and practice. *National Forum of Applied Educational Research Journal*, 13(1), 3-22.
- Dunn, Rita, Dunn, Kenneth, & Price, Gary E. (1989). *Learning Style Inventory*. Price Systems.
- Culková, D. (2017). The Sensation Seeking Tendency and Learning Style of Grammar School Students with Extended Physical Education and Sports Training. *The New Educational Review*, 50(4), 199-214. <https://doi.org/10.15804/ner.2017.50.4.16>
- Culková, D. (2013). Vyhledávání mimořádných prožitků a preference učebního stylu studenta. *Pedagogická Orientace*, 23(3), 364-385. <https://doi.org/10.5817/PedOr2013-3-364>
- Farmer, R., & Sundberg, N. D. (1986). Boredom Proneness—The Development and Correlates of a New Scale. *Journal of Personality Assessment*, 50(1), 4-17. https://doi.org/10.1207/s15327752jpa5001_2
- Mareš, J., & Skalská, H. (1994). LSI – dotazník stylů učení pro žáky základních a středních škol. *Psychológia a patopsychológia dieťaťa (název časopisu)*, 29(3), 248-264.
- Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J. F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc*, 35(8), 1381-1395. PubMed. <https://doi.org/10.1249/01.mss.0000078924.61453.fb>
- Hagströmer, M., Bergman, P., De Bourdeaudhuij, I., Ortega, F. B., Ruiz, J. R., Manios, Y., Rey-López, J. P., Philipp, K., von Berlepsch, J., Sjöström, M., & on behalf of the HELENA Study Group. (2008). Concurrent validity of a modified version of the International Physical Activity Questionnaire (IPAQ-A) in European adolescents: The HELENA Study. *International Journal of Obesity*, 32(5), S42-S48. <https://doi.org/10.1038/ijo.2008.182>
- Bösselmann, V., Amatriain-Fernández, S., Gronwald, T., Murillo-Rodríguez, E., Machado, S., & Budde, H. (2021). Physical Activity, Boredom and Fear of COVID-19 Among Adolescents in Germany. *Frontiers in Psychology*, 12, 624206. <https://doi.org/10.3389/fpsyg.2021.624206>
- Culková, D. (2015). Sensation Seeking Tendency as a Learning Influence Factor. *E-Pedagogium*, 15(3), 116-130. <https://doi.org/10.5507/epd.2015.039>

Роль фізичної активності, пошуку відчуттів та нудьги у формуванні стилів навчання підлітків

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 4 табл., 8 рис., 61 джерело.

Мета дослідження. Мета цього дослідження полягала у вивченні взаємозв'язку між фізичною активністю, схильністю до нудьги, пошуком відчуттів та стилями навчання серед учнів старших класів у Чеській Республіці.

Матеріали та методи. У дослідженні взяли участь 476 учнів віком 15–18 років (292 дівчини та 184 хлопці), які навчаються в загальноосвітніх та спортивних гімназіях. Для визначення рівня нудьги («Шкала схильності до нудьги»), пошуку відчуттів («Шкала пошуку відчуттів V»), стилів навчання («Тест на визначення стилів навчання») та рівнів фізичної активності («Міжнародний опитувальник фізичної активності») використовувалися стандартизовані інструменти. У дослідженні застосовувалися непараметричні тести, кореляційний аналіз та регресійне моделювання.

Результати. Результати засвідчили, що учні старшого віку відзначали нижчий рівень фізичної активності, більшу схильність до нудьги та знижену внутрішню мотивацію. Хлопці в загальноосвітніх гімназіях продемонстрували вищий рівень фізичної активності та надання переваги тиші та рухливості під час навчання, але нижчу наполегливість у порівнянні зі своїми однолітками. Дівчата в загальноосвітніх гімназіях виявляли сильнішу схильність до пошуку нових сенсорних досвідів. Слабкі взаємозв'язки спостерігалися між пошуком відчуттів, наполегливістю та перевагами соціального навчання. Регресійні моделі помірно передбачали вік та стать учнів на основі психологічних та поведінкових змінних.

Висновки. Результати дослідження показали, що такі чинники, як вік, стать та фізична активність, суттєво впливають на навчальні уподобання та мотивацію підлітків. Впровадження диференційованих стратегій викладання та емпіричного навчання, заснованого на руховій активності, сприятиме підвищенню залученості, особливо в учнів, схильних до нудьги або пошуку відчуттів.

Ключові слова: середня освіта, психологічні фактори, залученість до шкільного середовища, благополуччя учнів, індивідуальні відмінності.

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Neuromotor Intervention on Executive Functions in Early Childhood: A Randomized Controlled Trial of the BAPNE Method

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Abstract

Objectives. The study aimed to investigate the causal effect of a seven-month neuromotor intervention, the BAPNE method, on the core executive functions (EFs) of preschool-aged children, compared to a traditional music education program.

Materials and Methods. A randomized controlled trial with a pre-test/post-test design was conducted with a sample of 82 four-year-old children ($n = 82$; 41 in the experimental group, 41 in the active control group) in Caracas, Venezuela. The experimental group received the BAPNE intervention, while the control group underwent traditional music instruction. EFs were assessed through teacher ratings on the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P). Data were analyzed using Analysis of Covariance (ANCOVA), with pre-test scores as a covariate to control for initial differences.

Results. After controlling for baseline performance, the BAPNE group demonstrated statistically significant improvements, with large effect sizes, on all primary outcome measures compared to the control group. This includes the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), the Emergent Metacognition Index (EMI), and the Global Executive Composite (GEC) (all $p < .001$).

Conclusions. The findings provide strong evidence that the BAPNE method, grounded in the principles of neuromotoricity and cognitive stimulation through dual-tasking, is a highly effective intervention for enhancing the expression of executive functions in the everyday context of early childhood.

Keywords: executive functions, neuromotoricity, BAPNE method, body percussion, early childhood, randomized controlled trial, inhibitory control, working memory, cognitive flexibility.

Introduction

Executive functions (EFs) represent a set of high-level, top-down cognitive processes that orchestrate and direct thought, emotion, and behavior toward goal attainment (Anderson, 2002; Zelazo & Müller, 2002). This multifaceted construct, which encompasses skills such as inhibitory control, working memory, and cognitive flexibility, is universally recognized as a fundamental pillar for human development and success throughout the lifespan (Goldstein & Naglieri, 2014). Scientific evidence accumulated over the last few decades has unequivocally established that the preschool years, approximately between three and five years of age, constitute a time window of exceptional importance

for the development of these functions (Best & Miller, 2010; Blair, 2016; Garon et al., 2008). During this period, the child's brain is characterized by extraordinary synaptic plasticity and structural malleability, particularly in the prefrontal cortex and its extensive networks connecting to other brain regions, making it especially receptive to environmental influences (Diamond, 2013a, 2013b). The robustness of EFs in early childhood is not merely an indicator of cognitive maturity (Goldstein & Naglieri, 2014); it is a potent predictor of a wide range of future outcomes. Longitudinal research has shown that children with well-developed EFs at the start of their schooling exhibit greater academic readiness, achieve higher performance in reading and mathematics, and display better social and emotional adaptation in the classroom (Bowmer et al., 2018; Espy et al., 2004; Rus et al., 2024; Habibi et al., 2018). Conversely, early deficits in EFs are associated with a higher risk of learning difficulties, behavioral problems, and neurodevelopmental disorders. This reality underscores the

urgent need to identify and implement evidence-based early interventions that can strengthen these critical capacities at a time when the potential for change is greatest.

The recognition of this window of plasticity has spurred research into the role of environmental enrichment in optimizing neurodevelopmental trajectories. Far from being a purely deterministic and genetic process, the development of EFs is profoundly shaped by the quality and structure of a child's experiences (Wollesen et al., 2022). Structured and enriching activities that systematically and engagingly challenge the child act as catalysts for the formation and strengthening of the neural circuits that support self-control and goal-directed thinking. In this context, music education and movement-based activities have emerged as tools of extraordinary potential. Beyond their artistic and cultural benefits, active participation in music and dance demands the integration of attentional, mnemonic, motor, and sequencing processes, making them ecologically valid and highly motivating platforms for cognitive training (Bugos et al., 2017; Oberer et al., 2018).

The BAPNE Method as a specific neuromotor intervention

Within the spectrum of interventions based on music and movement, the BAPNE method (Biomechanics, Anatomy, Psychology, Neuroscience, and Ethnomusicology) is distinguished by its solid theoretical framework and its explicit focus on cognitive stimulation. Developed by PhD. Francisco Javier Romero Naranjo, BAPNE is not conceived as a mere music pedagogy, but as a neuromotor intervention program designed to enhance EFs through a central mechanism: the systematic application of dual-task paradigms (Mas-Mas et al., 2023; Wollesen et al., 2022). Unlike traditional approaches that often teach motor and cognitive skills sequentially, the BAPNE method demands the simultaneous and coordinated execution of motor tasks (body percussion, movement), rhythmic tasks (complex metric patterns), and cognitive tasks (spoken, sung, or recited language). This concurrent demand imposes a significant load on the central executive system, forcing it to manage, prioritize, and coordinate multiple streams of information efficiently. This fundamental characteristic theoretically positions the BAPNE method as a potentially more potent intervention for EF training than more general enrichment programs.

Problem statement and research objectives

Despite the theoretical robustness of the BAPNE method and a growing body of research supporting its benefits in various populations, there is a notable lack of rigorous experimental evidence demonstrating its causal impact on EFs in very young children. Most studies on music and cognition in preschoolers are correlational or lack adequate active control groups, limiting the ability to establish a cause-and-effect relationship. To address this gap, the present study was designed as a randomized controlled trial with the primary objective of determining whether a seven-month intervention with the BAPNE method produces superior improvements in executive functions, as evaluated by teachers in the natural classroom environment, in four-year-old Venezuelan children, compared to an active control group participating in a high-quality traditional music education program with the test BRIEF-P (Sherman & Brooks, 2010).

Hypotheses

Based on the theoretical framework presented, the following *a priori* hypotheses were formulated:

1. Does a seven-month neuromotor intervention based on the BAPNE method and characterized by neuromotricity (Bapne method) produce a causal effect on the improvement of global executive functions in four-year-old children that is superior to that of a high-quality traditional music education program?
2. Does the differential impact of the BAPNE intervention manifest itself specifically and significantly in the core components of executive functions, namely inhibitory self-control, cognitive flexibility, and emerging metacognition, compared to the active control group?
3. Is the magnitude of the effect of the BAPNE intervention on executive functions, as assessed through teacher observations in an ecological classroom setting, large enough to have significant practical and educational relevance?

Research Objectives

To answer the questions posed, the following objectives are proposed:

1. Determine the causal effect of the BAPNE neuromotor intervention on global executive function (as measured by the BRIEF-P Global Executive Composite) in preschoolers, compared to an active control group receiving traditional music instruction (flute, school orchestra).
2. Analyze the specific impact of the BAPNE intervention on the three primary indices of executive functions of the BRIEF-P: the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), and the Emerging Metacognition Index (EMI), to discern the effects of the program on different facets of executive control.
3. Quantify the effect size of the BAPNE intervention on each of the BRIEF-P scales and indices to establish the practical significance of the differences observed between the experimental and control groups, beyond mere statistical significance.

Operating Hypotheses

Based on the theoretical framework of neuromotricity, which posits that the cognitive load imposed by dual-tasking is the primary driver of neuroplastic change, the following *a priori* hypotheses were formulated. The primary inter-subject hypotheses are designed to be tested via one-way Analysis of Covariance (ANCOVA), with post-intervention scores as the dependent variable and pre-intervention scores as the covariate. Hypotheses are presented in null (H0) and alternative (Ha) form.

Inter-Subject Hypotheses (Between-Groups Analysis)

Hypothesis 1. Global executive composite (GEC)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Global

Executive Composite (GEC) between the experimental (BAPNE) and active control (Traditional Music) groups.

Ha: The experimental (BAPNE) group will exhibit a statistically significant lower adjusted post-intervention mean score on the GEC, indicating superior global executive functioning, compared to the active control group.

Hypothesis 2. Inhibitory self-control index (ISCI)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Inhibitory Self-Control Index (ISCI) between the experimental and active control groups.

Ha: The experimental group will exhibit a statistically significant lower adjusted post-intervention mean score on the ISCI, indicating superior inhibitory control, compared to the active control group.

Hypothesis 3. Flexibility index (FI)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Flexibility Index (FI) between the experimental and active control groups.

Ha: The experimental group will exhibit a statistically significant lower adjusted post-intervention mean score on the FI, indicating superior cognitive flexibility, compared to the active control group.

Hypothesis 4. Emergent metacognition index (EMI)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Emergent Metacognition Index (EMI) between the experimental and active control groups.

Ha: The experimental group will exhibit a statistically significant lower adjusted post-intervention mean score on the EMI, indicating superior emergent metacognition, compared to the active control group.

Intra-Subject Hypotheses (Within-Group Analysis)

To characterize the developmental trajectories within each condition, the following secondary, intra-subject hypotheses were proposed:

Hypothesis 5. Change within the BAPNE group

H0: There will be no statistically significant change in mean scores on the BRIEF-P indices from pre- to post-intervention within the experimental (BAPNE) group.

Ha: The experimental (BAPNE) group will demonstrate a statistically significant reduction in mean scores from pre- to post-intervention across all primary BRIEF-P indices, reflecting a robust improvement in executive functions attributable to the intervention.

Hypothesis 6. Change within the active control group

H0: There will be no statistically significant change in mean scores on the BRIEF-P indices from pre- to post-intervention within the active control (Traditional Music) group.

Ha: The active control (Traditional Music) group will demonstrate either no statistically significant change or a significantly smaller reduction in mean scores from pre- to post-intervention, reflecting effects attributable primarily to maturation and non-specific program participation rather than targeted EF training.

Executive functions as the basis for this study.

Executive functions are not a monolithic construct, but a system of interrelated processes that mature at different rates.

Research in developmental neuroscience has converged on the identification of three core components that form the basis of more complex EFs like planning and problem-solving. These three pillars are (Miyake et al, 2000, 2012):

Inhibitory Control: This function is the fundamental ability to deliberately suppress dominant, prepotent, or automatic responses, and to resist interference from irrelevant or distracting stimuli. It includes both the inhibition of motor responses (e.g., waiting for one's turn to speak) and attentional control (e.g., ignoring a noise in the hallway to focus on a task). In the preschool years, the development of inhibitory control is visible in the child's growing ability to follow rules, control impulses, and regulate emotions.

Working Memory: This refers to the ability to actively hold and manipulate a limited amount of information in the mind for a short period to guide behavior. It is not simple passive storage, but a dynamic mental workspace that allows, for example, following a multi-step instruction, remembering the beginning of a sentence to understand its end, or performing simple mental calculations. Its development in preschoolers is crucial for language learning and early mathematical concepts.

Cognitive Flexibility (or Set-Shifting): This is the ability to change perspectives, adapt to new rules or demands, and think flexibly to respond to changes in the environment. It allows a child to abandon a strategy that is not working and try a new one, see a problem from different angles, and adjust their behavior to changing social contexts. Cognitive flexibility is the basis of creativity and adaptability.

It is important to note that, although these three components are theoretically dissociable, in early childhood (between 3 and 5 years) their functioning is highly intercorrelated. Factor analysis studies often reveal a more unitary structure of EFs at this stage, where performance on an inhibition task is strongly related to performance on a working memory task. This relative undifferentiation justifies the use of assessment instruments like the BRIEF-P, which, while having specific scales, also provides a Global Executive Composite (GEC) that captures this shared variance and offers a comprehensive measure of the child's executive functioning in daily life.

From psychomotricity to neuromotricity.

To understand the proposed mechanism of action for the BAPNE method, it is essential to draw a clear conceptual distinction between traditional approaches to movement and the paradigm of neuromotricity. The specialized literature, led by Romero-Naranjo and Andreu-Cabrera (Andreu-Cabrera & Romero-Naranjo, 2021; Romero-Naranjo et al., 2024), proposes a terminological and conceptual evolution that reflects a deeper understanding of the mind-body interaction:

Motricity: Refers to the ability to execute voluntary and coordinated body movements, such as walking, running, or jumping. It is the observable result of the activation of the motor system.

Psychomotricity: A broader concept that integrates the interactions between cognitive, emotional, symbolic, and sensorimotor aspects. Psychomotricity considers movement as a form of expression and relationship of the individual with their psychosocial environment.

Neuromotricity: This term represents the most advanced paradigm, defined as an educational and neurorehabilitative process that uses movement as a vehicle for direct cognitive stimulation, with an explicit emphasis on executive functions. Its distinctive feature is the systematic incorporation of the dual-task (Mas-Mas et al., 2023). as a fundamental pedagogical tool. A practical and accurate example of neuromotor activity is the “talking cube” (Il cubo parlante) activities of the Bapne method, which contains all the parameters required by neuromotricity.

The theoretical framework of neuromotricity posits that the brain is not optimally trained when tasks are performed in isolation or sequentially. True cognitive enhancement occurs when the central nervous system is forced to manage multiple demands simultaneously. This principle is embodied in the dual-task paradigm, which in the context of the BAPNE method is classified into several types, the most relevant for this research being Rhythmic/Motor/Cognitive. The activity “the talking cube” (Il cubo parlante) requires all of these parameters.

The functioning of this paradigm can be conceived as a form of “cognitive weightlifting.” While traditional music education might teach a rhythm with the hands (motor task) and then ask the child to recite it (cognitive task), the BAPNE method demands, for example, that the child execute a rhythmic pattern with their feet, another different and dissociated pattern with their hands, and simultaneously sing a song or recite a numerical sequence. This controlled and concurrent overload of the motor, auditory, visual, and linguistic systems places an exceptionally high demand on executive functions. The brain must inhibit automatic movements, hold multiple patterns in working memory, flexibly switch between the rules for each limb, and monitor overall performance to correct errors in real-time.

This constant and structured demand is what, hypothetically, drives neuroplasticity. The repeated practice of dual tasks promotes the automation of motor sequences, which in turn frees up cognitive resources that can be reallocated to higher-level tasks. This process strengthens the connections between the prefrontal cortex (the seat of EFs) and other key structures such as the basal ganglia (involved in motor learning and the automation of routines) and the cerebellum (crucial for coordination and timing). Therefore, the BAPNE method not only teaches music or movement; it uses these modalities as a means to directly train the brain’s mechanisms of cognitive control.

The BAPNE method as a tool for cognitive stimulation.

The BAPNE method is an integrative pedagogical system that draws from multiple disciplines to create a holistic learning environment. Its acronym reflects this multidisciplinary foundation: Biomechanics (for movement efficiency and safety), Anatomy (for body awareness), Psychology (for motivational and socio-emotional aspects), Neuroscience (as the basis for cognitive stimulation), and Ethnomusicology (for the richness and diversity of rhythmic and cultural patterns). This methodology has more than 60 publications in Web of Science and exceeds four thousand academic citations. Its interdisciplinary nature allows it to be used with students of physical education, music, or students in general, with exclusive sessions or as an active

break activity (Alonso-Marco & Romero-Naranjo, 2022; Alonso-Sanz & Romero-Naranjo, 2015; Andreu-Cabrera & Romero-Naranjo, 2021). The BAPNE method has an official research group based at the University of Alicante (Spain), which is made up of around ninety researchers from various countries. The research group, called “Neuromotricity and Motor Literacy”, has more than two hundred scientific publications and has won several research awards.

For the present intervention, only the resources and activities from the “Bapne for Children” and “Cognitive Solfege” programs were used, which are specifically designed for the Early Childhood Education stage. These programs translate the principles of neuromotricity into playful and developmentally appropriate activities for 4-year-old children (Romero-Naranjo et al., 2024). Based on the development tables proposed by Romero-Naranjo, For this reason, the BAPNE method uses numerous resources such as ropes, hoops, wooden sticks of different sizes that are placed on the floor, cones, balls with different textures and weights, and most importantly, cubes for working in pairs called “il cubo parlante” (the talking cube).

Materials and Methods

Research Design

This study adheres to the highest standards of experimental research, employing a randomized controlled trial (RCT) design with two parallel groups (experimental and active control) and measurements at two time points (pre-test and post-test). This design is considered the gold standard for establishing causal inference, as the random assignment of participants to treatment conditions minimizes selection bias and allows observed differences in outcomes to be attributed to the intervention itself.

Participants and context

The sessions were given by BAPNE trainer Andreina Liendo Cárdenas at the Nuestra Señora del Carmen School and the BCV Early Education Center in Caracas (Venezuela). Approval was obtained from the institutional research ethics committee and the educational center before initiating any procedures. Informed consent letters were sent to the parents or legal guardians of all four-year-old children enrolled in the center. An initial total of 93 children whose parents gave their consent were recruited. Over the seven-month intervention period, there was an attrition rate of 11.8 %, with 11 participants dropping out of the study ($n = 6$ due to family relocation to another city, $n = 3$ due to prolonged illness unrelated to the intervention, and $n = 2$ due to parental decision to withdraw the child). This attrition rate is considered low and acceptable for longitudinal studies in this population.

The final sample for statistical analysis consisted of 82 children ($N = 82$) with a mean age of 4.52 years ($SD = 0.28$). The gender distribution showed a slight majority of girls, with 45 female participants (54.9%) and 37 male participants (45.1%). Participants were randomly assigned, using a numerical sequence generator by an independent statistician, to the BAPNE experimental group ($n = 41$) or the traditional music control group ($n = 41$).

Instrumentation. Behavior rating inventory of executive function–preschool (BRIEF-P)

The primary dependent variable, executive functions, was measured exclusively through the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P; (Sherman & Brooks, 2010)). The BRIEF-P is a standardized and norm-referenced questionnaire designed for parents and teachers to evaluate the behavioral manifestations of EFs in children aged 2 to 5 years in their everyday environments (home and school). This tool was selected for its high ecological validity, as it captures how deficits or strengths in EFs translate into observable behaviors in the real world, rather than measuring performance on decontextualized laboratory tasks. The instrument consists of 63 items rated on a 3-point Likert scale (“Never,” “Sometimes,” “Often”), where the informant indicates the frequency with which a behavior has been a problem in the last six months. These items are grouped into five theoretically and empirically derived clinical scales:

- Inhibit (16 items): Assesses the child’s ability to control impulses and stop their behavior appropriately.
- Shift (10 items): Measures the ability to move from one situation or activity to another, make transitions, and solve problems flexibly.
- Emotional control (10 items): Assesses the ability to modulate emotional responses according to the context.
- Working memory (17 items): Evaluates the ability to hold information in mind to complete a task.
- Plan/Organize (10 items): Measures the ability to manage current and future tasks, as well as to organize their environment. These five scales are combined to form three broader indices and a global composite:
- Inhibitory self-control index (ISCI): Composed of the Inhibit and Emotional Control scales.
- Flexibility index (FI): Composed of the Shift and Emotional Control scales.
- Emergent metacognition index (EMI): Composed of the Working Memory and Plan/Organize scales.
- Global executive composite (GEC): A total score that summarizes the child’s overall executive functioning.

The choice of the BRIEF-P is further justified by its excellent psychometric properties. The original studies report high internal consistency, with Cronbach’s alpha coefficients ranging from .80 to .95 for parent samples and from .90 to .97 for teacher samples, as well as moderate to high test-retest reliability. Of particular relevance to this study is the existence of Spanish adaptations and validations of the BRIEF-P, which have confirmed its reliability and structural validity in Spanish-speaking populations, thus ensuring the cultural and linguistic appropriateness of the instrument for use in the Venezuelan context (Zelazo & Müller, 2002).

Procedure

Following the collection of consents and random assignment, the pre-test phase was conducted. The head teachers of each classroom, who had a deep knowledge of the children’s daily behavior, completed the BRIEF-P (Sherman & Brooks, 2010) questionnaire for each participant in their class. It was ensured that the teachers were blind to the group

assignment of each child and to the specific hypotheses of the study to minimize observer bias. Immediately after, the seven-month intervention period began. Both groups, experimental and control, received their respective programs with identical frequency and duration: two 50-minute sessions per week, integrated into the regular school schedule. The BAPNE group sessions were taught by certified instructors in the method (Andreina Liendo Cárdenas), while the control group sessions were led by music educators with experience in the Orff and Kodály methodologies. Periodic monitoring was carried out to ensure the fidelity of implementation in both groups (Lu et al., 2024).

At the end of the seven-month intervention, the post-test phase was conducted. The same teachers who completed the initial assessments filled out the BRIEF-P questionnaire again for each child, maintaining the blind conditions.

Data analysis strategy

All statistical analyses were performed using IBM SPSS Statistics (Version 28), JASP, and Microsoft Excel. The level of statistical significance (alpha) was set at $p < .05$ for all hypothesis tests. The analytical strategy was designed to provide the most rigorous and powerful test of the study’s hypotheses. While an analysis of gain scores (post-test minus pre-test) or a t-test on post-test scores are valid options in a randomized design, Analysis of Covariance (ANCOVA) was selected as the primary statistical procedure. The choice of ANCOVA is based on its statistical superiority in pre-test/post-test designs. By including the pre-test score as a covariate in the model, ANCOVA statistically adjusts the post-test scores based on the initial variability of the participants. This adjustment has two crucial benefits: 1) it reduces the error variance, which increases the statistical power to detect a real effect of the intervention; and 2) it controls for any small baseline differences that might exist between the groups by chance despite randomization, providing a purer and more precise estimate of the treatment effect.

Therefore, for each of the hypotheses, a one-way ANCOVA was performed. In each analysis, the post-test score of the corresponding BRIEF-P scale or index served as the dependent variable, the group assignment (BAPNE vs. Control) as the between-subjects factor (independent variable), and the pre-test score of that same scale or index as the covariate.

Before running the ANCOVAs, their statistical assumptions were checked. The normality of the residuals was assessed using the Shapiro-Wilk test, and the homogeneity of variance was assessed using Levene’s test. Critically, the assumption of homogeneity of regression slopes was checked, which posits that the relationship between the covariate (pre-test) and the dependent variable (post-test) is the same in both groups. This assumption was evaluated by examining the interaction between the group factor and the covariate in the model; a non-significant interaction ($p > .05$) confirms that the assumption is met and that ANCOVA is appropriate.

To quantify the magnitude of the intervention’s effect, two types of effect size indices were calculated. The partial eta squared (η_p^2) was reported directly from the ANCOVA results, which indicates the proportion of variance in the

dependent variable that is attributable to the group factor after controlling for the covariate. Additionally, Cohen's d was calculated for the differences between the adjusted post-test means, providing a standardized measure of the magnitude of the difference between the groups. The values of η_p^2 were interpreted as small (0.01), medium (0.06), or large (0.14), and those of Cohen's d as small (0.20), medium (0.50), or large (0.80).

Results

This section presents the quantitative findings of the study in an objective and systematic manner. The analysis focuses on the comparison between the BAPNE experimental group and the traditional music control group on the measures of executive function.

Preliminary Analyses

The flow of participants throughout the study is detailed in table 1. Of the 93 children initially recruited, 82 completed all phases of the study and were included in the final analysis ($n = 41$ per group).

Table 1. Participant Flow Through the Randomized Controlled Trial

Stage	BAPNE Group (n)	Control Group (n)	Total (N)
Assessed for eligibility			105
Excluded			12
Did not meet inclusion criteria			5
Declined to participate			7
Randomized	46	47	93
Allocated to Intervention Arm	46	47	93
Lost to follow-up	5	6	11
Reason: Family relocation	5	1	6
Reason: Prolonged illness	0	3	3
Reason: Parental decision to withdraw	0	2	2
Completed study and included in final analysis	41	41	82

Note. This table details the flow of participants from initial eligibility screening to final data analysis. The distribution of attrition reasons for the Control Group is inferred from the total attrition data provided in the text and the specific reason provided for the BAPNE group in the original study diagram.

Table 2 presents the demographic characteristics and initial BRIEF-P scores. No statistically significant differences were found between the BAPNE group and the Control group in terms of mean age, $t_{(80)} = 0.45$, $p = .653$, or gender distribution, $\chi^2_{(1, N=82)} = 0.05$, $p = .823$. Crucially, independent samples t -tests confirmed that there were no significant differences in any of the BRIEF-P scales or indices at the pre-test measurement (all $p > .05$), demonstrating the success of the randomization process in creating comparable groups at the start of the study.

Table 2. Demographic characteristics and baseline (Pre-Test) scores by group

Characteristic	BAPNE Group (n = 41) Mean (SD)	Control Group (n = 41) Mean (SD)	Test Statistic	p
Age (Years)			$t_{(80)} = 0.45$	.653
Mean (SD)	4.54 (0.26)	4.50 (0.30)		
Gender (n, %)			$\chi^2_{(1)} = 0.05$	.823
Girls	23 (56.1%)	22 (53.7%)		
Boys	18 (43.9%)	19 (46.3%)		
BRIEF-P Pre-Test (T-Scores)				
Inhibition	52.1 (9.8)	51.8 (10.1)	$t_{(80)} = 0.14$	.889
Shift	51.5 (9.5)	52.3 (9.9)	$t_{(80)} = -0.38$	.705
Emotional Control	53.0 (10.2)	52.5 (9.7)	$t_{(80)} = 0.23$	.819
Working Memory	54.1 (10.5)	53.6 (10.0)	$t_{(80)} = 0.22$	.826
Plan/Organize	52.8 (9.9)	53.3 (10.3)	$t_{(80)} = -0.23$	.819
BRIEF-P Pre-Test Indices				
ISCI	52.9 (10.0)	52.5 (9.8)	$t_{(80)} = 0.18$	.858
FI	52.6 (9.7)	53.1 (9.8)	$t_{(80)} = -0.24$	.811
EMI	53.8 (10.3)	53.9 (10.1)	$t_{(80)} = -0.05$	.960
GEC	53.5 (10.1)	53.4 (9.9)	$t_{(80)} = 0.05$	.960

Note: BRIEF-P T-scores have a mean of 50 and a standard deviation of 10. Higher scores indicate greater executive function difficulties. ISCI = Inhibitory Self-Control Index; FI = Flexibility Index; EMI = Emergent Metacognition Index; GEC = Global Executive Composite.

Table 3 presents the unadjusted means and standard deviations for all BRIEF-P scales and indices at pre-test and post-test for both groups. A visual inspection of the means suggests a trend of improvement (decrease in scores) in both groups, but with a notably greater reduction in the BAPNE group compared to the control group.

Table 3. Descriptive statistics of BRIEF-P scores (T-Scores) at Pre-Test and Post-Test by group

Variable	Pre-Test Mean (SD)	Post-Test Mean (SD)	Pre-Test Mean (SD)	Post-Test Mean (SD)
Clinical Scales				
Inhibition	52.1 (9.8)	43.5 (8.5)	51.8 (10.1)	50.2 (9.6)
Shift	51.5 (9.5)	42.8 (8.2)	52.3 (9.9)	51.1 (9.1)
Emotional Control	53.0 (10.2)	44.1 (8.8)	52.5 (9.7)	50.9 (9.3)
Working Memory	54.1 (10.5)	45.0 (9.1)	53.6 (10.0)	52.0 (9.5)
Plan/Organize	52.8 (9.9)	43.9 (8.6)	53.3 (10.3)	51.8 (9.8)
Indices and Composite				
ISCI	52.9 (10.0)	44.0 (8.6)	52.5 (9.8)	50.9 (9.4)
FI	52.6 (9.7)	43.7 (8.4)	53.1 (9.8)	51.4 (9.2)
EMI	53.8 (10.3)	44.8 (8.9)	53.9 (10.1)	52.4 (9.6)
GEC	53.5 (10.1)	44.5 (8.7)	53.4 (9.9)	51.8 (9.4)

Analysis of primary outcomes

For each of the BRIEF-P outcome variables, a one-way ANCOVA was conducted to compare post-test scores between groups, statistically controlling for pre-test scores. Before each analysis, assumptions were checked. Levene's test for homogeneity of variances was not significant for any of the dependent variables (all $p > .05$). Critically, the test for homogeneity of regression slopes, assessed through the Group $\times$ Pre-Test interaction term, was also not significant in any case (all $p > .20$), confirming the appropriateness of the ANCOVA model.

Inhibitory self-control index (ISCI)

Table 4 presents the ANCOVA results for the ISCI and its constituent scales. After adjusting for pre-test scores, a statistically significant and large main effect of group was found on the ISCI, $F_{(1,79)} = 28.54$, $p < .001$, $\eta_p^2 = .265$. This effect was maintained in its component scales: Inhibition,

$F_{(1,79)} = 25.11$, $p < .001$, $\eta_p^2 = .241$, and Emotional Control, $F_{(1,79)} = 26.89$, $p < .001$, $\eta_p^2 = .254$. In all cases, the BAPNE group showed significantly lower (better) scores at post-test than the control group.

Flexibility index (FI)

The ANCOVA results for the FI and its unique scale (Shift, as Emotional Control was reported previously) are shown in Table 5. Again, a statistically significant and large main effect of group was observed for both the FI, $F_{(1,79)} = 31.22$, $p < .001$, $\eta_p^2 = .283$, and the Shift scale, $F_{(1,79)} = 34.56$, $p < .001$, $\eta_p^2 = .304$. The BAPNE group obtained significantly lower scores at post-test.

Emergent metacognition index (EMI)

Table 6 details the results for the EMI and its component scales. The pattern of results remained consistent. A statistically significant and large main effect of group was

Table 4. ANCOVA Results for the inhibitory self-control index (ISCI) and its scales

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
ISCI Post-Test	Covariate (Pre-Test)	3125.45	1	3125.45	85.12	< .001	.518
	Group	1048.77	1	1048.77	28.54	< .001	.265
	Error	2901.33	79	36.73			
Inhibition Post-Test	Covariate (Pre-Test)	2890.12	1	2890.12	79.50	< .001	.502
	Group	912.65	1	912.65	25.11	< .001	.241
	Error	2871.48	79	36.35			
Emotional Control Post-Test	Covariate (Pre-Test)	3011.56	1	3011.56	82.15	< .001	.510
	Group	985.93	1	985.93	26.89	< .001	.254
	Error	2896.71	79	36.67			

Note: Bold values indicate the main effect of the intervention.

Table 5. ANCOVA Results for the flexibility index (FI) and its scale

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
FI Post-Test	Covariate (Pre-Test)	2988.40	1	2988.40	88.54	< .001	.528
	Group	1056.21	1	1056.21	31.22	< .001	.283
	Error	2669.19	79	33.79			
Shift Post-Test	Covariate (Pre-Test)	2755.33	1	2755.33	86.97	< .001	.524
	Group	1094.88	1	1094.88	34.56	< .001	.304
	Error	2502.67	79	31.68			

Note: Bold values indicate the main effect of the intervention.

Table 6. ANCOVA Results for the emergent metacognition index (EMI) and its scales

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
EMI Post-Test	Covariate (Pre-Test)	3210.91	1	3210.91	90.13	< .001	.533
	Group	1064.30	1	1064.30	29.87	< .001	.274
	Error	2814.55	79	35.63			
Working Memory Post-Test	Covariate (Pre-Test)	3150.28	1	3150.28	85.34	< .001	.520
	Group	891.22	1	891.22	24.15	< .001	.234
	Error	2916.49	79	36.92			
Plan/Organize Post-Test	Covariate (Pre-Test)	3088.74	1	3088.74	89.13	< .001	.530
	Group	1073.96	1	1073.96	30.98	< .001	.282
	Error	2738.11	79	34.66			

Note: Bold values indicate the main effect of the intervention.

Table 7. ANCOVA Results for the global executive composite (GEC)

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
GEC Post-Test	Covariate (Pre-Test)	3199.67	1	3199.67	93.18	< .001	.541
	Group	1104.58	1	1104.58	32.18	< .001	.289
	Error	2710.32	79	34.31			

Note: Bold values indicate the main effect of the intervention.

Table 8. Adjusted post-test means and effect size (Cohen's d) for the difference between groups

Variable	BAPNE Group Adjusted Mean (SE)	Control Group Adjusted Mean (SE)	Mean Difference (95% CI)	Cohen's d
Clinical Scales				
Inhibition	43.6 (0.94)	50.1 (0.94)	-6.5 [-9.2, -3.8]	1.12
Shift	42.7 (0.89)	51.2 (0.89)	-8.5 [-11.1, -5.9]	1.25
Emotional Control	44.2 (0.95)	50.8 (0.95)	-6.6 [-9.4, -3.8]	1.14
Working Memory	45.2 (0.96)	51.8 (0.96)	-6.6 [-9.4, -3.8]	1.10
Plan/Organize	44.0 (0.93)	51.7 (0.93)	-7.7 [-10.4, -5.0]	1.24
Indices and Composite				
ISCI	44.1 (0.95)	50.8 (0.95)	-6.7 [-9.5, -3.9]	1.15
FI	43.8 (0.91)	51.3 (0.91)	-7.5 [-10.2, -4.8]	1.21
EMI	44.9 (0.94)	52.3 (0.94)	-7.4 [-10.1, -4.7]	1.18
GEC	44.6 (0.92)	51.7 (0.92)	-7.1 [-9.8, -4.4]	1.22

Note: Adjusted means are calculated at the mean of the covariate (pre-test score). SE = Standard Error. CI = Confidence Interval.

found on the EMI, $F_{(1,79)} = 29.87, p < .001, \eta_p^2 = .274$. This effect was robust on the scales of Working Memory, $F_{(1,79)} = 24.15, p < .001, \eta_p^2 = .234$, and Plan/Organize, $F_{(1,79)} = 30.98, p < .001, \eta_p^2 = .282$.

Global executive composite (GEC)

Finally, the analysis of the GEC, the most comprehensive measure of executive functioning, corroborated the previous findings (Table 7). The ANCOVA revealed a highly significant and large main effect of group, $F_{(1,79)} = 32.18, p < .001, \eta_p^2 = .289$. This result confirms that the BAPNE intervention had a profound and widespread impact on the participants' overall executive functioning.

Magnitude of Between-Group Differences

To assess the practical significance of these findings, the estimated marginal means (post-test means adjusted for the pre-test) and Cohen's d effect size for the difference between the groups on each variable were calculated. Table 8 summarizes these results. The adjusted means consistently show that the BAPNE group obtained lower scores (indicating better executive functioning) than the control group on all measures. The Cohen's d values were all large, ranging from 1.10 to 1.25, indicating that the mean difference between the two groups was more than one standard deviation on all facets of executive function evaluated.

Discussion

The present investigation provides a clear and compelling answer to its central research questions, demonstrating that a seven-month neuromotor intervention grounded in the

BAPNE method engenders profound and statistically robust improvements in the executive functions (EFs) of preschool-aged children. The findings confirm, unequivocally, all a priori hypotheses. After rigorously controlling for baseline performance via Analysis of Covariance (ANCOVA), the experimental group exhibited statistically significant enhancements across every primary outcome measure, including the Global Executive Composite (GEC), the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), and the Emergent Metacognition Index (EMI), with all effects reaching the highest level of significance ($p < .001$). This consistency across all indices points not to an isolated, narrow benefit, but to a pervasive and generalized impact on the entire executive control system as observed by teachers in an ecological setting.

While statistical significance establishes the reliability of these findings, it is the sheer magnitude of the intervention's effect that commands particular attention and situates this study's results as exceptional within the broader literature. The calculated Cohen's d values for the adjusted mean differences between the BAPNE and active control groups were remarkably large, ranging from 1.10 to 1.25 across all primary indices and their constituent subscales. An effect of this magnitude signifies that, at the conclusion of the trial, the average child in the BAPNE group was rated by their teacher as demonstrating executive control more than one full standard deviation superior to that of the average child in the high-quality traditional music control group. This finding is not merely statistically significant; it is educationally and clinically profound.

These results stand in stark contrast to the prevailing evidence in the field of early childhood cognitive intervention. A comprehensive meta-analysis of cognitive training programs for preschoolers reported a modest overall

effect size of $g = 0.352$. Similarly, meta-analytic reviews of cognitively engaging physical activity interventions have consistently documented small-to-moderate effects on children's EFs. Furthermore, studies targeting even younger children (up to age 3) or those employing parent-led intervention models have often yielded non-significant or highly variable results, precluding firm conclusions about efficacy. The BAPNE method, therefore, appears to produce effects that are an order of magnitude greater than those typically observed, suggesting that it may not represent a mere incremental advance but rather a potential paradigm shift in the efficacy of EF enhancement during the critical preschool years. This discrepancy demands a robust theoretical explanation, which can be found in the unique neurodevelopmental principles upon which the intervention is built.

The unprecedented effect sizes documented herein are not a statistical anomaly but rather the anticipated outcome of a theoretically grounded pedagogical model. The findings lend powerful empirical support to the construct of neuromotoricity and its central mechanism: the systematic application of dual-task paradigms as a catalyst for cognitive development. The conceptual distinction between traditional psychomotoricity—which views movement as an expressive medium—and neuromotoricity—which leverages movement as a direct vehicle for cognitive stimulation—is critical to interpreting these results.

The methodological rigor of employing an active control group that participated in a high-quality, structured music program is a cornerstone of this study's contribution. This design choice effectively isolates the "active ingredient" of the BAPNE method, moving beyond the non-specific benefits of social engagement, structured activity, or mere exposure to music. This is a crucial advantage, as many intervention studies are limited by comparisons to passive or no-treatment controls, which can confound the interpretation of results. The demonstrated superiority of the BAPNE group strongly suggests that it is the specific methodology of the intervention, not simply musical enrichment, that drives the observed cognitive gains.

The core of this methodology is the dual-task paradigm, aptly described as a form of "cognitive weightlifting". Activities central to the BAPNE method, such as "il cubo parlante," require children to simultaneously manage, coordinate, and execute dissociated motor patterns (e.g., different rhythms with hands and feet), maintain rhythmic precision, and engage in cognitive-linguistic processing (e.g., singing or reciting numerical sequences). This concurrent demand places a significant and sustained load on the central executive system, compelling it to inhibit prepotent responses, update information in working memory, flexibly shift between task rules, and monitor overall performance.

The profound efficacy of this approach can be understood within the context of early childhood neurodevelopment. During the preschool years, the core components of EF—inhibitory control, working memory, and cognitive flexibility—are not yet fully differentiated but function as a highly integrated, and perhaps unitary, system. Most cognitive training paradigms target these components in isolation, often leading to limited and non-transferable gains. The BAPNE method, in contrast, places a holistic, high-load demand on the entire developing executive system. By forc-

ing this integrated network to operate under a complex, controlled load, the intervention likely promotes more robust and widespread neuroplastic adaptation across the underlying prefrontal circuits than could be achieved by less integrated, uni-modal approaches. This provides a compelling theoretical rationale for both the exceptional magnitude of the effect and its broad impact across all measured domains of executive functioning.

Perhaps the most significant contribution of this study is its powerful demonstration of meaningful, real-world change. This is a direct consequence of the deliberate choice to use the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P) as the sole outcome measure. This choice directly addresses one of the most persistent challenges in cognitive science: the issue of ecological validity and the transfer of training gains to daily life.

The field of neuropsychological assessment has long grappled with the limited ecological validity (EV) of many traditional, laboratory-based EF tasks, which may not accurately reflect a child's capacity to navigate the complex cognitive demands of their environment (Arnau-Mollá & Romero-Naranjo, 2022). A useful distinction is often made between verisimilitude (the degree to which a test resembles a real-world task) and veridicality (the degree to which a test predicts real-world functioning) (Blair, 2016). The BRIEF-P is a quintessential measure of veridicality; it captures the expert observations of teachers regarding how a child's executive control manifests in the dynamic, unpredictable, and socially rich context of the preschool classroom.

This focus is particularly salient given the well-documented "test-rating disconnect," wherein performance on laboratory-based EF tests and informant-based rating scales like the BRIEF-P often show weak or non-significant correlations. This discrepancy suggests they may tap into different facets of the EF construct and raises the critical question of whether gains observed on a structured test translate into tangible behavioral change. The present study effectively circumvents this problem by demonstrating that the BAPNE intervention is potent enough to directly impact the behavioral outcome itself.

The large effects observed on the BRIEF-P provide robust evidence of "far transfer"—the generalization of trained skills to novel contexts and tasks, which is the ultimate, and often elusive, goal of cognitive intervention (Alonso-Sanz & Romero-Naranjo, 2015). The results indicate that children in the BAPNE group were observably better at waiting their turn, managing frustration, adapting to changes in routine, following multi-step instructions, and organizing their materials and actions. By producing such profound improvements on a measure of real-world functioning, this study effectively bridges the problematic test-rating gap. It establishes a higher standard for intervention research, confirming that the cognitive gains fostered by the BAPNE method are not only statistically reliable but are educationally and socially meaningful.

Limitations and a comprehensive roadmap for future inquiry

While the methodological strengths of this study—namely its randomized controlled trial design and the use of an active control group—provide a high degree of confidence

in the causal inference drawn, its limitations must be acknowledged. These limitations, however, should be viewed not as flaws but as the foundations for a comprehensive and programmatic line of future research.

First, the study was conducted within a specific educational context in Caracas, Venezuela. While this single-site design enhances internal validity by controlling for contextual variables, it necessarily constrains the generalizability of the findings to other sociocultural and socioeconomic populations. Therefore, multi-site replication trials across diverse cultural settings are an imperative next step to establish the universal efficacy and robustness of the BAPNE effect.

Second, the reliance on a single measurement modality—teacher ratings—while a key strength for establishing ecological validity, is also a limitation. It precludes a more granular examination of the specific cognitive micro-processes that were altered by the intervention. To build a complete, mechanistic model of the BAPNE method's impact, a multi-method, multi-level research program is essential. Such a program should proceed along three parallel tracks:

Cognitive and Behavioral elucidation. The immediate priority is to establish convergent validity. Future RCTs must incorporate a multi-method assessment battery that combines informant ratings (e.g., BRIEF-P) with direct, performance-based neuropsychological tasks. This battery should include validated measures of the core EFs, such as inhibitory control (e.g., Preschool Flanker, Go/No-Go tasks), working memory (e.g., Corsi Block-Tapping Task, Backward Digit Span), and cognitive flexibility (e.g., Dimensional Change Card Sort). Demonstrating concurrent improvements on both ratings and performance-based tasks would provide a comprehensive account of EF enhancement and definitively address the test-rating disconnect for this intervention.

Neurophysiological investigation. The theoretical framework of neuromotoricity posits that BAPNE training drives functional and structural changes in the prefrontal cortex (PFC) and its associated networks. This neuroplasticity hypothesis is directly testable using child-friendly neuroimaging technologies. Functional near-infrared spectroscopy (fNIRS) is particularly well-suited for this population due to its non-invasive, portable, and motion-tolerant nature. A powerful future study could use fNIRS to measure resting-state functional connectivity (rsFC) within the PFC before and after the intervention, testing the hypothesis that changes in neural network efficiency mediate the observed behavioral improvements on the BRIEF-P. The co-registration of fNIRS with electroencephalography (EEG) would provide an even richer, multi-modal dataset, allowing for the simultaneous examination of slow hemodynamic responses (fNIRS) and the fast electrophysiological signatures of cognitive control, such as event-related potentials (ERPs) linked to attention and working memory (e.g., P300).

Longitudinal tracking. The current pre-post design provides a critical snapshot in time but cannot speak to the durability of the intervention's effects. Longitudinal studies that track the BAPNE and control cohorts into primary and secondary education are essential. Such research would determine if the substantial EF gains observed at age

four are sustained over time and, critically, whether they translate into the predicted long-term benefits for academic achievement, social competence, and overall well-being that have been strongly associated with early EF skills in correlational research.

Conclusion

This methodologically rigorous randomized controlled trial provides the first strong causal evidence that the BAPNE neuromotoricity method engenders widespread and exceptionally large improvements in the real-world expression of executive functions in preschool-aged children. Over a seven-month period, this neuromotor intervention, predicated on cognitive stimulation through the systematic application of dual-task paradigms, produced significantly greater gains in inhibitory control, cognitive flexibility, and emergent metacognition compared to a high-quality traditional music education program. The magnitude of these effects, which far exceeds the typical outcomes reported in the cognitive training literature, suggests a profound and practically meaningful impact on children's daily self-regulatory behavior in the classroom.

The findings lend powerful empirical validation to the theoretical construct of neuromotoricity, suggesting that the intervention's potency derives from its unique capacity to place a holistic and synergistic demand on the developing, integrated executive function system of the young child. By demonstrating these effects using an ecologically valid measure of classroom behavior, this study confirms that the cognitive benefits of BAPNE training successfully transfer to the complex and dynamic settings where they matter most. Ultimately, the BAPNE method should be conceptualized not merely as an innovative approach to music education, but as a potent, evidence-based pedagogical tool for cultivating the foundational self-regulatory capacities that are critical for school readiness and lifelong success. The present findings provide a compelling mandate for both its broader consideration in early childhood educational policy and for a continued, multi-level scientific inquiry into its mechanisms and enduring benefits.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

- Anderson, P. J. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, 8(2), 71-82. <https://doi.org/10.1076/chin.8.2.71.8729>
- Zelazo, P.D., & Müller, U. (2002). *Executive function in typical and atypical development*. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 445-469). Blackwell Publishing.
- Goldstein, S., & Naglieri, J.A. (Eds.). (2014). *Handbook of executive functioning*. Springer New York.
- Best, J.R., & Miller, P.H. (2010). A developmental perspective on executive function. *Child Development*, 81(6), 1641-1660.
- Blair, C. (2016). Developmental science and executive function. *Current Directions in Psychological Science*, 25(1), 3-7.

- Garon, N., Bryson, S.E., & Smith, I.M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, 134(1), 31-60.
- Diamond, A. (2013a). Executive functions. *Annual Review of Psychology*, 64, 135-168.
- Diamond, A. (2013b). *Interventions shown to aid executive function development in children 4 to 12 years of age*. In S. Goldstein & J. A. Naglieri (Eds.), *Handbook of executive functioning* (pp. 203-230). Springer New York.
- Bowmer, A., Mason, K., Knight, J., & Welch, G. (2018). Investigating the impact of a musical intervention on preschool children's executive function. *Frontiers in Psychology*, 9, 2389.
- Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology*, 26(1), 465-486. https://doi.org/10.1207/s15326942dn2601_6
- Rus, A., Dohotaru, A.I., Catalano, H., Ani-Rus, A., & Mestic, G. (2024). Development of Social-Emotional Skills in Early Education Through Musical Activities. Experimental Study. *Educatie* 21(28), 0_1-133.
- Habibi, A., Damasio, A., Ilari, B., Sachs, M.E., & Damasio, H. (2018). Music training and child development: A review of recent findings from a longitudinal study. *Annals of the New York Academy of Sciences*, 1423(1), 73-81.
- Wollesen, B., Janssen, T.I., Müller, H., & Voelcker-Rehage, C. (2022). Effects of cognitive-motor dual task training on cognitive and physical performance in healthy children and adolescents: A scoping review. *Acta Psychologica*, 224, 103498.
- Bugos, J.A., & DeMarie, D. (2017). The effects of a short-term music program on preschool children's executive functions. *Psychology of Music*, 45(6), 855-867.
- Oberer, N., Gashaj, V., & Roebers, C.M. (2018). Executive functions, visual-motor coordination, physical fitness and academic achievement: Longitudinal relations in typically developing children. *Human Movement Science*, 58, 69-79.
- Andreu-Cabrera, E., & Romero-Naranjo, F. J. (2021). Neuromotricidad, Psicomotricidad y Motricidad. Nuevas aproximaciones metodológicas (Neuromotricity, Psychomotricity and Motor skills. New methodological approaches). *Retos*, 42, 924-938. <https://doi.org/10.47197/retos.v42i0.89992>
- Romero-Naranjo, F. J., Andreu-Cabrera, E., & Arnau-Mollá, A. F. (2024). Neuromotricity in early childhood education. Development tables as an interdisciplinary proposal according to the BAPNE method. *Retos: Nuevas Perspectivas de Educación Física, Deporte y Recreación*, 53.
- Mas-Mas, D., Arnau, A.F., & Romero, F.J. (2023). Doble tarea y movimiento: estudio bibliométrico basado en motores búsqueda de alto impacto. *Retos: Nuevas tendencias en Educación Física, Deporte y Recreación*, 50, 995-1009.
- Alonso-Marco, M., & Romero-Naranjo, F.J. (2022). Introducción al análisis cinemático de los movimientos básicos de la percusión corporal según el Método BAPNE. *Retos: Nuevas tendencias en Educación Física, Deporte y Recreación*, 46, 950-971.
- Alonso-Sanz, A., & Romero-Naranjo, F. J. (2015). El círculo en la relación espacio y cuerpo. Foto-Ensayo a partir de Isidro Blasco y el método BAPNE. *Arte, Individuo y Sociedad*, 27(3), 359-374.
- Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., & Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49-100.
- Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, 21(1), 8-14.
- Sherman, E.M., & Brooks, B.L. (2010). Behavior rating inventory of executive function-preschool version (BRIEF-P): Test review and clinical guidelines for use. *Child Neuropsychology*, 16(5), 503-519.
- Lu, Y., Shi, L., & Musib, A.F. (2024). Effects of music training on executive functions in preschool children aged 3-6 years: Systematic review and meta-analysis. *Frontiers in Psychology*, 15, 1522962.
- Arnau-Mollá, A. F., & Romero-Naranjo, F. J. (2022). La percusión corporal como recurso pedagógico. Estudio bibliométrico sobre percusión corporal basado exclusivamente en motores de búsqueda secundarios. *Retos: Nuevas tendencias en Educación Física, Deporte y Recreación*, 46, 809-825. <https://doi.org/10.47197/retos.v46.95178>
- Blair, C. (2016). Developmental science and executive function. *Current Directions in Psychological Science*, 25(1), 3-7. <https://doi.org/10.1177/0963721415622634>

Нейромоторна інтервенція щодо виконавчих функцій у ранньому дитинстві: Рандомізоване контрольоване дослідження методу BAPNE

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 8 табл., 26 джерел.

Мета дослідження. Мета дослідження полягала у вивченні причинно-наслідкового впливу семимісячної нейромоторної інтервенції, методу BAPNE, на основні виконавчі функції (ВФ) дітей дошкільного віку, порівнюючи з традиційною програмою музичної освіти.

Матеріали та методи. Проведено рандомізоване контрольоване дослідження із застосуванням претестового/посттестового дизайну за участю вибірки з 82 чотирирічних дітей (N = 82; 41 в експериментальній групі, 41 в активній контрольній групі) у Каракасі, Венесуела. Експериментальна група отримала інтервенцію BAPNE, тоді як контрольна група проходила традиційне навчання музиці. Показники виконавчих функцій визначались за допомогою рейтингів викладачів, застосовуючи опитувальник оцінки поведінки виконавчих функцій – дошкільна версія (Behavior Rating Inventory of Executive Function–Preschool Version, BRIEF-P). Аналіз даних проводився із використанням коваріаційного аналізу (ANCOVA) з претестовими балами як коваріатою для контролю первинних відмінностей.

Результати. Після контролю вихідних показників група BAPNE продемонструвала статистично значущі поліпшення з великими розмірами ефекту за всіма основними показниками результатів порівняно з контрольною групою. Це включає індекс інгібиторного самоконтролю (ISCI), індекс гнучкості (FI), індекс емерджентної метакогніції (EMI) та глобальний виконавчий композит (GEC) (усі показники $p < .001$).

Висновки. Отримані результати надають переконливі докази того, що метод BAPNE, який ґрунтується на принципах нейромоторики та когнітивної стимуляції через двозадачність, є високоефективною інтервенцією для розвитку прояву виконавчих функцій у повсякденному контексті раннього дитинства.

Ключові слова: виконавчі функції, нейромоторика, метод BAPNE, перкусія тіла, раннє дитинство, рандомізоване контрольоване дослідження, інгібиторний контроль, робоча пам'ять, когнітивна гнучкість.

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Integrating Virtual Reality and Project Based Flipped Learning in Sport Massage Education: A Tri Pramana Based Innovation

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Abstract

Background. Sport massage education often struggles to deliver effective practical experiences due to limited real-world practice opportunities and outdated teaching methods.

Objectives. This study aimed to develop and evaluate an innovative learning model that integrates Virtual Reality (VR), Project-Based Flipped Learning (PBFL), and the Tri Pramana philosophy to enhance student competence in sport massage.

Materials and Methods. Utilizing a Research and Development (R&D) approach with the ADDIE model, this study involved 80 undergraduate students enrolled in a sport massage course. Participants were divided into an experimental group receiving VR-PBFL learning and a control group using conventional methods. Data were collected through pre- and post-tests, observational checklists, and questionnaires.

Results. Statistical analysis using paired and independent sample t-tests showed a significant improvement in the experimental group's motor skills and theoretical understanding compared to the control group ($p < 0.05$). Students also reported higher satisfaction and engagement levels with the VR-based learning environment. The integration of Tri Pramana — Pratyaksa (direct experience), Anumana (logical reasoning), and Sabda (credible sources) — provided a philosophical and cultural foundation for holistic learning. This study confirms that VR and PBFL, when grounded in local educational philosophy, can significantly enhance the quality of sport massage education.

Conclusions. The findings support the adoption of immersive and culturally adaptive technologies in physical education programs, thereby opening pathways for future innovation in health and sports science education.

Keywords: virtual reality, project-based flipped learning, sport massage education, Tri Pramana, immersive learning.

Introduction

Sport massage education continues to face critical challenges in delivering effective and engaging learning experiences. Conventional methods, such as lectures and limited practical demonstrations, often fail to provide adequate opportunities for students to develop hands-on skills and real-time clinical judgment (Fang & Yao, 2021). Consequently, students may graduate with insufficient motor competence and limited confidence in applying

sport massage techniques. The increasing availability and affordability of immersive technologies, especially Virtual Reality (VR), has opened new opportunities in sports and health education. VR enables students to practice skills in a simulated environment that mirrors real-life settings, enhancing both cognitive understanding and psychomotor ability without physical risk (Moro, Štromberga, Raikos, & Stirling, 2017). Meta-analytic findings suggest VR applications significantly improve knowledge retention and practical outcomes in anatomy and clinical learning environments. Complementing VR is the pedagogical model of Project-Based Flipped Learning (PBFL), which combines the advantages of flipped classrooms and project-oriented instruction. PBFL allows students to engage with learning content before class and apply their understanding through

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meaningful collaborative projects (Guo, Saab, Post, & Admiraal, 2020). This approach promotes learner autonomy, critical thinking, and problem-solving all of which are essential for practical disciplines like sport massage (Østerlie et al., 2023).

Despite the proven individual benefits of VR and PBFL, their integration in sport massage education has yet to be systematically explored. Existing studies have primarily focused on these approaches in broader contexts such as nursing, medical anatomy, or general physical education, with minimal focus on specialized massage training (Putranto et al., 2022; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). This lack of integration represents a clear research gap. In Indonesia, the cultural and philosophical foundation of education emphasizes Tri Pramana a knowledge acquisition framework based on direct perception (Pratyaksa), inference (Anumana), and authoritative knowledge (Sabda). This indigenous epistemology aligns closely with the principles of experiential and reflective learning (Sindu, Sudarma, Hartati, & Gunantara, 2024). However, the Tri Pramana approach remains underutilized in contemporary, technology-enhanced instructional design. Integrating Tri Pramana into immersive, student-centered pedagogies like VR and PBFL offers a novel and culturally relevant model for sport massage education. While global literature highlights the pedagogical effectiveness of VR and PBFL, few studies have contextualized these innovations through indigenous philosophical frameworks, particularly in Southeast Asia. The inclusion of Tri Pramana may bridge the gap between global innovations and local educational values (Tisna et al., 2022).

Theoretically, this research is grounded in constructivist learning theory, which emphasizes that meaningful learning occurs when learners actively engage in constructing knowledge through experience and reflection. In this framework, VR supports direct experiential learning (Pratyaksa), PBFL fosters analytical reasoning (Anumana), and instructional scaffolding provides the reliable guidance of Sabda. These three components collectively offer a holistic approach to learning in physical education (Adinata et al., 2024). Given this foundation, the current study aims to develop and evaluate a sport massage learning model that integrates VR, PBFL, and Tri Pramana. Specifically, the research examines the impact of this integrative model on students' motor skills, theoretical understanding, and reflective capacity in sport massage practices. This study contributes to the literature by offering a pedagogical innovation that fuses immersive technology and student-centered learning with culturally rooted philosophical perspectives. The results are expected to inform both theory and practice in physical education, particularly in designing culturally responsive and technologically enriched sport massage curricula.

In today's rapidly evolving educational landscape, physical education must adapt to the demands of Education 4.0, where digital literacy, critical thinking, and contextual adaptability are core competencies (Bento & White, 2018). This evolution is especially crucial in practice-based fields like sport massage, where learning must be both technologically enriched and pedagogically sound. The fusion of VR and PBFL within a Tri Pramana framework aligns with global trends in personalized, immersive,

and reflective learning, offering a robust response to the limitations of outdated instructional practices. Furthermore, empirical evidence supports the idea that culturally relevant pedagogy can significantly enhance student motivation and learning engagement (Gay, 2018). Integrating Tri Pramana into instructional design not only situates learning within local wisdom but also fosters deeper cognitive and emotional connections to the learning material. This is particularly important in Indonesia, where philosophical and spiritual values are deeply intertwined with education and well-being (Winataputra, 2017). By grounding learning in both technology and tradition, this model creates a more meaningful and transformative educational experience.

Ultimately, this study proposes a novel instructional model that responds to both global innovation and local educational philosophy. It serves as a pioneering step toward integrating immersive technology, student-centered pedagogy, and indigenous knowledge in physical education. The implications of this research extend beyond sport massage, offering valuable insights for curriculum developers, instructional designers, and policymakers seeking to elevate learning outcomes through culturally grounded digital pedagogy.

Materials and Methods

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation) to create and test an innovative instructional model. The model integrates Virtual Reality (VR), Project-Based Flipped Learning (PBFL), and the Tri Pramana framework to enhance learning outcomes in sport massage education. To assess the effectiveness of the developed model, a quasi-experimental design with a pretest-posttest control group was used in the implementation phase.

Participants

Participants consisted of 80 undergraduate students enrolled in a sport massage course at the Faculty of Sports and Health, Universitas Pendidikan Ganesha, Indonesia. Participants were selected using purposive sampling based on enrollment and prior experience. They were divided into two equal groups:

- The experimental group (n = 40), which received instruction using the developed VR-PBFL-Tri Pramana model.
- The control group (n = 40), which received traditional instruction using lectures and direct demonstration without VR or project-based activities.

All participants gave informed consent, and ethical approval was obtained from the university's ethics committee prior to data collection.

Procedure

Analysis Phase. A needs analysis was conducted through literature review, student surveys, and focus group discussions with educators to identify gaps in current sport

massage instruction. The analysis focused on technological limitations, pedagogical approaches, and cultural dimensions often neglected in conventional learning.

Design Phase. Based on the findings, a conceptual instructional model was developed. The model combined immersive VR content for simulating sport massage techniques, PBFL for encouraging active learning and collaboration, and Tri Pramana principles (Pratyaksa, Anumana, and Sabda) for epistemological grounding.

Development Phase. VR learning modules were developed using Unity 3D and integrated with gamified features. These included motion tracking, visual simulation of massage points, feedback mechanisms, and real-time practice in virtual environments. Learning materials for flipped learning and project guidelines were also prepared, supported by theoretical content aligned with the Tri Pramana philosophy.

Implementation Phase. Over a period of 8 weeks, both groups underwent instruction. The experimental group engaged in:

- Pre-class activities (video lectures and readings).
- In-class VR simulations.
- Project-based collaborative tasks.
- Guided reflection using Tri Pramana.

The control group participated in standard classroom lectures and practice on mannequins without VR or flipped instruction.

Evaluation Phase. Formative and summative assessments were carried out to measure learning outcomes. Student performance, feedback, and engagement were documented through a combination of quantitative and qualitative instruments.

Data Collection Instruments

- **Skill Performance Rubric:** Assessed students' practical abilities in performing sport massage techniques (motor domain).
- **Written Test:** Measured theoretical understanding of sport massage concepts and anatomy.
- **Reflective Journal Checklist:** Evaluated how students applied Tri Pramana elements in their learning reflection.
- **Questionnaires:** Captured students' perceptions of learning experience, motivation, and satisfaction using a validated 5-point Likert scale.
- **Observational Protocols:** Used by instructors to document student behavior, interaction, and application of techniques during sessions.

Statistical Analysis

Quantitative data were analyzed using IBM SPSS 26.

- Descriptive statistics (mean, standard deviation) were used to summarize overall performance.
- Paired sample t-tests were conducted within groups to compare pretest and posttest scores.
- Independent sample t-tests compared mean score differences between experimental and control groups.
- A significance level of $p < .05$ was used for all statistical tests.

- Qualitative data from journals and observations were coded thematically to identify patterns in student learning behavior related to the Tri Pramana framework.

Validity and Reliability

All instruments were reviewed by sport education experts to ensure content validity. A pilot test with 10 non-participating students was conducted to assess instrument clarity and internal consistency. Cronbach's alpha scores for the motivation and satisfaction questionnaires were $\alpha = 0.86$ and $\alpha = 0.89$, respectively, indicating high reliability.

Ethical Considerations

This study complied with ethical research guidelines in educational research. Written informed consent was obtained, and participants were assured of the confidentiality and anonymity of their responses. The intervention posed no risk and was conducted as part of regular course activities.

Results

This study evaluated the impact of an instructional model integrating Virtual Reality (VR), Project-Based Flipped Learning (PBFL), and the Tri Pramana framework on students' performance in sport massage education. The findings are presented in the following subsections: learning performance improvements, between-group comparisons, student perceptions, and qualitative reflection based on Tri Pramana.

Learning Performance Improvement (Within-Group Analysis)

The paired sample t-test results show a significant improvement in the experimental group's performance from pretest to posttest. The average pretest score was $M = 64.85$ ($SD = 7.12$), while the posttest score increased to $M = 84.30$ ($SD = 6.98$). This difference was statistically significant, $t_{(39)} = 15.24$, $p < .001$. Similarly, the control group improved from a mean pretest score of $M = 65.22$ ($SD = 6.97$) to a posttest score of $M = 73.55$ ($SD = 7.34$), with $t_{(39)} = 7.89$, $p < .01$, although the magnitude of improvement was notably smaller than in the experimental group.

Table 1. Pretest and Posttest Scores Within Groups (Paired Sample t-test)

Group	Test Type	Mean (M)	SD	t	p
Experimental	Pretest	64.85	7.12	15.24	< .001
	Posttest	84.30	6.98		
Control	Pretest	65.22	6.97	7.89	< .01
	Posttest	73.55	7.34		

Between-Group Comparison of Posttest Scores

To evaluate the effectiveness of the VR-PBFL-Tri Pramana learning model, an independent samples t-test was conducted. The posttest scores of the experimental group (M

= 84.30, SD = 6.98) were significantly higher than those of the control group (M = 73.55, SD = 7.34), with $t(78) = 6.87$, $p < .001$. This demonstrates that the integration of immersive learning and project-based instruction grounded in local epistemology led to improved academic outcomes.

Table 2. Comparison of Posttest Scores Between Groups (Independent Sample t-test)

Group	N	Posttest Mean	SD	t	p
Experimental	40	84.30	6.98	6.87	< .001
Control	40	73.55	7.34		

Student Motivation and Satisfaction

Student perceptions of the learning experience were measured using a validated Likert-scale questionnaire (1–5). Results indicate that students in the experimental group had higher motivation (M = 4.44, SD = 0.46) and greater satisfaction (M = 4.52, SD = 0.41) compared to the control group (motivation: M = 3.65, SD = 0.63; satisfaction: M = 3.71, SD = 0.55). Independent sample t-tests confirmed these differences were statistically significant ($p < .001$ for both).

Table 3. Student Motivation and Satisfaction Scores

Dimension	Group	Mean (M)	SD	t	p
Motivation	Experimental	4.44	0.46	6.12	< .001
	Control	3.65	0.63		
Learning Satisfaction	Experimental	4.52	0.41	7.03	< .001
	Control	3.71	0.55		

Reflection on Learning Experience Based on Tri Pramana

Qualitative findings from student journals and instructor observations supported the successful integration of Tri Pramana components:

- Pratyaksa (direct experience): Students stated that VR helped them feel as if they were practicing on real patients.
- Anumana (reasoning): Group discussions and project work helped students critically analyze sport massage procedures.
- Sabda (trusted knowledge): Theoretical references and instructor feedback reinforced student understanding during debriefings.

Approximately 88% of students in the experimental group agreed that the learning approach effectively connected theory and practice. In contrast, only 55% of control group students reported similar outcomes.

Discussion

The findings of this study demonstrate that the integration of Virtual Reality (VR), Project-Based Flipped Learning (PBFL), and Tri Pramana significantly enhances students' cognitive and psychomotor outcomes in sport massage education. The experimental group outperformed the control group in both theoretical understanding and practical skill performance. This aligns with prior evidence

suggesting that immersive technologies provide highly engaging and effective environments for kinesthetic learning, especially in domains that require procedural mastery (Merchant et al., 2014). The significant increase in posttest scores within the experimental group supports the notion that immersive environments such as VR can replicate the depth of real-life experiences. When students can visualize and simulate movements and techniques in a virtual setting, they are more likely to achieve better skill acquisition and memory retention (Makransky & Mayer, 2022). Moreover, by using VR as a tool for experiential learning, the study affirms Kolb's experiential learning cycle, which emphasizes concrete experience and active experimentation as critical to skill development (Kolb, 2015).

The project-based flipped learning model further contributed to the success of the instructional approach by placing learners at the center of the knowledge construction process. The flipped model allowed students to access theoretical content in advance and engage in applied learning during in-class VR sessions. This echoes findings from van Alten et al. (2019), who concluded that flipped classroom models improve knowledge transfer and promote deeper learning when combined with active learning tasks. Additionally, the project-based component fostered teamwork and problem-solving, reinforcing the real-world application of sport massage techniques (Thomas, 2000). Integrating the Tri Pramana philosophical framework added a unique cultural and cognitive dimension to the instructional model. Students' reflections showed evidence of applying Pratyaksa (direct experience) through VR, Anumana (reasoning) during group discussions, and Sabda (authoritative knowledge) via instructor feedback and literature. Incorporating such indigenous epistemologies into learning has been shown to enhance engagement and contextual understanding, particularly in Southeast Asian educational settings (Tuihai Smith, 2012; Sarathchandra & Dhand, 2021). This integration bridges the gap between Western instructional design models and local philosophical traditions, creating a more inclusive and resonant learning experience.

The improvement in motivation and satisfaction observed in the experimental group further emphasizes the impact of learner-centered, technology-supported instruction. Students found the immersive, project-based approach more meaningful, likely because it provided a sense of autonomy and real-world relevance. According to Deci and Ryan's Self-Determination Theory, motivation increases when learners experience autonomy, competence, and relatedness—elements inherently present in the VR-PBFL model (Deci & Ryan, 2000). This supports the argument that educational innovation must address both cognitive and affective domains to foster optimal learning outcomes. Overall, this study contributes to the growing body of literature advocating for immersive and culturally adaptive pedagogy in physical education. While previous research has examined VR and flipped learning separately, this study is among the few that combines both with a local philosophical approach in a practice-based course. As educational institutions increasingly aim for curriculum internationalization while maintaining cultural integrity, this model provides a promising example of how global and local paradigms can be harmonized to support holistic learning.

Conclusion

This study developed and evaluated an innovative instructional model that integrates Virtual Reality (VR), ProjectBased Flipped Learning (PBFL), and the Tri Pramana philosophical framework to enhance sport massage education. The quasiexperimental results demonstrated that students exposed to the VRPBFLTri Pramana model achieved significantly higher gains in both practical skills ($M\Delta = 19.45$ vs. 8.33) and theoretical understanding compared to those in a conventional learning environment. They also reported markedly greater motivation and satisfaction, indicating that immersive, studentcentered, and culturally grounded pedagogy can more effectively engage learners in complex psychomotor domains. By combining immersive simulation, active learning projects, and indigenous epistemology, this model addresses critical gaps in traditional sport massage instruction—namely limited practice opportunities, passive content delivery, and lack of cultural context. The findings support the adoption of mixedreality technologies and flipped, projectbased approaches within physical education curricula, while also demonstrating the value of situating innovation within local philosophical constructs. Future research should explore scalability across different institutions and disciplines, longterm retention effects, and costbenefit analyses to guide broader implementation. This integrative framework holds promise not only for sport massage but for any practicebased discipline seeking to harmonize global pedagogical advances with cultural relevance.

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Conflict of Interest

The authors declare that there is no conflict of interest.

References

- Fang, M., You, F., & Yao, R. (2021). Application of virtual reality technology (VR) in practice teaching of sports rehabilitation major. *Journal of Physics: Conference Series*, 1852(4), 042007. <https://doi.org/10.1088/1742-6596/1852/4/042007>
- Moro, C., Štromberga, Z., Raikos, A., & Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anatomical Sciences Education*, 10(6), 549-559. <https://doi.org/10.1002/ase.1696>
- Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of*

- Educational Research*, 102, 101586. <https://doi.org/10.1016/j.ijer.2020.101586>
- Østerlie, O., Sargent, J., Killian, C., Garcia-Jaen, M., García-Martínez, S., & Ferriz-Valero, A. (2023). Flipped learning in physical education: A scoping review. *European Physical Education Review*, 29(1), 125-144. <https://doi.org/10.1177/1356336X211059173>
- Putranto, J. S., Heriyanto, J., Kenny, Achmad, S., & Kurniawan, A. (2022). Implementation of virtual reality technology for sports education and training: Systematic literature review. *Procedia Computer Science*, 216, 293-300. <https://doi.org/10.1016/j.procs.2022.12.139>
- Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, 147, 103778. <https://doi.org/10.1016/j.compedu.2019.103778>
- Sindu, I. G. P., Sudarma, M., Hartati, R. S., & Gunantara, N. (2024). Classification of Tri Pramana learning activities in virtual reality environment using convolutional neural network. *IAES International Journal of Artificial Intelligence*, 13(3), 2840-2853. <https://doi.org/10.11591/ijai.v13.i3.pp2840-2853>
- Tisna, G., Parwati, N., Warpala, I., Sudatha, I. G., Sudarmika, P., & Suartama, I. K. (2022). The impact of project-based e-learning on cognitive and psychomotor learning achievement in sports massage course. *Cypriot Journal of Educational Sciences*, 17(12), 4393-4408. <https://doi.org/10.18844/cjes.v17i12.7751>
- Adinata, K. C., Ganesha, U. P., & Ganesha, P. (2024). Increasing cognitive learning and sport massage skills through a project-based blended learning model. *Edu Sportivo*, 7(2), 134-148. <https://doi.org/10.31258/sportivo.7.2.134-148>
- Bento, F., & White, L. (2018). Education for life in the era of Education 4.0: Reflections from a critical perspective. *International Journal of Education and Learning*, 7(1), 47-59.
- Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice* (3rd ed.). Teachers College Press.
- Winataputra, U. S. (2017). Local wisdom as a base for character education development. *Journal of Education and Practice*, 8(7), 183-189.
- Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education*, 70, 29-40. <https://doi.org/10.1016/j.compedu.2013.07.033>
- Makransky, G., & Mayer, R. E. (2022). Benefits of taking a virtual field trip in immersive virtual reality: Evidence for the immersion principle in multimedia learning. *Educational Psychology Review*, 34(4), 1771-1792.
- Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education.
- van Alten, D. C. D., Phielix, C., Janssen, J., & Kester, L. (2019). Effects of flipping the classroom on learning outcomes and satisfaction: A meta-analysis. *Educational Research Review*, 28, 100281. <https://doi.org/10.1016/j.edurev.2019.05.003>
- Thomas, J. W. (2000). *A review of research on project-based learning*. Buck Institute for Education.
- Tuhiwai Smith, L. (2012). *Decolonizing methodologies: Research and indigenous peoples* (2nd ed.). Zed Books.

Sarathchandra, D., & Dhand, A. (2021). Cultural humility and epistemic pluralism in global education. *Teaching in Higher Education*, 26(5), 705-721.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4), 227-268.

Інтеграція віртуальної реальності та проектно-орієнтованого перевернутого навчання в галузі освіти зі спортивного масажу: Інновація на основі трьох праман (джерела пізнання істини)

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 6 с., 3 табл., 20 джерел.

Історія питання. Освіта в галузі спортивного масажу часто стикається з труднощами в наданні ефективних практичних досвідів через обмежені можливості практики в реальних умовах та застарілі методи навчання.

Мета дослідження. Мета цього дослідження полягала у розробленні та оцінці інноваційної моделі навчання, що поєднує віртуальну реальність (VR), проектно-орієнтоване перевернуте навчання (PBFL) та філософію трьох праман, для підвищення компетентності студентів у галузі спортивного масажу.

Матеріали та методи. Використовуючи підхід науково-дослідних та дослідно-конструкторських робіт (R&D) із застосуванням моделі ADDIE, до проведення дослідження було залучено 80 студентів бакалаврату, які навчалися на курсі спортивного масажу. Учасників було розділено на експериментальну групу, яка проходила навчання за методикою VR-PBFL, та контрольну групу, в якій використовувались традиційні методи. Збір даних здійснювався шляхом проведення пре- та пост-тестів, обсерваційних контрольних списків та опитувальників.

Результати. Статистичний аналіз із застосуванням t-критеріїв для парних і незалежних вибірок показав значне поліпшення моторики та теоретичного розуміння в експериментальній групі, порівнюючи з контрольною групою ($p < 0.05$). Студенти також повідомили про підвищення рівня задоволеності та залученості до навчального середовища, що базується на використанні технології віртуальної реальності. Інтеграція трьох праман — пратьякша (безпосередній досвід), анумана (логічне міркування) та сабда (достовірні джерела) — забезпечила філософську та культурну основу для цілісного навчання. Це дослідження підтверджує, що застосування технології віртуальної реальності та методу проектно-орієнтованого перевернутого навчання, ґрунтуючись на місцевій філософії освіти, може значно підвищити якість освіти в галузі спортивного масажу.

Висновки. Результати дослідження підтверджують доцільність впровадження імерсивних та культурно-адаптивних технологій у програми фізичного виховання, відкриваючи шляхи для майбутніх інновацій у галузі здоров'я та спортивної наукової освіти.

Ключові слова: віртуальна реальність, проектно-орієнтоване перевернуте навчання, освіта в галузі спортивного масажу, три прамани, імерсивне навчання.

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Comprehensive Analysis of the Perception of Virtues in 5–6-Year-Old Preschoolers with Different Judo Experience Based on an Authorial Scale

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Abstract

Objectives. The study aimed to analyze the perception and development of virtues in 5–6-year-old children with varying experience in activities based on the philosophy of judo.

Materials and Methods. This study involved 36 preschool children divided into three groups according to their judo experience: novices (no prior practice), one year, and two years of practice. At this age stage, training excluded throwing techniques and focused on fundamental elements, preparatory exercises, and play-based forms aligned with judo principles. An authorial observation scale was developed to assess four virtues — friendship, respect, honesty, and participation. Data were collected through structured observations during physical activity sessions and analyzed quantitatively.

Results. Children with longer judo experience demonstrated significantly higher scores across all assessed virtues compared to novices. The two-year practice group achieved the highest results in friendship and respect, indicating the positive role of judo-based educational activity in fostering moral values.

Conclusions. The study highlights the importance of integrating judo-based activities not only as physical training but also as a pedagogical tool for cultivating social and emotional competence in early childhood. The findings confirm the effectiveness of the authorial observation scale for monitoring virtue development in preschool education.

Keywords: virtues, preschool children, judo philosophy, preschool education, virtue observation scale, development.

Introduction

The development of virtues in early childhood is a crucial aspect of education, contributing to the formation of prosocial behavior, emotional regulation, and readiness for social interaction (Wulandari & Suhma, 2024; Chi-Kin Lee et al., 2024). In recent years, researchers have increasingly emphasized the importance of integrating value-based content into physical education to support holistic child development (Arda Tuncdemir et al., 2022). Martial arts, particularly judo, have drawn attention as effective pedagogical tools for transmitting values through structured physical activity (Song, 2022; Kwok, 2024).

Judo, founded on the philosophy of mutual benefit and personal growth, naturally incorporates virtues such as respect, friendship, honesty, and responsibility into

its training process. While many studies highlight the virtues and social benefits of judo in school-aged children, there remains a lack of empirical research targeting preschoolers—especially those in the critical age of 5–6 years (Křižalkovičová et al., 2024). Furthermore, few studies offer observation-based tools adapted for this age group, capable of capturing subtle dynamics in the development of virtues during regular judo sessions (Jadwiszczak et al., 2025).

A core issue addressed in this study is the relationship between the amount of judo experience and the perception of key virtues in preschool children (Soengkono, 2024; Martín-Rodríguez et al., 2024). Despite judo's educational potential, it is not yet fully understood how the duration of practice affects value development at such an early age (Garbeloto, F., Miarka, B., Guimarães, 2023).

Research question of this study is that preschool children with more extensive judo experience will demonstrate a higher level of virtue development than those with less or no experience. The purpose of the study is to perform

a comprehensive analysis of the perception of virtues in 5–6-year-old preschoolers with different judo experience levels, using an authorial observation scale specifically designed for early childhood education settings.

Materials and Methods

Participants and Setting

The study involved 36 preschool boys (5–6 years old) participating in a judo educational program at the Vsevolods Zelonijs Sports School in Riga, Latvia. Only boys were included to ensure sample homogeneity and clarity of results, as no girls were enrolled in these groups. The judo sessions lasted 45 minutes each and were conducted three times per week according to each group's schedule. Participants were divided into three groups of 12 children based on their prior judo experience:

- Group 1: two years of participation in the judo-based program.
- Group 2: one year of participation.
- Group 3: no prior judo experience (control group).

The activities were adapted for this age group and did not include formal judo techniques such as throws but focused on preparatory exercises, imitation drills, cooperative games, and partner tasks. These activities aimed to promote social interaction, emotional regulation, and virtues development through physical engagement, in accordance with the educational philosophy of Jigoro Kano (Shishida, 2012).

Virtue Assessment Observation Scale Development

The author developed an original instrument - the Virtue Assessment Observation Scale – to assess the manifestation of virtues in preschool children involved in physical activity related to the philosophy of judo. The scale employs a hierarchical framework with three analytical levels: virtues (macro-level), criteria (meso-level), and indicators (micro-level). Its construction was based on a thorough review of recent pedagogical and developmental psychology literature (Jarilkapovich, 2025; Borich & Tombari, 2021; Birhan et al., 2021) and practical experience in preschool sports education.

Structure of the Virtue Assessment Observation Scale

The scale includes four core virtues essential for children's virtues and social development: friendship, respect, honesty, and participation. Each virtue is operationalized by specific criteria reflecting observable behavioral tendencies. Criteria are further divided into 26 concrete behavioral indicators, which are rated on a 3-point Likert-type scale: 3 – consistently observed, 2 – occasionally observed, and 1 – not observed. Overall, the scale contains 11 criteria and 26 indicators. This structure supports both quantitative evaluation and qualitative interpretation of virtues development within physical education contexts.

Data Collection Procedure

Structured observations were performed by the author and a trained research assistant during routine judo-based physical education sessions. Each session lasted

approximately 45 minutes and was conducted three times weekly, depending on the group schedule. Observations focused on naturally occurring behaviors without researcher interference or instruction. The Virtue Assessment Observation Scale was used to systematically record each child's behavioral manifestations of the defined virtues during collaborative and free-movement activities.

Statistical Analysis

Each behavioral indicator was rated on the 3-point scale, and scores were normalized using min–max transformation to enable comparison across groups. Descriptive statistics (median and interquartile ranges) were computed. The non-parametric Kruskal–Wallis H test was applied to identify differences between the three groups, followed by post-hoc pairwise comparisons with Bonferroni correction. Effect sizes were calculated using Cohen's *f* statistic to assess the magnitude of observed differences. Data analysis was conducted using IBM SPSS Statistics version 29, with inter-rater reliability cross-validated to ensure consistency of observations (McCredie & Morey, 2018).

Ethical Considerations

The study received approval from the Ethics Committee of the Latvian Academy of Sport Education (LASE) (May 31, 2024, No. 3/51813). Parental informed consent was obtained for all child participants. The research adhered strictly to ethical standards governing scientific investigations involving minors, prioritizing participant safety and compliance with established ethical norms. The investigation focused on examining the influence of judo philosophy-based exercises on children's virtues development within the Health and Physical Activity curriculum of a preschool educational institution.

Results

Participants were assessed on 26 indicators, grouped into 11 criteria and 4 virtues: Friendship, Respect, Honesty, and Participation. Scores were normalized using two-staged min-max normalization and converted into a scale from 0 to 1. Median values and interquartile ranges (Q1–Q3) for each virtue are shown in Table 1.

Table 1. Descriptive statistics indicators for virtue assessments according to the author's methodology

Groups	Virtues	Median	Q1-Q3
VZSS without experience (n=12)	Friendship	0.260	0.109-0.734
	Respect	0.292	0.083-0.632
	Honesty	0.083	0.000-0.493
	Participation	0.375	0.000-0.500
VZSS 1 year (n=12)	Friendship	0.688	0.396-0.922
	Respect	0.972	0.792-1.000
	Honesty	0.972	0.667-1.000
	Participation	1.000	0.813-1.000
VZSS 2 years (n=12)	Friendship	0.802	0.427-1.000
	Respect	1.000	0.903-1.000
	Honesty	1.000	0.917-1.000
	Participation	1.000	1.000-1.000

As seen in Table 1, children with two years of judo experience demonstrated the highest median scores across all virtues. A progressive trend is observed in each virtue, with values increasing from the group with no experience to the group with two years of training. This pattern suggests that sustained participation in judo-based educational activities positively correlates with the development of prosocial values.

As illustrated in Fig. 1-4 below, preschoolers with longer judo experience (2 years) demonstrated higher median scores in all four virtues compared to novices. The boxplots show a progressive increase in scores with increased training duration, with visibly reduced variability in the most experienced group.

The group with two years of experience consistently scored higher than the other groups, especially for honesty and participation. The novice group showed the lowest scores in all categories, indicating minimal spontaneous development of virtues without structured pedagogical intervention.

The effect sizes in statistically significant tests ranged from medium to large, confirming the practical significance of the results.

The non-parametric Kruskal-Wallis H test was used to determine if there were statistically significant differences in virtue scores among the three independent groups.

For each virtue, the following were computed:

- H-value and p-value (Kruskal-Wallis test exact significance was used in view of small sample sizes);
- Post-hoc comparisons using Bonferroni adjustment;
- Effect size coefficients: Cohen's *f* for overall Kruskal-Wallis test and Cohen's *r* for pairwise comparisons;
- Z-statistics and mean ranks.

Friendship

The results of a comparative analysis of the friendship virtue between the three groups are illustrated in Fig. 1 and Tables 2 and 3 below.

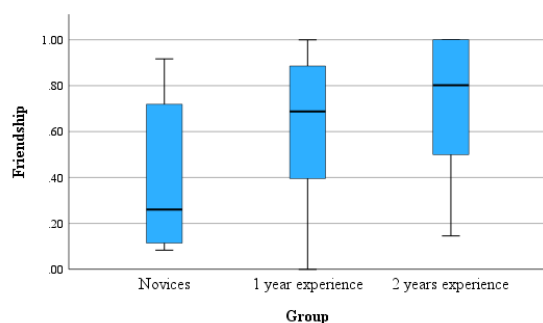


Fig. 1. Distribution of scores on friendship across groups of children with different experience in judo training

The below table summarises the results obtained in the Kruskal-Wallis test for the virtue friendship.

Despite the overall significance of the Kruskal-Wallis test exceeds the threshold of 0.05, the effect size estimation (Cohen's *f* being larger than 0.4 signifying large difference between the groups) makes us to proceed with

Table 2. Virtue: Friendship – Kruskal-Wallis test results

Group	n	Mean Rank	Kruskal-Wallis H-statistic	p	Cohen's <i>f</i>
Novices	12	12.88			
1-year experience	12	19.42	5.961	0.051	0.453
2-year experience	12	23.21			(large effect)

further pairwise comparisons (Table 3) and to confirm the statistically significant difference between the two extreme groups: novices and children with 2-year experience.

Table 3. Virtue: Friendship - pairwise comparisons across groups

Comparison	Z statistic	p-value (adjusted)	Cohen's <i>r</i>
Novices vs 1-year experience	1.528	0.380	0.311 (medium effect)
Novices vs 2-year experience	2.413	0.047	0.493 (medium effect)
1-year vs 2-year experience	0.885	1.000	0.181 (small effect)

Children in the 1-year experience group have their friendship scores in between of the groups of novices and 2-year experience group, but the effect sizes are smaller and these differences do not reach the level of statistical significance.

Respect

The results of a comparative analysis of the respect virtue between the three groups are illustrated in Fig. 2 and Tables 4 and 5 below.

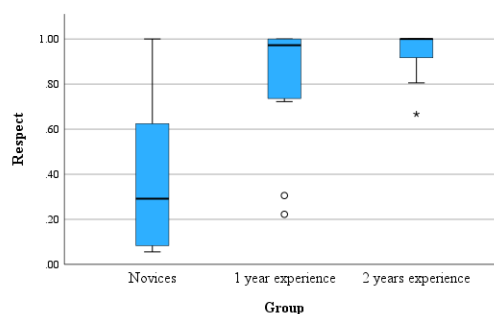


Fig. 2. Distribution of scores on respect across groups of children with different experience in judo training

The below table summarises the results obtained in the Kruskal-Wallis test for the virtue respect.

The overall significance of the Kruskal-Wallis test and the effect size estimation (Cohen's *f* being larger than 0.4 signifying large difference between the groups) make us to proceed with further pairwise comparisons (Table 5) and to confirm the statistically significant difference between the

Table 4. Virtue: Respect – Kruskal-Wallis test results

Group	n	Mean Rank	Kruskal-Wallis H-statistic	p	Cohen's f
Novices	12	10.00			
1-year experience	12	20.96	13.612	0.001	0.798 (large effect)
2-year experience	12	24.54			

novices on the one side and both experienced groups on the other side.

Table 5. Virtue: Respect - pairwise comparisons across groups

Comparison	Z statistic	p-value (adjusted)	Cohen's r
Novices vs 1-year experience	2.668	0.023	0.545 (large effect)
Novices vs 2-year experience	3.541	0.001	0.723 (large effect)
1-year vs 2-year experience	0.873	1.000	0.178 (small effect)

Despite children in 2-year experience group demonstrate higher scores on virtue respect than those in 1-year experience group, the difference between them has small effect size and is not statistically significant.

Honesty

The results of a comparative analysis of the honesty virtue between the three groups are illustrated in Fig. 3 and Tables 6 and 7 below.

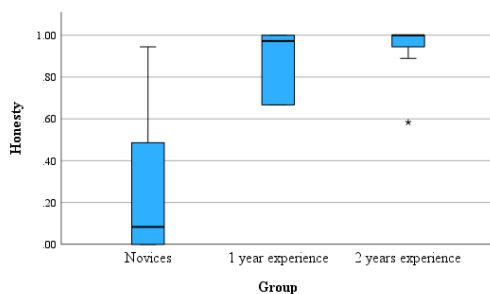


Fig. 3. Distribution of scores on honesty across groups of children with different experience in judo training

The below table summarises the results obtained in the Kruskal-Wallis test for the virtue honesty and subsequent post-hoc group pairwise comparison.

Table 6. Virtue: Honesty – Kruskal-Wallis test results

Group	n	Mean Rank	Kruskal-Wallis H-statistic	p	Cohen's f
Novices	12	8.38			
1-year experience	12	21.38	19.097	<0.001	1.096 (large effect)
2-year experience	12	25.75			

Similarly to the above analysis of the virtue respect, the overall significance of the Kruskal-Wallis test and the effect size estimation make us to proceed with further pairwise comparisons (Table 7) and to confirm the statistically significant difference between the novices on the one side and both experienced groups on the other side.

Table 7. Virtue: Honesty - pairwise comparisons across groups

Comparison	Z statistic	p-value (adjusted)	Cohen's r
Novices vs 1-year experience	3.143	0.005	0.642 (large effect)
Novices vs 2-year experience	4.201	<0.001	0.858 (large effect)
1-year vs 2-year experience	1.058	0.870	0.216 (small effect)

Despite children in 2-year experience group demonstrate higher scores on virtue honesty than those in 1-year experience group, the difference between them has small effect size and is not statistically significant.

Participation

The results of a comparative analysis of the participation virtue between the three groups are illustrated in Fig. 4 and Tables 8 and 9 below.

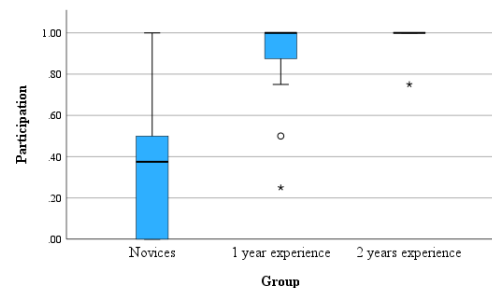


Fig. 4. Distribution of scores on participation across groups of children with different experience in judo training

Table 8 summarises the results obtained in the Kruskal-Wallis test for the virtue participation.

Table 8. Virtue: Participation – Kruskal-Wallis test results

Group	n	Mean Rank	Kruskal-Wallis H-statistic	p	Cohen's f
Novices	12	8.50			
1-year experience	12	22.00	20.959	<0.001	0.453 (large effect)
2-year experience	12	25.00			

The overall significance of the Kruskal-Wallis test and the large effect size estimation make us to proceed with further pairwise comparisons (Table 7) and, as in the previous two comparisons, to confirm the statistically significant difference between the novices on the one side and both experienced groups on the other side.

Table 9. Virtue: Participation - pairwise comparisons across groups

Comparison	Z statistic	p-value (adjusted)	Cohen's r
Novices vs 1-year experience	3.516	0.001	0.718 (large effect)
Novices vs 2-year experience	4.297	<0.001	0.877 (large effect)
1-year vs 2-year experience	0.435	1.000	0.089 (no effect)

Again, children in 2-year experience group demonstrate higher scores on virtue participation than those in 1-year experience group, but the difference between them has negligible effect size and is not statistically significant.

The results of all four virtue development comparisons confirm that preschoolers with more extensive judo experience demonstrate higher levels of virtues, especially honesty and participation. This supports the view that judo, as a discipline based on ethical behavior, provides a favorable environment for values-based education. These findings are consistent with previous research highlighting the role of martial arts in social-emotional learning. The structured and repetitive nature of judo may enhance prosocial behavior even in the early stages of development.

Discussion

The aim of this study is to investigate the perception and development of the virtues of Friendship, Respect, Honesty and Participation in preschool children with different levels of experience in judo philosophy-based physical activity. The results provide strong evidence that structured physical activity based on judo philosophy significantly contributes to the development of virtues in preschool children (Kowalczyk et al., 2023). Data analysis revealed a consistent and positive trend in the development of virtues corresponding to the amount of experience in judo philosophy-based physical activity, with the highest scores observed in the group with two years of experience (Krauze et al., 2024).

The most pronounced differences were found in the domains of Honesty and Participation, where the effect sizes were large and statistically significant between the novice and two-year experience groups. These results are in line with the core principles of judo, which emphasize ethical behavior, self-control and mutual respect. Because judo-philosophy-based activities often require rule-following, fair play, and cooperation, they inherently provide a context for the development of these virtues (Kano & Murata, 2005; Bradić, 2023).

Interestingly, although both the one- and two-year-old groups outperformed novices on most virtues, no significant differences were observed between the two experienced groups in follow-up comparisons, suggesting a possible threshold effect: the development of most virtues may occur during the initial period of structured instruction in judo-philosophy-based physical activity. This is consistent with findings from other early childhood interventions indicating that the most rapid virtuous and behavioral gains occur during the first months of systematic social-emotional learning (Blewitt et al., 2021; Mondì et al., 2021).

The observed low scores among novice children on all virtues may reflect the limitations of unstructured or spontaneous virtue development at this age. This highlights the importance of intentional pedagogical efforts to nurture social and ethical competencies. The results of this study support the growing body of literature advocating for values-based curriculum in early childhood, particularly those that include physical activity based on judo philosophy (Jotov & Ratković, 2024; Parry et al., 2024).

Furthermore, the author's observation scale used in the study was effective in differentiating the levels of virtue among children with different levels of involvement in physical activity based on judo philosophy. Its structure, including 11 criteria and 26 indicators, allowed for a nuanced assessment adapted to preschoolers' developmental stages. This supports the methodological validity of using structured observation instruments in studies of virtue education in preschoolers (Davison et al., 2016).

However, several limitations of the study should be acknowledged. Although the sample size was sufficient for non-parametric statistical procedures, it limits the generalizability of the findings. Furthermore, the limited number of participant groups and the short duration of the observation period restricted the ability to track the dynamics of virtues development in preschoolers over time (Killen & Dahl, 2021; Alexander, 2016). Previous studies emphasize the importance of longitudinal designs and broader sample coverage when exploring value formation in early childhood (Niyozova, 2025). Future research should therefore consider expanding the sample size, applying longitudinal approaches, and testing the developed observation scale across diverse preschool environments and within alternative physical education models rooted in judo philosophy (Kozdras, 2019).

Conclusions

The results of this study indicate that preschool children's recognition and embodiment of the virtues of friendship, respect, honesty, and participation are significantly related to the length of their participation in judo-based educational programs. Analysis of the data revealed a clear and consistent pattern: children who had been practicing judo for two years scored significantly higher on all measured virtues compared to those with shorter or no previous experience.

The observation instrument developed by the author, the Virtue Observation Scale, was found to be a reliable and valid tool for assessing and comparing social and ethical behavior among preschool children in a judo-based physical education program. Statistically significant differences emerged not only between novices and experienced participants, but also between children with one and two years of training, highlighting the progressive nature of virtue acquisition over time.

These findings support the inclusion of Judo-based educational initiatives in preschool curricula as an effective approach to fostering positive behavior and character development. Furthermore, the study highlights the need for ongoing and systematic participation in such programs to promote sustainable development of virtues during the formative years.

Implications for Practice:

Integrate structured, value-based physical education activities based on Judo philosophy into preschool

educational frameworks, emphasizing virtues such as friendship, respect, honesty, and participation.

Ensure continuity and frequency of the program, as long-term participation (at least one year) significantly enhances virtue development in children aged 5 to 6 years.

Use validated observation tools such as the Virtue Observation Scale to regularly monitor and assess social and virtuous behaviors during early childhood.

Provide training for preschool teachers and coaches in values-based pedagogy inspired by the philosophy of judo to support a consistent focus on cultivating kind and ethical behavior.

Promote an environment that encourages the internalization and practical application of virtues beyond physical exercise and into everyday social interactions.

Promote collaboration between parents, teachers, and coaches to enhance the development of virtues in both educational settings and at home.

Conflict of Interest Statement

The authors declare that they have no conflict of interest related to this study.

References

- Wulandari, I. I., & Suhma, F. M. (2024). Developing Prosocial Skills in 4–5-Year-Olds Through Collaborative Learning Models: A Qualitative Study. *GENIUS: Indonesian Journal of Early Childhood Education*, 5(2), 157–168. <https://doi.org/10.35719/gns.v5i2.177>
- Chi-Kin Lee, J., Wong, K. L., & Kong, R. H. M. (2021). Secondary school teachers' self-efficacy for moral and character education and its predictors: a Hong Kong perspective. *Teachers and Teaching*, 27(1–4), 32–47. <https://doi.org/10.1080/13540602.2021.1920907>
- Arda Tuncdemir, T.B., Burroughs, M.D., & Moore, G. (2022). Effects of philosophical ethics in early childhood on preschool children's social-emotional competence and theory of mind. *International Journal of Child Care and Education Policy*, 16(1), 5.
- Song, I. (2022). A Study on the Teaching Method of Judo Subjects as Practical Personality Self-Reflection and Martial Arts. *International Journal of Martial Arts*, 7(1), 1–12.
- Kwok, W.W. (2024). *Strategies for Integrating Martial Arts-Based Mindfulness Into Educational Settings* (Doctoral dissertation, Northeastern University). <https://doi.org/10.17760/D20649864>
- Křižalkovičová, Z., Szabó, P., Kumli, K., Štefanovský, M., Makai, A., & Szentpéteri, J. (2024). Neurodevelopmental benefits of judo training in preschool children: a multinational, mixed methods follow-up study. *Frontiers in Psychology*, 15, 1457515. <https://doi.org/10.3389/fpsyg.2024.1457515>
- Jadwiszczak, M., Wawrzyniak, S., & Pezdek, K. (2025). More than movement: a systematic review of moral and social development in adolescents physical education. *BMC Public Health*, 25(1), 2076. <https://doi.org/10.1186/s12889-025-23169-2>
- Soengkono, M.S. Y.R. (2024). *Customers' Expectations and Perceptions of SERVQUAL Dimensions in Children's Martial Arts Programs* (Doctoral dissertation, California Southern University).
- Martín-Rodríguez, A., Gostian-Ropotin, L.A., Beltrán-Velasco, A.I., Belando-Pedreño, N., Simón, J.A., López-Mora, C., Navarro-Jiménez, E., Tornero-Aguilera, J.F., & Clemente-Suárez, V.J. (2024). Sporting Mind: The Interplay of Physical Activity and Psychological Health. *Sports*, 12(1), 37. <https://doi.org/10.3390/sports12010037>
- Garbeloto, F., Miarka, B., Guimarães, E., Gomes, F. R. F., Tagusari, F. I., & Tani, G. (2023). A New Developmental Approach for Judo Focusing on Health, Physical, Motor, and Educational Attributes. *International Journal of Environmental Research and Public Health*, 20(3), 2260. <https://doi.org/10.3390/ijerph20032260>
- Shishida, F. (2012). A Judo that incorporates Kendo: Jigoro Kano's ideas and their theoretical development. *Archives of Budo*, 8(4), 225–233.
- Jarilkapovich, M.A. (2025). Program Technology for Choosing an Effective Educational Methodology Based on Modern Pedagogical Research in The Educational System. *Current Research Journal of Pedagogics*, 6(02), 30–33.
- Borich, G. D., & Tombari, M. L. (2021). *Educational psychology: A contemporary approach*.
- Birhan, W., Shiferaw, G., Amsalu, A., Tamiru, M., & Tiruye, H. (2021). Exploring the context of teaching character education to children in preprimary and primary schools. *Social Sciences & Humanities Open*, 4(1), 100171. <https://doi.org/10.1016/j.ssaho.2021.100171>
- McCredie, M. N., & Morey, L. C. (2018). Evaluating new supplemental indicators for the Personality Assessment Inventory: Standardization and cross-validation. *Psychological Assessment*, 30(10), 1292. <https://doi.org/10.1037/pas0000574>
- Kowalczyk, M., Zgorzalewicz-Stachowiak, M., & Kostrzewa, M. (2023). Health Outcomes of Judo Training as an Organized Physical Activity for Children and Adolescents: A Literature Review. *Children*, 10(8), 1290. <https://doi.org/10.3390/children10081290>
- Krauze, J., Ābele, A., & Bula Biteniece, I. (2024). Interrelations between the Morals of 5–6 Year Old Children and Balance Exercises in Judo Physical Activities. *LASE Journal of Sport Science*, 15(1–2). https://doi.org/10.25143/lase_joss.v15i1-2.04
- Kano, J., & Murata, N. (2005). Mind over muscle: Writings from the founder of judo. *Revista de Artes Marciales Asiáticas*, 1(3–2006), 89. <https://doi.org/10.18002/rama.v1i3.262>
- Bradić, S. (2023). *Judo as a Method of Moral and Psychological Development*.
- Blewitt, C., O'Connor, A., Morris, H., May, T., Mousa, A., Bergmeier, H., Nolan, A., Jackson, K., Barrett, H., & Skouteris, H. (2021). A systematic review of targeted Social and Emotional Learning interventions in early childhood education and care settings. *Early Child Development and Care*, 191(14), 2159–2187. <https://doi.org/10.1080/03004430.2019.1702037>
- Mondi, C.F., Giovanelli, A., & Reynolds, A.J. (2021). Fostering socio-emotional learning through early childhood intervention. *International Journal of Child Care and Education Policy*, 15(1), 1–43.
- Jotov, M., & Ratković, T. (2024). A proposal for applying the Kaizen method in youth and professional sports. *Baština*, 34(62). <https://doi.org/10.5937/bastina34-48549>
- Parry, J., Martínková, I., & Reppold Filho, A.R. (2024). Sport ethics around the globe. *Movimento*, 30, e30051. <https://doi.org/10.22456/1982-8918.143568>

- Davison, I., Harrison, T., Hayes, D., & Higgins, J. (2016). How to assess children's virtue literacy: methodological lessons learnt from the Knightly Virtues programme. *Journal of Beliefs & Values*, 37(1), 16-28. <https://doi.org/10.1080/13617672.2016.1141526>
- Killen, M., & Dahl, A. (2021). Moral Reasoning Enables Developmental and Societal Change. *Perspectives on Psychological Science*, 16(6), 1209-1225. <https://doi.org/10.1177/1745691620964076>
- Alexander, H. A. (2016). Assessing virtue: measurement in moral education at home and abroad. *Ethics and Education*, 11(3), 310-325. <https://doi.org/10.1080/17449642.2016.1240385>
- Niyozova, M. . (2025). Methodological approaches to the formation of spirituality and moral qualities in preschool children. *Journal of Multidisciplinary Sciences and Innovations*, 1(2), 86-91. Retrieved from <https://inlibrary.uz/index.php/jmsi/article/view/85214>
- Kozdras, G.P. (2019). Empathy in children practising judo compared to their non practicing peers. *Revista de Artes Marciales Asiáticas*, 14(2s). <https://doi.org/10.18002/rama.v14i2s.5950>

Комплексний аналіз сприйняття чеснот у дошкільнят віком 5–6 років з різним досвідом занять дзюдо на основі авторської шкали

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 9 табл., 4 рис., 28 джерел.

Мета дослідження. Дослідження мало на меті проаналізувати сприйняття та розвиток чеснот у дітей віком 5–6 років з різним досвідом занять, заснованих на філософії дзюдо.

Матеріали та методи. У представленому дослідженні взяли участь 36 дітей дошкільного віку, розділених на три групи залежно від їхнього досвіду в дзюдо: новачки (без попереднього досвіду), один рік і два роки практики. На цьому віковому етапі тренування не включали техніки кидків і зосереджувалися на основних елементах, підготовчих вправах та ігрових формах, що відповідають принципам дзюдо. Розроблено авторську шкалу спостереження для оцінки чотирьох чеснот — дружби, поваги, чесності та залучення. Збір даних здійснювався за допомогою структурованих спостережень під час занять фізичною активністю та піддавався кількісному аналізу.

Результати. Діти з тривалішим досвідом занять дзюдо продемонстрували значно вищі показники за всіма оцінюваними чеснотами порівняно з новачками. У групі, яка мала дворічну практику, було досягнуто найвищих результатів у категоріях дружба та повага, що свідчить про позитивну роль освітньої діяльності на основі дзюдо у вихованні моральних цінностей.

Висновки. Дослідження підкреслює важливість інтеграції занять на основі дзюдо не тільки як фізичного тренування, але й як педагогічного інструменту для культивування соціальної та емоційної компетентності в ранньому дитинстві. Результати підтверджують ефективність застосування авторської шкали спостереження для моніторингу розвитку чеснот у дошкільній освіті.

Ключові слова: чесноти, діти дошкільного віку, філософія дзюдо, дошкільна освіта, шкала спостереження за чеснотами, розвиток.

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The Meaning of Pedagogical and Research Practice in Physical Education and Sports Degree Programs in the City of Medellín

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Abstract

Objectives. The study aimed to explore the meaning of pedagogical and research practice in physical education teacher training in the city of Medellín, as part of a broader study on the Pedagogical Content Knowledge (PCK) of these professionals regarding research.

Materials and Methods. An interpretive approach with a multiple case study design was employed. Semi-structured interviews, validated by experts, were conducted with 18 teachers from the four universities that offer degrees in physical education and sports in the city of Medellín. The data was analyzed using Atlas.ti v25 software through open, axial and selective coding.

Results. Six key purposes of pedagogical and research practice were identified: training the teacher-researcher, developing critical thinking, combining theory and practice, contextual reading, recognizing professional fields of action, and training in research. Project-based learning was found to be a recurring methodology. Furthermore, a tension was identified between traditional practical training in physical education and the need to develop research skills.

Conclusions. Pedagogical and research practice should overcome the dichotomy between theory and practice through active pedagogies, develop skills for contextualized action research, and address various professional fields. The study contributes a framework for redesigning curricula that integrate research as a cross-cutting theme in physical education teacher training.

Keywords: pedagogical practice, research, physical education, initial training, teacher.

Introduction

Teacher training is a recurring field of study within the lines of research in different disciplines that focus on education. The aim is to “understand the triad of policy, practice, and research as a model for understanding, intervening, transforming, and building knowledge in the field of teacher training.” (Cisternas, 2011, p. 133). In this way, it stands as a field with discussions of scientific relevance in the area of education, since it allows questions and discussions to be raised in order to shape a theoretical and research corpus that can guide public policies and training practices carried out within teacher training (Burgos Calderón & Cifuentes Garzón, 2015), given that teachers

are immersed in the educational process and represent a mediating figure who, as an actor in the educational system responsible for training and cultural reproduction, establishes a pedagogical relationship with their students based on a common mission: to form an ideal subject.

On the other hand, it is imperative to mention the fact that society is in constant evolution, and education as a development strategy tries to respond to its demands, making its goals, purposes, philosophical positions, and management frameworks continually adapt to promote social and cultural development (Díaz Domínguez & Alemán, 2008). This justifies the education system taking on a fundamental purpose for its students: to develop the ability to discern, identify, and overcome the limitations of established knowledge, while simultaneously teaching them to think critically and independently, without dissolving the essence of thought, where the teacher emerges as a mediator between social demands and education.

Thus, pedagogical knowledge and its construction have been the subject of relevant study in the field of education. Therefore, this issue is fundamental to understanding how teacher training is approached with respect to the disciplinary knowledge that education professionals must have. In this sense, Lemus (1997) defines pedagogy as the “intentional, systematic, and scientific study of education” (p. 43), which, laconically, is configured as the science of education oriented toward theoretical reflection on the educational phenomenon.

Accordingly, educational theory and practice are fundamental concepts that give meaning to pedagogical practice, which emerges as a space for the application, reflection, and transition of theoretical knowledge acquired during teacher training into contextualized educational experiences, through which future professionals acquire fundamental skills for their work in the classroom. (Tardif, 2014). Its importance lies in providing future teachers with a space for reflection in which they can connect theory with educational reality, thus fostering the construction of a solid professional identity. It also promotes the development of teaching and methodological skills appropriate to the sociocultural context in which they work and the acquisition of a critical view of their own professional performance. This training process empowers future teachers with their professional work and social responsibility.

In addition, when future teachers are faced with a practical scenario, they are expected to engage in reflection on their practice “in order to improve and/or strengthen it and, from that point, develop new knowledge, as in their professional practice they will continue to teach and build knowledge when faced with particular situations in the classroom” (Díaz Quero, 2006, p. 89). This allows for a situated reading of current educational, pedagogical, and didactic contexts, which in turn implies the emancipation of the realities of children and young people through their educational work, recognizing the situated experiences of students and enhancing their development.

Within this exercise of experiencing and inhabiting the educational phenomenon (Di Franco, 2023), research has been linked as a recurring tool for teaching practice, since through inquiry, future teachers can build pedagogical knowledge from their specific context of action (Burgos Calderón & Cifuentes Garzón, 2015). Authors such as Stenhouse (2012) have developed a theoretical corpus to conceptualize teachers as researchers of their own practice, which must transcend the technical application and reproduction of knowledge to advance the production of knowledge in education.

In this way, the practical training of education professionals has become immersed in the field of research, thus taking on a pedagogical and investigative character (pedagogical and research practice, PRP) (Bolívar Osorio, 2019). This relationship is established so that, when future teachers face an educational scenario, they can integrate formative research as a tool for reflection and the construction of knowledge based on experience, as well as being able to respond to different problems that may arise in the scenario in which they are involved (Bolívar Osorio, 2021). At the same time, research training is integrated, as it allows future teachers to learn about and appropriate different methodological tools belonging to the field of educational

science. This appropriation facilitates the configuration of best practices through rigorous research that leads to the transformation of educational realities with scientific basis and contextual relevance (García López, 2015).

Focusing on the specific field of Physical Education (PE) (Pérez Restrepo, 2024), allows the traditional dichotomy between theory and motor praxis to be overcome, promoting a teaching profile that builds pedagogical knowledge based on systematic reflection on its educational action in movement contexts. The starting point is the problem that those who train as PE teachers have a strong tendency to develop more pragmatic than theoretical, investigative, and reflective skills. This is due to the large number of career opportunities other than teaching that are integrated into the training: sports coach, sports administrator, physical activity and health instructor, health professional, among others (Pérez Restrepo, 2024). Thus, within the PRP in PE teacher training, it is mandatory to have at least one year of teaching experience in an educational institution, whether at preschool, elementary, middle, or high school level.

This integration allows future PE teachers to acquire theoretical and practical knowledge by addressing different subjects that are fundamental to their work as teachers in the school setting, where motor development, body expression, sports initiation, and inclusion through movement are highlighted (Cuervo Jiménez, 2024). In this context, the acquisition of physical fitness and skills such as sociomotor (Pérez Restrepo et al., 2024), psychomotor (Patiño Ardila et al., 2020) and perceptual-motor skills (Cuervo Zapata et al., 2023) are fundamental to human development (Castañer Balcels & Camerino Foguet, 2013).

Therefore, research in PE ceases to be an activity exclusive to external specialists and becomes a constitutive dimension of professional teaching practice, where the PE teacher-researcher develops skills to systematically observe motor behaviors, analyze bodily learning processes, design innovative teaching proposals, and evaluate their impact on the comprehensive development of students. For all the above reasons, it is necessary to question the meaning of pedagogical and research practice (PRP) in PE, since, as mentioned, physical educators, at least in Colombia, have a wide range of career opportunities, skills, and knowledge that must be continuously developed and evaluated in relation to their area of activity. Therefore, this study aims to reveal the meaning of PRP in PE from the perspective of teachers with degrees in PE from universities in the city of Medellín.

Materials and Methods

Sample Selection

The sample was selected using intentional and convenience sampling, considering that participants were selected based on their accessibility and proximity to the researcher (Sandoval Casilimas, 1996). Thus, the group of interest in this study consisted of 18 teachers from the aforementioned universities. The inclusion criteria were: being an active teacher in the PE and sports degree program at one of the aforementioned universities and being a professional practice advisor. The exclusion criteria were: not being an active teacher, not teaching any of the aforementioned courses, and not signing the informed consent form.

Design and Procedures

The study is based on an interpretive approach, as its main purpose is aligned with the understanding and interpretation of human experiences and actions in a specific historical and social context, where social, educational, and personal practices emerge. This is based on a descriptive and comprehensive interest in reality through its social actors (Bolívar, 2004; González Palacio, 2019). The nature of this research is qualitative, as the data are unstructured, given that they arise from the voices of the participants (González Palacio, 2019; Strauss & Corbin, 2002). In turn, qualitative studies focus on “studying reality in its natural context, as it happens, trying to interpret phenomena according to the meanings they have for the people involved” (Rodríguez et al., 1996, p. 32).

On the other hand, the design of this research is that of a case study (Chaverra Fernández et al., 2019), since it focuses on understanding the meaning of PRP, it is framed within a specific experience. In this way, it is configured as a multiple case since, as it is carried out with teachers from PE degree programs at different universities, each one refers to a case, and they are developed simultaneously in order to understand, explore, and identify the reality of the object to be studied (Galeano Marín, 2018; Stake, 1998). Thus, four cases are presented, corresponding to the bachelor's programs in physical education and sports offered in the city of Medellín, corresponding then to the University of San Buenaventura, the University of Antioquia, the Minuto de Dios University Corporation and the Jaime Isaza Cadavid Polytechnic.

Information Gathering Techniques

Data collection was carried out using interviews, which, according to Díaz-Bravo et al. (2013), “are a technical instrument that takes the form of a colloquial dialogue” (p. 163). This “allows for the collection of more in-depth and detailed information that even the interviewee and interviewer had not identified, as it adapts to the context and characteristics of the interviewee” (2013, p. 166). In addition, it was developed in depth in order to reveal detailed information about the object of study through life stories and experience.

On the other hand, the question guide was sent to three experts in the field of education and physical education and validated through the procedure proposed by Hernández Nieto (2002). It is evident that the 24 questions that make up the guide initially 22 have excellent content validity ($CVC > 0.90$) and two have acceptable validity ($0.71 < CVC < 0.80$), so the interviews were conducted using the initial guide for implementation. Now, it is important to note that this research was approved by the bioethics committee of the University of San Buenaventura in Medellín (11/08/2024) and was determined to be risk-free according to Resolution 8430 of 1993 of the Colombian Ministry of Health.

Qualitative Analysis

Subsequently, the information was collected in a comfortable, closed space, in an office provided by the university to which the teacher under investigation belonged.

Each interview was audio recorded and then manually transcribed in Microsoft Word. The analysis was carried out using Atlas.ti version 25, employing open and axial coding techniques (Strauss & Corbin, 2002), procedures that allow the data to be fragmented and reconfigured in order to reveal differences and similarities between the cases investigated in relation to the meaning of pedagogical and research practice.

Finally, the report of the results was prepared based on the Standards for Reporting Qualitative Research (SRQR) offered by O'Brien et al. (2014), which provide a structured framework for communicating this type of research with transparency and scientific rigor. In this sense, each category of analysis is supported by a testimony extracted from the different interviews, which were coded as follows: initially, reference is made to the type of document, interview (Int.), followed by the citation code generated by the analysis program, for example 1:22, where the first number is linked to the subject or interview number and the second to the citation sequence coded in Atlas.ti.

Results

Initially, the subjects surveyed were characterized (Table 1). As mentioned above, this group consisted of 18 teachers who were advisors for teaching practice in physical education and sports degree programs.

In terms of gender, the sample consisted of 61.1 % men and 38.9 % women. In terms of professional training, there was a predominance of teachers with a bachelor's degree in physical education and sports, accounting for 77.8 %. At the same time, it is important to note that, despite being an undergraduate degree, not all teachers have training in this specific area, as there were professionals with training in biomedical engineering (5.6 %), physical therapy (5.6 %), special education (5.6 %), and sociology (5.6 %). This diversity of profiles reflects the trans- and interdisciplinary nature of the field of PE, where different disciplines are integrated for the study of education, the body, sports, and motor skills. With regard to the highest degree attained at the time of the interview, 61.1 % had master's degrees and 38.9 % had doctorates. The vast majority had degrees related to education, PE, and social sciences.

On the other hand, the sample was mostly made up of teachers from the University of Antioquia (33.3 %), an institution where 100 % of the participants had a PhD, followed by the Jaime Isaza Cadavid Colombian Polytechnic (27.8 %), where 100 % of the teachers who participated in the study had a master's degree. The University of San Buenaventura made up 22.2 % of the sample, with one teacher holding a doctoral degree and two holding master's degrees. Finally, the Minuto de Dios University Corporation contributed 16.7 % of the sample, where 100 % of the teachers held master's degrees.

In a second stage, based on the objective of the study, the testimonies and accounts of each of the teachers were analyzed using open and axial coding. The first refers to “the analytical process by which concepts are identified and their properties and dimensions are discovered in the data” (Strauss & Corbin, 2002, p. 110), and the second consists of the “process of relating categories to their subcategories, called ‘axial’ because the coding occurs around the axis of a category and links the categories in terms of their properties and dimensions” (p. 134).

Table 1. Poblacion characterization

Gender	N	%
Male	11	61.1 %
Female	7	38.9 %
Undergraduate degree	N	%
Bachelor's in physical education and sport	14	77.8 %
Biomedical engineering	1	5.6 %
Physioteray	1	5.6 %
Bachelor's in special education	1	5.6 %
Sociology	1	5.6 %
Titulo mas alto	N	%
Master in business administration	1	5.6 %
Master in education	7	38.9 %
Phd in physical education	1	5.6 %
Master in motor skill-human development	2	11.1 %
Phd in didactic innovation and teacher training	1	5.6 %
Phd in business magement	1	5.6 %
Phd in social sciences	1	5.6 %
Phd in physical activity and sport scinces	2	11.1 %
Phd in education	1	5.6 %
Master in exercise physiology	1	5.6 %
Universidad	N	%
University of san buenaventura	4	22.2 %
University of antoquia	6	33.3 %
Jaime isaza cadavid polytechnic	5	27.8 %
Minuto de dios university corporation	3	16.7 %

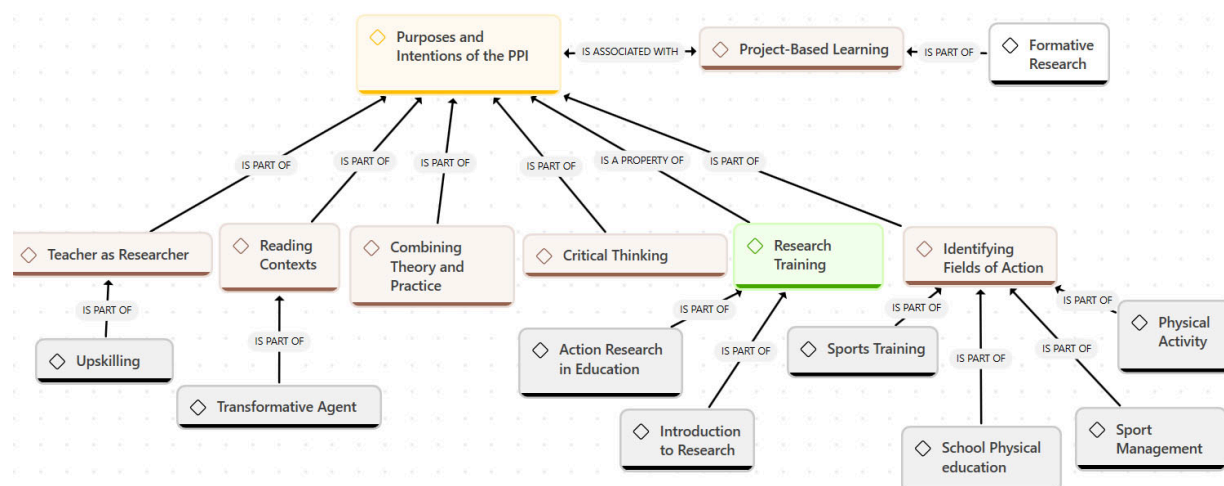
In this vein, we present the semantic network (Figure 1) that accounts for the macro-category: purposes and intentions of PRP. From this, six main categories emerge that refer to the purposes and intentions that give meaning to the investigative pedagogical and research practice (PRP). The first corresponds to the teacher-researcher, which is rooted in one of the fundamental objectives of teacher training in

Colombia (MEN, 2022). The second is closely related to the teacher's ability to read the context in order to transform it or establish a more contextualized practice in line with the environment in which it is developed. The third refers to combining theory and practice, which is linked to the need for teacher trainees to transcend theory and move into the practical sphere of their field of work through PRP. The fourth refers to the development of critical thinking, which allows them to question the reality they experience within the practice center and develop reflective skills about their own teaching actions (Freire, 2005) The fifth falls within the framework of research training, which is linked to research methodology, research from an educational perspective, and methodological aspects such as data analysis

Finally, the sixth category is aimed at recognizing fields of action, which seeks to introduce students to a professional field of practice in order to immerse them in the various job possibilities for physical educators, including sports administration, school physical education, sports training, and the promotion of physical activity for health. Finally, the macro-category is associated with the dimension of Project-Based Learning (PBL), which refers to the teaching methodology used to effectively transpose and articulate all the purposes and intentions of the PRP, allowing the meaning of the PRP in the training of physical educators to be revealed.

These categories and their respective subcategories form a categorical network that complement the analysis of the testimonies and accounts provided by the teachers surveyed, with the aim of integrating the meaning of PRP into the field of PE, allowing for an understanding of the multiple dimensions and relationships that are established in this educational field.

To begin to elucidate the meaning of PRP in the training of PE and sports graduates, it is imperative to name the purposes and intentions that teacher advisors perceive about this fundamental component of teacher training. In this sense, one of the most recurrent objectives is to ensure that future teachers become teacher-researchers, given that "to be a teacher, it is necessary to develop as a reflective professional, since teaching requires questions, ideas, and issues, and therefore teaching demands a minimum amount

**Fig. 1.** Semantic Red of categorical analysis

of research" (Int. 2:9). In addition, this allows future teachers to be at the forefront of knowledge in relation to topics of interest and those that are part of their professional and disciplinary field, such as pedagogy and didactics. Therefore, future teachers must "know how to read science, know how to read advances and apply them to their profession. This exercise is what allows them to develop a spirit of constant questioning, which implies keeping up to date and improving practices in a certain sense" (Int. 2:16). Accordingly, this conception of the teacher-researcher has a direct relationship with the qualification of the future teacher, since being immersed in practice allows "the student to transform. After being in practice, the student is not the same; the student is in a permanent metamorphosis, in the sense that they are improving their praxis" (Int. 3:7). In turn, this has a practical meaning, since PE is increasingly becoming an interdisciplinary and transdisciplinary field in which "the profile of the physical educator is increasingly demanding, increasingly challenging, so it has become necessary to transcend practice and theory to an even more reflective and problem-solving sense, which greatly qualifies the profile in terms of job performance" (Int. 10:6).

Based on this qualification, students develop different skills that enable them to perform adequately in the professional field. Among these, the development of the ability to read and interpret contexts, particularly those in which they intervene or develop their pedagogical practice, stands out as a fundamental purpose of the PRP. This perspective is one of the central axes, as one of the teachers points out:

"In teaching, you always have to assess the students, the institution, and the teachers. You have to understand who you are going to talk to and who you are going to intervene with. This always happens regardless of the grade level or the name of the school or institution" (Int. 1:4).

This contextual analysis skill is considered fundamental in the training of physical educators, as it determines the effectiveness of pedagogical intervention. As another interviewee puts it:

"There are different contexts, different interests, different sociodemographic conditions. This reading of the context often allows students to adapt the curriculum content to specific needs" (Int. 2:11).

This skill allows future teachers to see themselves as agents of change in their practice and social contexts. This conception is rooted in critical perspectives on physical education, in which teachers are seen as transformative intellectuals and promoters of social change (McLaren, 2003). In line with this thinking, the teacher trainers interviewed placed special emphasis on the importance of cultivating this transformative dimension:

"Physical education graduates must be trained with the drive to penetrate the discipline in order to transform the subjects with whom they interact" (Int. 3:4).

This conception of the physical educator as a transformative agent is oriented toward an ethical-political commitment to social transformation from the educational and/or sports sphere. Another teacher reaffirms this vision by mentioning:

"I tell students all the time that they are transformers of life, that they are critical, and that they have the power to change many things through teaching praxis" (Int. 7:5).

The nexus between teaching and research is predicated on the practitioner's capacity to translate questions about educational phenomena into critical self-reflection aimed at transforming their professional context

"If a teacher has a good research base, they question and reflect on their own practice and seek mechanisms or routes to improve the realities in which they intervene and interact all the time" (Int. 16:2).

This dialectical approach between reflection and intervention forms the basis of transformative pedagogical practice in the field of PE, positioning future physical educators as professionals with the critical capacity to contribute to the improvement of educational, sporting, and health promotion conditions in diverse sociocultural contexts.

This perspective reflects a complementarity with the objective of combining the theory learned during their training with practical knowledge that they can use in their practice. In this sense, the teachers pointed out that:

"It is in this practice that you manage to understand what the pedagogy and didactics books say. You have to refer to them in order to plan your practice, whether it is with a certain number of children taking a PE class or with athletes seeking to achieve high performance. With that theory, you have to make some adaptations and develop your skills in the field" (Int. 4:1).

"The importance that is combined in this practice is that theory and practice are interwoven because it allows you to learn how to do and how to be" (Int. 7:1).

In addition, the objective of future teachers developing critical thinking through pedagogical and research practice is reinforced, because "there is an issue there with critical thinking and reflection in students. It is a space where students learn to question the established order, analyze different perspectives, and construct solid arguments based on evidence" (Int. 16:3)

In this context, in order to qualify future teachers, the importance of linking pedagogical practice with research emerges. This gives rise to research training, which refers to the content, actions, and strategies developed in professional training so that students develop attitudes toward the production and adoption of scientific knowledge (Guerrero, 2007). When viewed within the context of training graduates in PE and sports, the teachers surveyed pointed out that:

"It helps students adopt tools that will be useful in their development and professional performance" (Int. 2:5).

"Research will allow them to transform themselves, their practices, and their knowledge" (Int. 11:2).

Following this reasoning, in order to achieve this, there is content that teachers consider essential for students to adopt the logic of research and transcend it within their practice. Initially, there is a clear interest in students understanding research methodology

"It is important that they first recognize the origin of research, scientific knowledge, and its dogmas. I often use a text called Philosophy of Social and Human Sciences, which is excellent for understanding research" (Int. 9:1).

Thus, the integration of various methods emerges within the research training process, which are observed holistically and implemented in a complementary manner in the training of graduates in PE and sports. These methods provide different ways of approaching knowledge. In relation to this methodological diversity, the teachers pointed out:

"I explain everything related to quantitative research, designs, and approaches" (Int. 18:10).

"I focus more on the qualitative. When we talk about school, it is a complex phenomenon, so the questions that arise there are more about understanding. That's why I give them a little bit of phenomenology, hermeneutics, ethnography, and all those qualitative research designs" (Int. 17:4).

Methodological integration is also evident in mixed approaches: "I recently started implementing mixed research, where we do some tests, but then we do interviews" (Int. 16:12). Finally, contemporary approaches emerge that recognize the transdisciplinary nature of PE:

"it is possible to find a relationship with art. That intersection is observed in the object and reflection on the body. So I have implemented the post-qualitative approach that invites us to reconsider corporeality beyond simple biological materiality. We no longer talk only about bodies that move according to biomechanical parameters, but about bodies that are simultaneously materiality and sensitivity" (Int. 9:4).

On the other hand, research training is developed in conjunction with immersion in pedagogical practice, which, as mentioned above, fundamentally means that students, through their research training, can adopt, improve, and develop a praxis related to the specific field in which they practice. In this context, it is essential to understand that pedagogical practice allows students to recognize the various fields of professional action that their training offers them.

"Physical educators can work in gyms, sports clubs, compensation funds, schools, so this practice allows them to identify that and what they like" (Int. 5:4).

"Students choose one of four possible areas of emphasis: academics, sports training, physical activity, and sports administration. That choice is made based on their interests and comfort level" (Int. 10:1).

This perspective is rooted in the idea of two strands of educational research: research on education and research in (from education). According to Pérez Abril (2003), the former refers to all research carried out within an educational institution, while the latter is based on reflection on pedagogical practice itself. In this vein, it is clear that research in (from) education functions as a thematic axis and formative purpose within PRP when future teachers are immersed in school practice:

"The aim is for them to be able to generate knowledge by researching their own practice and, based on this, to improve their practice by researching themselves" (Int.1:28).

"It is the pillar that every teacher must have, because if the teacher has a good practical foundation in research, they question and reflect on their own practice and seek mechanisms or routes to improve the realities they face" (Int. 2:16).

Furthermore, this is linked to the recognition of PE as a dynamic discipline, which implies understanding that "the reality of PE is not static, but rather changes in terms of content, assessment, and new trends" (Int. 16:1). However, reductionist perceptions persist: "Currently, even with much progress, PE is still seen as a subject for recreation, a complementary subject, focused solely on sport" (Int. 7:3). In view of this, the discipline requires future teachers to develop research skills to adapt to its changes and respond

to contextual demands, since, as the same testimony points out, in practice "other areas of knowledge such as the body, motor skills, physiology, and pedagogy are integrated, allowing students to recognize the complex reality of their discipline" (Int. 7:3).

In order for students to achieve these objectives and integrate the different conceptions of Pedagogical and Research Practice (PRP), it is necessary to implement teaching strategies that facilitate an effective didactic transposition from theory to practice. In this context, project-based learning (PBL) stands out as a strategy that allows future teachers to build pedagogical knowledge and appropriate theory through action. According to the literature, PBL is "a learning model in which students actively work, plan, implement, and evaluate projects with real-world applications beyond the classroom" (p. 12, EAFIT).

This methodology involves practical immersion: "They are initially asked to make a diagnosis, from which they identify the project to be developed, followed by a methodological process of accompaniment and intervention to solve the problem addressed" (Int. 10:5). Furthermore, these projects are not limited to intervention, but can be "research, management, or even entrepreneurship, with the aim of linking practice with the development of a project" (Int. 5:7). To achieve this, formative research is integrated, where research becomes a tool in the teaching-learning process, allowing students to articulate theoretical and practical knowledge through research.

In this way, PRP in the training of PE and Sports graduates is seen as a comprehensive process where future teachers are immersed in real contexts to problematize, critically analyze, and transform their professional practice. Through the reading of specific educational situations, they identify problems that give rise to intervention, research, or innovation projects, articulating disciplinary knowledge with applied research methodologies. This immersion fosters a permanent reflective stance, where students, by appropriating conceptual and methodological tools, evolve towards a profile of teacher-researcher, positioning formative research as a cross-cutting axis of pedagogical practice that allows them to question, improve, and reconfigure both educational practices and their own understanding of the discipline.

On the other hand, a Sankey diagram (Figure 1) is presented, which allows us to find patterns that reveal differences and similarities in investigative pedagogical practice among the four physical education training institutions studied.

In this order, it is evident that the University of San Buenaventura has a tendency to emphasize formative research, that is, to integrate research tools for the development of practice rather than rigorous and specific research training. In turn, this is linked to the objective of helping students find their field of interest by understanding age groups and areas of work performance.

For its part, the University of Antioquia presents the most diversified configuration, with significant connections to critical thinking, research methodology, and the ability to read contexts, evidencing a holistic approach to the meaning of PRP, where the critical, the practical, and the transformation of contexts through practice converge.

On the other hand, the Jaime Isaza Cadavid Polytechnic shows a distinctive orientation towards project-based

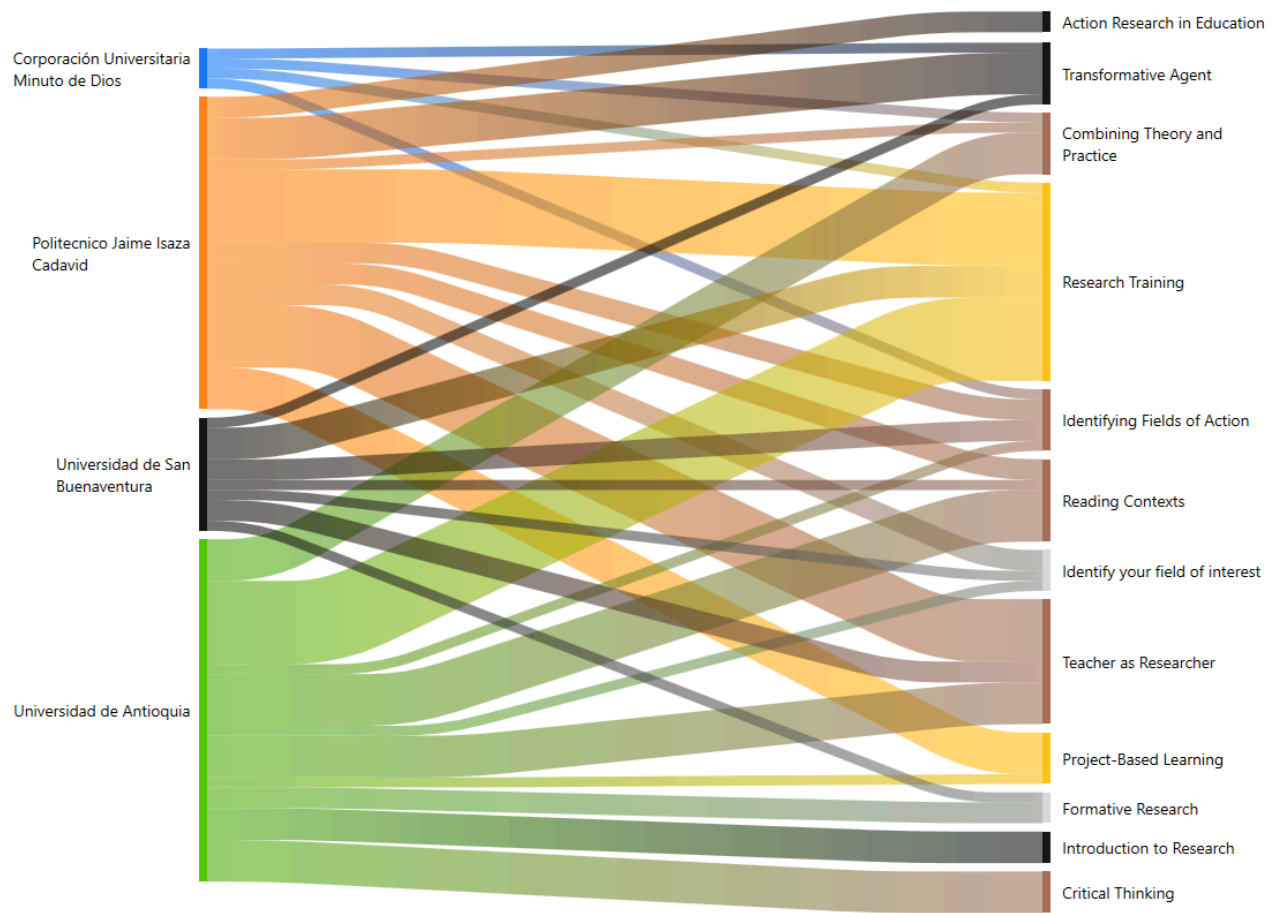


Fig. 2. Sankey diagram

learning and the recognition of professional fields of action, suggesting a training model anchored in contextualized professional competencies, while the Minuto de Dios University Corporation privileges research from education and the disciplinary recognition of PE, thus strengthening the epistemological identity of the field in its students.

These institutional variations coexist with three shared conceptual cores: training in research, the conception of the teacher as a researcher, and the integration of theory and practice, reflecting both the epistemological-pedagogical diversity and the common concerns that currently characterize teacher training in PE in Colombia, where the tension between the specific disciplinary and the general pedagogical constitutes one of the fundamental debates, similar to what is observed in international contexts.

Discussion

In line with the objective of this study to reveal the meaning of PRP in the training of PE and sports graduates in the city of Medellín, it was noted that, after a literature review carried out for data triangulation, academic production on this topic is in its infancy.

However, a quantitative study was found in Colombia (Sanabria Navarro et al., 2024), that designed and validated a questionnaire that allowed for the analysis of PRP in a bachelor's degree program in PE, recreation, and sports. This

study reported that the main focus of the program is on recreation, which is a disadvantage for students in training, given that, within their professional development, when they take up teaching or administrative positions in educational or sports institutions, broader competencies are required. This conclusion is in line with what the teachers in this study said, where the essence of pedagogical practice is that the teacher in training can develop and gain experience in fields that are related to their professional training, which, in the case of PE, is diverse, not just recreational.

In addition, the same study (Sanabria Navarro et al., 2024) highlighted the need for practice to provide the necessary knowledge for job performance, where related aspects are rooted in skills such as critical reflection and research skills, given that these enable students to develop a situated reflection on their own practice that allows them to identify opportunities for improvement in their job performance. This suggests the importance of linking pedagogical practice with research, since its meaning lies in the possibility for students to improve and innovate their own practice through research skills.

The research carried out by Molano Tobar et al. (2021) analyzed the pedagogical practices carried out by PE students in the field of preschool education. It initially complements the findings of this analysis by addressing the emphasis on PE in schools; this perspective is enriched in the sense that, in this emphasis, physical educators are not confined to

a single educational level but, at least in Colombia, have four levels at which they can work (preschool, primary, secondary, and middle school). In this sense, the authors mention the importance of teacher training, at least in the area of PE, requiring teachers to have experience working with preschool-aged children, as this allows them to develop an understanding of how to overcome the dichotomy between theory and practice and recognize the importance of human development theories in order to create meaningful practices with children. In contrast to the cited research, a new line of research is suggested. This perspective emerges from the need to reveal the specific meaning of PRP in each of the four fields of action of the physical educator evidenced in the research: school PE, physical activity and health, sports training, and sports administration.

This line of research contributes significantly to the existing conception of PRP, which has been reductionist and generalized, recognizing that each field of performance demands particular training objectives, differentiated pedagogical strategies, and specific professional competencies, as evidenced in the institutional connections in the diagram, where situated practical knowledge and contextualized recognition of each field constitute the particular training emphases that institutions prioritize in a differentiated manner.

At the international level, the research of Moen and Standal (2016) in Norway stands out, which aimed to understand the relationship between the triad of teacher advisors (university), cooperating teachers (practice center), and future teachers through a qualitative study implementing network analysis and figurative sociology. It was concluded that the core of the practice is the cooperating teachers, as they play a fundamental role in effectively placing future teachers within the construction of their professional identity and their development within the specific area. In contrast to the research carried out, which does not consider the role of these cooperating teachers and places importance on the development and advising of pedagogical projects as a means for the construction of pedagogical knowledge. However, there are similarities in placing practice as a fundamental means for the recognition of fields of work and the recurring concern that students and trainers have to effectively link the theoretical content of the practice, understanding the complexity of PE and the existing imaginary that physical educators are only trained in doing, leaving aside their epistemological content.

Likewise, the study conducted by Bolívar Osorio (2021) found that PRP is based on the objective of promoting an integrative curriculum that allows the knowledge developed in practice to be linked to the epistemological knowledge that is founded within training, linking them to the processes of reflection and improvement of their praxis, coinciding with the foundation of an articulating strategy that combines theory with practice. In the research carried out, there are similarities in the sense that different methodologies are found to transcend this theory-practice dichotomy, which results in or gives rise to active pedagogies and their implementation to carry out investigative and reflective exercises during pedagogical practice.

On the other hand, the research carried out by Ripoll-Rivaldo (2021) with undergraduate students of early childhood education showed that the articulating axis of pedagogical practice is located in didactics, in which students within their teacher training manage to develop new didactic strategies to implement in the classroom,

which combines an amalgam of components that give primacy to professional practice, which are related to the knowledge developed within the practice, the collaboration established between the different agents belonging to the teaching practice, and the development of problem-solving skills in the development of classes. In contrast, the research presented here showed that teachers, at least those in PE, do not have school teaching as their only field, but also have the possibility of working as coaches and administrators, so the articulating axis is not based on an exclusively educational concern, but rather on research skills as an integrating element of the different emphases in which they work.

Finally, with regard to pedagogical practice, it is possible to establish relationships between the results of this study and those of Castillo Gutiérrez and García Sandoval (2017) which confirms the inherent tendency of pedagogical practice to be a reflective component that allows future teachers to analyze real situations in their field of emphasis in order to achieve a transformation within their professional work. Likewise, in both cases, educational research is presented as the articulating axis of reflective practice, recognizing that teachers, within their work, need to develop minimum research skills. In turn, the recognition of contexts plays a fundamental role in pedagogical practice, highlighting the imperative need to understand the sociodemographic and biological conditions of the population to be served before intervening.

However, there are complementary differences between the comparative studies. Regarding the ethical dimension, previous studies emphasize that critical reflection can strengthen the ethical and moral training necessary in teaching. Accordingly, the importance of the teaching role in the 21st century is highlighted, a perspective that was not developed extensively in our study but is considered one of the most important aspects of pedagogical practice. In the current educational environment, there is evidence of the constant evolution of this role and the continuous integration of new methodologies, thus generating emerging paradigms of teaching. This perspective is fundamental to understanding how pedagogical practices effectively allow future physical educators to situate their role within a changing society.

Conclusions

The study concludes that the PRP in PE degree programs is a multifaceted process with several key implications for teacher training.

Integration of Theory and Practice: The PRP serves as a fundamental component for interweaving theory with practice, overcoming the traditional dichotomy between them. It enables future PE teachers to transform academic knowledge into applied professional skills by situating their learning in real-world scenarios.

Development of Reflective and Research Competences: A central purpose of the PRP is to cultivate critical thinking and research skills, preparing students to become teacher-researchers who can systematically reflect on and improve their own practice. This includes training in diverse methodological approaches that allow them to analyze complex educational phenomena related to the body and movement.

Practice as a Tool for Understanding Context and Professional Fields: The PRP is essential for developing the ability to perform an analytical reading of educational

contexts, which allows for curricular adaptations based on the specific needs of the population being served. Furthermore, it provides opportunities for students to recognize and explore the multiple professional fields of action available to a physical educator, including school PE, sports training, health promotion, and sports administration.

Implications for Curriculum Redesign: The findings support the need to redesign curricula to integrate research as a cross-cutting theme in teacher training. It is recommended that programs structure practicums around a progressive Action Research model, using active methodologies like Project-Based Learning (PBL). This approach ensures that practical interventions are grounded in a critical analysis of the context, moving beyond unreflective activism.

Conflict of interest

If the authors have any conflicts of interest to declare.

References

- Cisternas, T. (2011). La investigación sobre formación docente en Chile: Territorios explorados e inexplorados. *Calidad En La Educación*, 35, 131-164. <https://doi.org/10.4067/S0718-45652011000200005>
- Burgos Calderón, D.B., & Cifuentes Garzón, J.E. (2015). La práctica pedagógica investigativa: Entre saberes, querer y poderes. *Revista de La Facultad de Educación, Ciencias Humanas y Sociales*, 17(2), 118-127. <https://dialnet.unirioja.es/servlet/articulo?codigo=5455073>
- Díaz Domínguez, T., & Alemán, P.A. (2008). La educación como factor de desarrollo. *Revista Virtual Universidad Católica Del Norte*, 23, 1-15. <http://www.redalyc.org/articulo.oa?id=194220391006>
- Lemus, L.A. (1997). *Pedagogía: temas fundamentales* (Concepto de Pedagogía, Cap. III). En G. Cordero y M. Quesada (Compiladores) *Educación y Epistemología*, Centro de Investigación y Docencia en Educación (CIDE), Universidad Nacional, 43-52.
- Tardif, M. (2014). *Los saberes del docente y su desarrollo profesional*. NARCEA.
- Díaz Quero, V. (2006). Formación docente, práctica pedagógica y saber pedagógico. *Laurus Revista de Educación*, 12, 88-103. <http://www.redalyc.org/articulo.oa?id=76109906>
- Di Franco, M.G. (2023). Habitar la universidad y las escuelas. *Praxis Educativa*, 27(1), 1-5. <https://doi.org/10.19137/praxiseducativa-2023-270101>
- Bolívar Osorio, R.M. (2019). Investigar la práctica pedagógica en la formación inicial de maestros. *Pedagogía y Saberes*, 51, 9-22. <https://doi.org/10.17227/pys.num51-2881>
- Bolívar Osorio, R.M. (2021). Miradas críticas a la apropiación de la práctica reflexiva en la formación docente. Una revisión de literatura. *Encuentro Educativo*, 2(1), 104-132. <https://revistas.uncu.edu.ar/ojs3/index.php/encuentroE/article/view/4948>
- García López, G. (2015). La investigación en la formación docente inicial. Una mirada desde la perspectiva sociotransformadora. *SABER. Revista Multidisciplinaria Del Consejo de Investigación de La Universidad de Oriente*, 27(1), 143-151. https://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1315-01622015000100017
- Pérez Restrepo, T., Valencia Gómez, M.A., Howard Henry, J.B., & Cuervo Zapata, J.J. (2024). Abordaje de las capacidades socio motrices en la clase de educación física. Una revisión sistemática exploratoria 2019-2024. *EmásF*, 19(90), 15-36. <https://dialnet.unirioja.es/servlet/articulo?codigo=9680280>
- Cuervo Jiménez, D.S. (2024). ¿Y qué es eso llamado Educación Física? Una aproximación hacia la contextualización. *MENTOR Revista de Investigación Educativa y Deportiva*, 3(8), 526-546. <https://doi.org/10.56200/mried.v3i8.7837>
- Patiño Ardila, J.E., Ramírez Berrio, J.H., & Ayala Lopera, D. (2020). *Correlación entre la motivación y las capacidades físicas motrices en la clase de educación física* [Pregrado, Universidad de San Buenaventura]. <http://hdl.handle.net/10819/7978>
- Cuervo Zapata, J.J., Montoya, N.E., & González Palacio, E.V. (2023). Evaluación de las capacidades perceptivo motrices en el contexto escolar – Diseño y validación de una batería (Evaluation of motor perceptual capabilities in the school context – Design and validation of a battery). *Retos*, 47(47), 593-602. <https://doi.org/10.47197/retos.v47.95726>
- Castañer Balcels, M., & Camerino Foguet, O. (2013). *La educación Física en la enseñanza primaria: una propuesta curricular para la reforma*. INDE.
- Sandoval Casilimas, C.A. (1996). *Investigación cualitativa*. ICFES.
- Bolívar, A. (2004). El conocimiento de la enseñanza: explicar, comprender y transformar. *Mimesis-Ciencias Humanas*, 25(1), 17-42. https://secure.unisagrado.edu.br/static/biblioteca/mimesis/mimesis_v25_n2_2004_art_01.pdf
- González Palacio, E. V. (2019). *Representaciones sociales sobre la formación inicial y ser maestro en estudiantes de educación física del departamento de Antioquia* [Doctorado]. Universidad de Antioquia.
- Strauss, A. L., & Corbin, J. M. (2002). *Bases de la investigación cualitativa: técnicas y procedimientos para desarrollar la teoría fundada*. Editorial Universidad de Antioquia, Facultad de Enfermería de la Universidad de Antioquia
- Rodríguez, R., Gil, J., & García, E. (1996). *Metodología de la investigación cualitativa*. Algibe
- Chaverra Fernández, B. E., Gaviria Cortés, D. F., & González Palacio, E. V. (2019). El estudio de caso como alternativa metodológica en la investigación en educación física, deporte y actividad física. Conceptualización y aplicación. *Retos*, 35, 422-427. <https://doi.org/10.47197/retos.v0i35.60168>
- Galeano Marín, M. E. (2018). *Estrategias de investigación social cualitativa. El giro en la mirada* (2nd ed.). Universidad de Antioquia. Facultad de Ciencias Sociales y Humanas. Fondo Editorial FCSH.
- Stake, R. E. (1998). *Investigación con estudio de casos*. Ediciones Morata.
- Díaz-Bravo, L., Torruco-García, U., Martínez-Hernández, M., & Varela-Ruiz, M. (2013). La entrevista, recurso flexible y dinámico. *Investigación En Educación Médica*, 2(7), 162-167. <http://riem.facmed.unam.mx/index.php/riem/article/view/430/397>
- Hernández Nieto, R. (2002). *Contributions to Statistical Analysis*. Universidad de los Andes.
- O'Brien, B. C., Harris, I. B., Beckman, T. J., Reed, D. A., & Cook, D. A. (2014). Standards for Reporting Qualitative Research. *Academic Medicine*, 89(9), 1245-1251. <https://doi.org/10.1097/ACM.0000000000000388>
- Pérez Abril, M. (2003). La investigación sobre la propia práctica como escenario de cambio escolar. *Pedagogía y Saberes*, 18, 70-74. <https://doi.org/10.17227/01212494.18pys70.74>

Sanabria Navarro, J.R., Castillo Gómez, M.E., & Hoyos Babilonia, L. del C. (2024). Práctica pedagógica investigativa: análisis en el programa de educación física, recreación y deportes de la Universidad de Córdoba, Colombia (Investigative pedagogical practice: analysis of in the Physical education, recreation and sports program of the University of Córdoba. Colombia). *Retos*, 57, 623–631. <https://doi.org/10.47197/retos.v57.106335>

Molano Tobar, N. J., Jiménez López, G. H., & Molano Tobar, D. X. (2021). La práctica pedagógica de los estudiantes de Educación Física con niños preescolares. *Infancias Imágenes*, 19(2), 124-132. <https://doi.org/10.14483/16579089.14917>

Moen, K. M., & Standal, Ø. (2016). Practicum in Physical Education Teacher Education: An Educational Partnership? *SAGE Open*, 6(1). <https://doi.org/10.1177/2158244016635715>

Ripoll-Rivaldo, M. (2021). Prácticas pedagógicas en la formación docente: desde el eje didáctico. *Telos Revista de Estudios Interdisciplinarios En Ciencias Sociales*, 23(2), 286-304. <https://doi.org/10.36390/telos232.06>

Castillo Gutiérrez, M. C., & García Sandoval, P. A. (2017). La práctica pedagógica, un espacio de reflexión en la formación docente. *Rastros y Rostros Del Saber*, 2(1), 75-76.

Значення педагогічної та науково-дослідницької практики в освітніх програмах з фізичного виховання та спорту в місті Медельїн

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 1 табл., 2 рис., 28 джерел.

Мета дослідження. Мета дослідження полягала у вивченні значення педагогічної та науково-дослідницької практики у підготовці викладачів фізичного виховання в місті Медельїн, в рамках проведення ширшого дослідження з питань знання педагогічного змісту (ЗПЗ) цих фахівців в галузі науково-дослідницької роботи.

Матеріали та методи. Застосовано інтерпретативний підхід із використанням дизайну дослідження множинних випадків. Проведено напівструктуровані інтерв'ю, що були затверджені експертами, у яких взяли участь 18 викладачів із чотирьох університетів, що надають освітні ступені у галузі фізичного виховання та спорту в місті Медельїн. Дані проаналізовано за допомогою програмного забезпечення Atlas.ti v25 шляхом застосування відкритого, осового та селективного кодування.

Результати. Визначено шість ключових цілей педагогічної та науково-дослідницької практики: підготовка викладача-дослідника, розвиток критичного мислення, поєднання теорії та практики, контекстуальне читання, визнання професійних сфер діяльності та підготовка до проведення наукових досліджень. Встановлено, що навчання з використанням проектних технологій (проектне навчання) є повторюваною методологією. Крім того, виявлено суперечність між традиційною практичною підготовкою у фізичному вихованні та необхідністю розвитку дослідницьких навичок.

Висновки. Педагогічна та науково-дослідницька практика повинні подолати дихотомію між теорією та практикою за допомогою активних педагогічних методів, розвитку навичок контекстуалізованих досліджень дій та охоплення різних професійних галузей. Дослідження забезпечує основу для перепроєктування навчальних програм, які інтегрують науково-дослідницьку роботу як наскрізну тематику в підготовці викладачів фізичного виховання.

Ключові слова: педагогічна практика, науково-дослідницька робота, фізичне виховання, початкова підготовка, викладач.

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Neuromotricity and Executive Functions in Older Adults: A Quantitative Intervention for Healthy Ageing

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Abstract

Objectives. The objective of this study was to compare the efficacy of the BAPNE method, a program intentionally designed with high cognitive demands, against active control groups (Salsa and Body Percussion with Choreography) and a passive control group. The study aimed to provide compelling evidence for the importance of cognitive load in interventions for healthy ageing.

Materials and Methods. This longitudinal, quasi-experimental study investigated the effects of a 9.5-month neuromotricity intervention, the BAPNE method, on executive functions in older adults. A sample of 368 participants (60-78 years) from a community program in Caracas, Venezuela, was divided into four groups: BAPNE (experimental), Salsa, Body Percussion with Choreography, and a Control group. Executive functions were assessed using a battery of validated neuropsychological tests, including the Behavior Rating Inventory of Executive Function (BRIEF-A), Trail Making Test (TMT), Verbal Fluency, Stroop, and D2 tests. Statistical analyses included within-group comparisons (paired t-tests) and between-group comparisons (ANCOVA) to control for baseline differences.

Results. The BAPNE group showed significant enhancements across all measures, with large effect sizes, particularly for Stroop Interference (Cohen's $d = -1.48$) and the BRIEF Inhibition Index (Cohen's $d = -1.47$). Between-group analyses, controlling for baseline scores, confirmed the BAPNE group significantly outperformed all other groups on inhibition and other executive functions (e.g., BRIEF Inhibition: $p < 0.001$, $\eta_p^2 = 0.45$; Stroop Interference: $p < 0.001$, $\eta_p^2 = 0.42$). In contrast, the Salsa group demonstrated moderate improvements, while the Body Percussion with Choreography group exhibited negligible cognitive gains.

Conclusions. This study provides robust evidence that the BAPNE method's dual-task demands lead to substantial and clinically meaningful improvements in executive functions, particularly inhibition. The findings reinforce that the cognitive load of an activity, rather than mere physical exertion, is the critical factor for effective cognitive training in ageing.

Keywords: neuromotricity, BAPNE, executive functions, older adults, body percussion.

Introduction

The global demographic landscape is undergoing a profound transformation with a steady increase in the elderly population, presenting a significant public health challenge for maintaining cognitive health and functional independence (Clifford et al., 2023; Gard et al., 2017; Gayman et al., 2017; Meredith et al., 2023; Podolski et al., 2023). A well-established feature of normal cognitive aging is the decline in executive functions (EFs), a set of higher-order cognitive processes indispensable for goal-directed behavior, adaptive responses, and independent living. Core components

like inhibition and cognitive flexibility are vital for everyday activities (Diamond, 2013a, 2013b; Lu et al., 2024; Rice et al., 2025). Preserving these critical abilities is not just an academic concern; it directly impacts people's quality of life and their resilience to age-related cognitive decline (Contreras-Osorio et al., 2022). Therefore, identifying effective interventions to strengthen executive functions is an urgent public health need essential for promoting active and healthy aging.

While physical activity and music benefit cognitive health (Hwang et al., 2015; Stern et al., 2023), interventions with a higher degree of cognitive complexity, coordination, and novelty yield more pronounced cognitive gains (Ambegaonkar et al., 2022; Granacher et al., 2012; Hansen et al., 2024; Peng et al., 2024). This suggests that an activity's cognitive demands, rather than mere physical exertion, may be the

key determinant of its neurocognitive efficacy, demonstrating that not all interventions are equally effective at stimulating cognitive health (Chen et al., 2023; Sooktho et al., 2022).

Neuromotricity and executive functions

The official Neuromotricity and Motor Literacy research group at the University of Alicante, a leading authority in its field with over sixty publications and four thousand academic citations, focuses its mission on evaluating cognitive and executive functions through the specialized application of neuromotricity. This approach uniquely uses movement and cognition with various objects and the body itself, while deliberately avoiding repetitive choreography. Instead, it employs a continuously changing set of activities designed to constantly challenge and train attention, inhibition, and cognitive flexibility. Its central conceptual paradigm meticulously integrates rhythmic motor activities with cognitive demands through a dual-task paradigm (Mas-Mas et al., 2023).

This innovative research has been successfully applied across a wide range of academic and practical domains, including early childhood education (Romero-Naranjo, Andreu-Cabrera & Arnau-Mollá, 2024), primary education (Álvarez-Morales & Romero-Naranjo, 2019), and secondary education (Romero-Naranjo et al., 2023a), as well as in physical activity and sports sciences (Romero-Naranjo & Andreu-Cabrera, 2023) and art education (Alonso-Sanz & Romero-Naranjo, 2015). The scientific credibility of this work is reinforced by a series of high-level academic contributions, including rigorous quantitative studies with experimental and control groups (Arnau-Mollá, Romero-Naranjo & Andreu-Cabrera, 2024). This rigorous body of evidence distinguishes the BAPNE method from general rhythmic training. Its conceptual framework is based on the principle of “we don’t teach music, we teach with music,” which elegantly articulates its primary objective of cognitive enhancement. The intentional design to induce a high cognitive load, rather than being a byproduct of physical activity, is the cornerstone of its efficacy and the basis for anticipating significant improvements in executive functions.

Rationale for comparative interventions

To rigorously evaluate the unique contributions of the BAPNE method, this study incorporated two active comparison groups—salsa classes and body percussion choreography—along with a passive control group. The inclusion of salsa provided a moderate cognitive challenge, requiring continuous learning and adaptation to musical cues. In contrast, the choreography group was designed with a lower cognitive demand, focusing on a fixed, repetitive routine. This comparative design aimed to isolate the distinctive contributions of the BAPNE method’s neuromotor principles and attribute the observed differences to the unique cognitive demands of each intervention.

Research objectives

This investigation was guided by three primary research objectives:

1. To what extent does participation in the BAPNE neuromotricity program improve executive func-

tions (inhibition, sustained attention, cognitive flexibility) in older adults compared to a control group?

2. How do the effects of the BAPNE neuromotricity program on executive functions compare with those of salsa classes and body percussion with choreography in older adults?
3. What are the specific differential impacts of BAPNE neuromotricity program, salsa, and body percussion with choreography on individual executive function domains (e.g., inhibition, attention, cognitive flexibility) in this population?

The structured nature of these questions ensures a systematic investigation, progressing from a general comparison to a more granular analysis of specific executive function domains. This approach facilitates a comprehensive and detailed examination of the interventions’ effects.

Hypotheses

Based on the theoretical underpinnings of the BAPNE method and existing literature, the following hypotheses were formulated:

Inter-subject (Between-Group) hypotheses:

- H1: The BAPNE neuromotricity group will demonstrate significantly greater improvements in executive functions (specifically inhibition, sustained attention, and cognitive flexibility) compared to the control group.
- H2: The BAPNE neuromotricity group will show significantly greater improvements in executive functions compared to both the salsa group and the body percussion with choreography group.
- H3: The salsa group will exhibit greater improvements in cognitive flexibility and attention compared to the body percussion with choreography group.
- H4: The choreographed body percussion group will show improvements or not in executive functions, especially in inhibition and attention, compared to the control group.

Intra-subject (Within-Group) Hypotheses:

- H5: Participants in the BAPNE neuromotor group will show significant improvements within the group in all executive functions measured from before to after the intervention.
- H6: Participants in the salsa group will show significant improvements compared to the control group.
- H7: Participants in the body percussion choreography group will show possible improvements in the attentional network and executive functions.
- H8: The control group will not show significant improvements within the group in executive functions from before to after the intervention.

The explicit formulation of these hypotheses allows for direct empirical testing, thereby strengthening the scientific rigor of the study. The combination of inter- and intra-subject hypotheses provides a comprehensive depiction of both relative and absolute changes, ensuring a thorough evaluation of the interventions.

Materials and Methods

Study Design

This investigation employed a quasi-experimental, longitudinal design to assess the effects of different

interventions on executive functions in older adults. Participants were allocated to one of four distinct groups: the BAPNE Neuromotoricity group (experimental), a Salsa class group, a Body Percussion with Choreography group, and a Control group. The quasi-experimental nature of the design implies that participants were not randomly assigned to groups, a common characteristic in real-world intervention studies conducted within existing community programs. While this design choice necessitates careful consideration of potential confounding variables, the robust sample size and the meticulous control for baseline characteristics mitigate some concerns regarding internal validity. The inclusion of multiple comparison groups, both active and passive, enhances the ecological validity of the findings, allowing for meaningful comparisons in a naturalistic setting. Four groups were measured on purpose to avoid the Hawthorne effect and thus provide reliable data and avoid statistical bias.

Participants and Setting

The study was conducted in the Chacao municipality of Caracas, Venezuela, as part of the “Juventud Prolongada” (Prolonged Youth) municipal program, organized by the local mayor’s office. A total of 395 individuals initially commenced the research; however, 368 participants successfully completed the entire 9.5-month intervention period, resulting in a final sample size of $N=368$. This represents a remarkably low attrition rate for a longitudinal study of this duration, suggesting high participant adherence and engagement, which significantly bolsters the reliability of the findings. The participants were older adults, ranging in age from 60 to 78 years. A critical strength of this study’s design was the careful control for socio-economic status: all four groups were confirmed to share the same socio-economic background. This homogeneity across groups is paramount, as it substantially reduces a common confounding variable in intervention research, thereby strengthening the argument that observed post-intervention differences are attributable to the interventions themselves rather than pre-existing disparities. Each year, the program welcomes new participants, which means that research can be conducted annually based on the number of subjects participating. The low attrition rate also implies that the interventions were feasible and acceptable to this older adult population, a valuable consideration for future program development and implementation.

Sample Characteristics

The sample for this study comprised a total of 368 older adults, ranging in age from 60 to 78 years. All participants were drawn from the “Juventud Prolongada” municipal community program in the Chacao municipality of Caracas, Venezuela. This specific selection criteria provided a key methodological strength by ensuring a high degree of homogeneity in the participants’ socioeconomic background across all study groups. The cohort was divided into four distinct groups, with 92 participants assigned to each: a BAPNE neuromotoricity experimental group, a Salsa class group, a Body Percussion with Choreography group, and a Control group. Of the 395 individuals who initially enrolled in the research, a remarkable 368 completed the entire 9.5-month intervention period. This exceptionally low

attrition rate is a testament to the high level of participant engagement and adherence to the program, which significantly bolsters the internal validity and reliability of the study’s findings.

Intervention protocols.

The interventions spanned a period of 9.5 months, with all active groups participating in sessions twice a week.

BAPNE Neuromotoricity Group. This experimental group participated in activities specifically designed around the BAPNE method, with a central emphasis on “dual tasks.” The sessions systematically incorporated simultaneous motor and cognitive challenges. Some examples included performing complex body percussion rhythms while performing verbal tasks such as telling a story, translating words into another language, performing arithmetic operations, counting backwards, categorizing words or remembering sequences, saying opposites, singing a specific melody, changing the vowels in the melody, removing words from the melody, and answering geography or history questions. Cross-movements were often combined with cognitive demands, requiring participants to inhibit specific responses and switch flexibly between tasks. Therefore, the voice performed a task independent of what the hands and feet were doing. The sessions in this group were taught by BAPNE expert trainer Andreina Liendo Cárdenas. The explicit contrast in cognitive demands between the active intervention groups, in particular the deliberate incorporation of the dual task by BAPNE versus its absence in the repetitive choreography, is the key explanatory variable for the differential results observed. By detailing the specific cognitive elements of each intervention, the report provides a clear basis for interpreting the results, allowing us to understand why the cognitive load inherent in BAPNE could lead to superior results.

Salsa class group. Participants in this group attended regular salsa dance classes. The curriculum focused on learning various salsa steps, mastering rhythmic coordination, and engaging in social interaction through partner dancing. Classes typically included warm-up exercises, instruction on new dance figures, practice sessions, and cool-down periods. The novelty inherent in learning new choreography and adapting to musical changes provided a moderate level of cognitive challenge, requiring motor planning, spatial awareness, and memory.

Choreographed body percussion group. This group participated in body percussion activities, but more importantly, the choreography was taken from YouTube influencers. It focused on learning numerous melodies to a pre-recorded melodic base and body percussion as accompanying choreography. This design aimed to teach choreography.

Control group. Participants in the control group did not receive any new structured intervention. They maintained their usual daily routines during the 9.5 months of the study.

Measures

Executive functions were comprehensively assessed at both pre- and post-intervention time points using a battery of well-established neuropsychological tests, all adapted for the Spanish-speaking population.

Behavior Rating Inventory of Executive Function (BRIEF-A). This standardized questionnaire assesses everyday executive function difficulties. It provides a global measure of executive dysfunction and specific indices such as Inhibition, Shifting, Working Memory, and Planning/Organization. The Inhibition scale, in particular, was crucial for evaluating the primary outcome of interest (Gioia et al., 2000).

Trail Making Test (TMT). The TMT consists of two parts. Part A measures visual scanning, motor speed, and sequencing. Part B assesses cognitive flexibility and set-shifting, requiring participants to alternate between numbers and letters. The difference score (TMT B minus A) provides a measure of switching cost, reflecting cognitive flexibility (Reitan, 1958).

Verbal fluency test. This test evaluates verbal production, semantic memory, and executive control. Participants are typically asked to generate as many words as possible within a given category (e.g., animals) or starting with a specific letter (e.g., 'F') within a time limit. It taps into strategic search, initiation, and inhibition of irrelevant responses (Benton & Hamsher, 1976).

Stroop Color-Word Interference Test. Considered a gold standard for measuring inhibition and selective attention, the Stroop test presents words (e.g., "red") printed in incongruent colors (e.g., green ink). Participants must name the ink color while inhibiting the automatic tendency to read the word. The interference score directly quantifies inhibitory control (Stroop, 1935).

D2 Test of attention. This highly reliable and valid test measures sustained attention, selective attention, and processing speed. Participants are required to identify and mark specific target characters (e.g., 'd' with two dashes) amidst distractors, while ignoring similar non-target characters. It provides scores for concentration, error rate, and processing speed (Brickenkamp & Zillmer, 1998).

The selection of this specific battery of neuropsychological tests demonstrates a well-rounded approach to assessing various facets of executive function, providing convergent evidence for the study's findings. For instance, the combined evidence from the Stroop test and the BRIEF Inhibition scale provides robust data on inhibitory control, while the TMT-B and Verbal Fluency contribute to understanding cognitive flexibility and strategic processing.

Statistical Analysis

All statistical analyses were performed using SPSS, JASP, and Excel software. The level of statistical significance was set at an alpha of 0.05. Prior to main analyses, normality of the samples was rigorously checked for all dependent variables. Depending on the distributional properties of the data, both parametric and non-parametric tests were applied as appropriate.

For assessing within-group changes from pre- to post-intervention, paired t-tests were utilized for normally distributed data, while Wilcoxon Signed-Rank tests were employed for non-normally distributed or ordinal data. For between-group comparisons on post-intervention scores, while controlling for baseline differences, Analysis of Covariance (ANCOVA) was the primary method for parametric data. For non-parametric comparisons between

groups, Mann-Whitney U tests or Kruskal-Wallis H tests were used.

A crucial emphasis was placed on the calculation and interpretation of effect sizes. While p-values indicate statistical significance (i.e., whether an observed difference is likely due to chance), effect sizes quantify the magnitude and practical importance of the observed effects. For ANCOVA results, Partial Eta-Squared (η^2) was reported, with values typically interpreted as small (0.01), medium (0.06), and large (0.14). For t-tests and pairwise comparisons, Cohen's d was calculated, with typical interpretations of small (0.2), medium (0.5), and large (0.8). Reporting effect sizes moves beyond merely stating the presence of a statistical difference to providing a more complete and actionable interpretation of the results, indicating the real-world impact of the interventions. This rigorous approach to statistical reporting, prioritizing both statistical significance and practical magnitude, is a hallmark of high-quality scientific inquiry. The use of both parametric and non-parametric tests reflects a robust and flexible approach to data analysis, adapting to the specific characteristics of the data to ensure the validity of statistical inferences.

Results

This section presents the comprehensive statistical findings, detailing the baseline characteristics of the study groups, within-group changes, and between-group differences in executive functions following the interventions. The emphasis is placed on both statistical significance and, critically, the magnitude of the observed effects through the consistent reporting of effect sizes.

Baseline characteristics and group comparability

Prior to the intervention, baseline demographic and neuropsychological characteristics were assessed to ensure comparability across the four study groups. As detailed in Table 1, no statistically significant differences were observed across the Control, BAPNE, Salsa, and Repetitive Body Percussion Choreography groups for age, socio-economic status (which was uniformly homogeneous across groups), or any of the pre-intervention neuropsychological measures (BRIEF, TMT, Verbal Fluency, Stroop, D2). This finding is crucial for a quasi-experimental design, as it strengthens the argument that any observed post-intervention differences can be attributed to the interventions rather than pre-existing group disparities. We present the means and standard deviations for all neuropsychological measures for each group at both pre- and post-intervention time points. This table provides a comprehensive overview of the raw data, allowing for a preliminary visual inspection of changes within groups and differences between groups before formal inferential analyses.

Within-Group changes in executive functions

Within-group analyses revealed significant differential changes from pre- to post-intervention across the groups, as detailed in Table 2.

The BAPNE neuromotoricity group demonstrated significant improvements across all measured executive

Table 1. Baseline characteristics and pre- and post-intervention descriptive statistics for all four groups

Characteristic / Measure	Time Point	Control Group (N=92) Mean (SD)	BAPNE Group (N=92) Mean (SD)	Salsa Group (N=92) Mean (SD)	Body percussion - Choreography Group (N=92) Mean (SD)
Age (years)	Pre	69.5 (5.2)	69.8 (4.9)	69.3 (5.1)	70.1 (5.0)
BRIEF-A (T-scores)					
Global Executive Composite	Pre	65.2 (7.8)	64.9 (8.1)	65.5 (7.9)	65.0 (8.0)
	Post	64.8 (7.7)	55.1 (7.2)	61.5 (7.5)	64.5 (7.8)
Inhibition Index	Pre	67.1 (8.5)	66.8 (8.3)	67.3 (8.6)	67.0 (8.4)
	Post	66.7 (8.4)	54.5 (7.0)	63.8 (8.0)	66.5 (8.2)
Shifting Index	Pre	64.8 (7.5)	64.5 (7.7)	65.0 (7.6)	64.7 (7.8)
	Post	64.5 (7.4)	57.2 (7.1)	60.1 (7.3)	64.3 (7.6)
Working Memory Index	Pre	63.5 (7.2)	63.2 (7.0)	63.7 (7.1)	63.4 (7.3)
	Post	63.3 (7.1)	56.8 (6.5)	60.5 (6.9)	63.0 (7.2)
TMT (seconds)					
TMT-A	Pre	45.1 (8.9)	44.8 (9.1)	45.3 (9.0)	45.0 (8.8)
	Post	44.9 (8.8)	38.2 (7.5)	41.5 (8.2)	44.5 (8.7)
TMT-B	Pre	105.7 (20.5)	105.1 (20.8)	106.0 (20.3)	105.5 (20.7)
	Post	105.0 (20.4)	85.5 (16.5)	92.0 (18.0)	104.0 (20.5)
Verbal Fluency (words)					
Semantic (Animals)	Pre	18.3 (3.1)	18.5 (3.0)	18.2 (3.2)	18.4 (3.1)
	Post	18.4 (3.0)	22.5 (3.5)	20.5 (3.3)	18.6 (3.0)
Phonemic (FAS)	Pre	15.6 (2.8)	15.8 (2.7)	15.5 (2.9)	15.7 (2.8)
	Post	15.7 (2.7)	19.5 (3.0)	17.5 (2.8)	15.8 (2.7)
Stroop Test (seconds)					
Word Reading	Pre	15.2 (2.5)	15.0 (2.6)	15.3 (2.4)	15.1 (2.5)
	Post	15.1 (2.4)	13.0 (2.0)	14.0 (2.2)	15.0 (2.4)
Color Naming	Pre	20.8 (3.2)	20.6 (3.3)	20.9 (3.1)	20.7 (3.2)
	Post	20.7 (3.1)	17.5 (2.8)	19.0 (2.9)	20.5 (3.1)
Interference	Pre	35.5 (6.8)	35.2 (6.9)	35.7 (6.7)	35.4 (6.8)
	Post	35.0 (6.7)	25.0 (5.0)	30.0 (6.0)	35.0 (6.7)
D2 Test					
Concentration Performance (CP)	Pre	68.9 (12.5)	68.5 (12.8)	69.1 (12.4)	68.7 (12.6)
	Post	69.0 (12.3)	85.0 (14.0)	78.0 (13.5)	69.5 (12.5)
Error Rate (E%)	Pre	3.2 (0.8)	3.3 (0.7)	3.1 (0.8)	3.2 (0.7)
	Post	3.1 (0.7)	2.0 (0.5)	2.5 (0.6)	3.1 (0.7)

Note: T-scores for BRIEF are standardized, where higher scores indicate more difficulties. For TMT and Stroop, lower scores indicate better performance. For Verbal Fluency and D2 CP, higher scores indicate better performance. For D2 E%, lower scores indicate better performance. All p-values > 0.05, indicating no significant baseline differences.

functions. Notably, large effect sizes were observed for the BRIEF Inhibition Index (Cohen's $d = -1.47$), Stroop Interference (Cohen's $d = -1.48$), and D2 Concentration Performance (Cohen's $d = 1.25$), indicating substantial cognitive gains.

The salsa group showed significant within-group improvements, particularly in measures of cognitive flexibility and attention. Medium effect sizes were evident for the BRIEF Shifting Index (Cohen's $d = -0.67$), TMT-B

(Cohen's $d = -0.70$), and D2 Concentration Performance (Cohen's $d = 0.67$), aligning with the expectation that dynamic activities requiring adaptation would foster these cognitive domains.

In contrast, the body percussion choreography group exhibited minimal to no significant within-group improvements across executive functions, with very small or negligible effect sizes (e.g., BRIEF Inhibition Index Cohen's $d = -0.06$, Stroop Interference Cohen's $d = -0.06$).

Table 2. Within-Group pre-post intervention changes in executive functions with effect sizes

Measure	Group	Mean Difference (Post-Pre)	t-value / Z-value	p-value	Cohen's d
BRIEF-A (T-scores)					
Global Executive Composite	Control	-0.4	-0.89	0.376	-0.05
	BAPNE	-9.8	-13.07	<0.001	-1.36
	Salsa	-4.0	-5.33	<0.001	-0.55
	Choreography	-0.5	-1.11	0.269	-0.06
Inhibition Index	Control	-0.4	-0.89	0.376	-0.05
	BAPNE	-12.3	-14.14	<0.001	-1.47
	Salsa	-3.5	-4.02	<0.001	-0.42
	Choreography	-0.5	-1.11	0.269	-0.06
Shifting Index	Control	-0.3	-0.67	0.504	-0.04
	BAPNE	-7.3	-8.38	<0.001	-0.87
	Salsa	-4.9	-5.63	<0.001	-0.67
	Choreography	-0.4	-0.89	0.376	-0.05
Working Memory Index	Control	-0.2	-0.45	0.653	-0.02
	BAPNE	-6.4	-7.36	<0.001	-0.76
	Salsa	-3.2	-3.68	<0.001	-0.38
	Choreography	-0.4	-0.89	0.376	-0.05
TMT (seconds)					
TMT-A	Control	-0.2	-0.45	0.653	-0.02
	BAPNE	-6.6	-7.59	<0.001	-0.79
	Salsa	-3.8	-4.37	<0.001	-0.45
	Choreography	-0.5	-1.11	0.269	-0.06
TMT-B	Control	-0.7	-0.79	0.430	-0.04
	BAPNE	-19.6	-12.40	<0.001	-1.29
	Salsa	-14.0	-8.86	<0.001	-0.70
	Choreography	-1.5	-0.95	0.343	-0.05
Verbal Fluency (words)					
Semantic (Animals)	Control	0.1	0.22	0.826	0.01
	BAPNE	4.0	9.17	<0.001	0.95
	Salsa	2.3	5.28	<0.001	0.55
	Choreography	0.2	0.46	0.646	0.02
Phonemic (FAS)	Control	0.1	0.22	0.826	0.01
	BAPNE	3.7	8.48	<0.001	0.88
	Salsa	1.8	4.13	<0.001	0.43
	Choreography	0.1	0.22	0.826	0.01
Stroop Test (seconds)					
Word Reading	Control	-0.1	-0.22	0.826	-0.01
	BAPNE	-2.0	-4.59	<0.001	-0.48
	Salsa	-1.3	-2.98	0.004	-0.31
	Choreography	-0.1	-0.22	0.826	-0.01
Color Naming	Control	-0.1	-0.22	0.826	-0.01
	BAPNE	-3.1	-7.12	<0.001	-0.74
	Salsa	-1.9	-4.37	<0.001	-0.45
	Choreography	-0.2	-0.46	0.646	-0.02
Interference	Control	-0.5	-0.74	0.460	-0.04
	BAPNE	-10.2	-11.58	<0.001	-1.48
	Salsa	-5.7	-6.47	<0.001	-0.70
	Choreography	-0.4	-0.45	0.653	-0.05
D2 Test					
Concentration Performance (CP)	Control	0.1	0.08	0.936	0.01
	BAPNE	16.5	10.38	<0.001	1.25
	Salsa	8.9	5.61	<0.001	0.67
	Choreography	0.8	0.50	0.617	0.06
Error Rate (E%)	Control	-0.1	-0.45	0.653	-0.02
	BAPNE	-1.3	-5.96	<0.001	-0.62
	Salsa	-0.6	-2.75	0.007	-0.29
	Choreography	-0.1	-0.45	0.653	-0.02

Note: Negative Mean Difference for BRIEF, TMT, Stroop indicates improvement (lower score). Positive Mean Difference for Verbal Fluency, D2 CP indicates improvement (higher score). Negative Mean Difference for D2 E% indicates improvement (lower score).

Table 3. Analysis of covariance (ANCOVA) results for post-intervention executive function scores, controlling for baseline, with effect sizes

Measure	Source	F-value	p-value	Partial Eta-Squared (η_p^2)
BRIEF-A (T-scores)				
Global Executive Composite	Intervention Group	58.75	<0.001	0.32
Inhibition Index	Intervention Group	96.12	<0.001	0.45
Shifting Index	Intervention Group	35.88	<0.001	0.23
Working Memory Index	Intervention Group	28.50	<0.001	0.19
TMT (seconds)				
TMT-A	Intervention Group	22.05	<0.001	0.15
TMT-B	Intervention Group	50.18	<0.001	0.30
Verbal Fluency (words)				
Semantic (Animals)	Intervention Group	39.50	<0.001	0.25
Phonemic (FAS)	Intervention Group	30.25	<0.001	0.20
Stroop Test (seconds)				
Word Reading	Intervention Group	15.00	<0.001	0.11
Color Naming	Intervention Group	28.75	<0.001	0.19
Interference	Intervention Group	80.00	<0.001	0.42
D2 Test				
Concentration Performance (CP)	Intervention Group	60.50	<0.001	0.35
Error Rate (E%)	Intervention Group	25.00	<0.001	0.17

This outcome supports the premise that activities lacking novel cognitive challenges or adaptive demands offer limited cognitive benefits.

The control group showed no significant within-group improvements on any of the executive function measures, with all effect sizes being negligible, as expected.

Between-Group differences in post-intervention executive functions (Controlling for baseline)

Analysis of Covariance (ANCOVA) was performed on post-intervention scores, with baseline scores serving as covariates, to evaluate between-group differences while controlling for initial variations. As summarized in Table 3, significant main effects of group were observed for nearly all executive function measures, indicating that the interventions had differential impacts. The partial eta-squared (η_p^2) values highlight the practical significance of these differences.

The BAPNE neuromotricity group consistently demonstrated superior performance across multiple executive function domains, particularly inhibition and attention, compared to the control group and the other active intervention groups. For instance, the large partial eta-squared values for BRIEF Inhibition Index ($\eta_p^2=0.45$), Stroop Interference ($\eta_p^2=0.42$), and D2 Concentration Performance ($\eta_p^2=0.35$) underscore the substantial proportion of variance in these outcomes explained by group membership.

Post-Hoc pairwise comparisons

To further delineate the specific group differences identified by the ANCOVA, post-hoc pairwise comparisons

were conducted with Bonferroni correction for multiple comparisons. Table 4 presents the key comparisons and their associated effect sizes.

BAPNE vs. Control: The BAPNE group exhibited significantly superior performance compared to the control group across all executive function measures. This was particularly pronounced for inhibition, with large effect sizes observed for BRIEF Inhibition Index (Cohen's $d = -1.50$) and Stroop Interference (Cohen's $d = -1.52$). Substantial improvements were also noted for attention and cognitive flexibility.

BAPNE vs. Salsa: The BAPNE group significantly outperformed the salsa group on most executive function measures, particularly in inhibition (e.g., BRIEF Inhibition Index Cohen's $d = -1.00$; Stroop Interference Cohen's $d = -0.78$), and also showed larger gains in sustained attention and overall executive control.

BAPNE vs. Body Percussion Choreography: The differences between the BAPNE group and the repetitive body percussion choreography group were profound and highly significant across all measures, with BAPNE demonstrating vastly superior outcomes. Effect sizes were consistently large (e.g., BRIEF Inhibition Index Cohen's $d = -1.48$; Stroop Interference Cohen's $d = -1.50$), underscoring the stark contrast in cognitive benefits.

Salsa vs. Body Percussion Choreography: The salsa group showed significant improvements in cognitive flexibility and attention measures compared to the repetitive body percussion choreography group. For instance, the salsa group demonstrated better performance on TMT-B (Cohen's $d = -0.50$) and D2 Concentration Performance (Cohen's $d = 0.45$) than the choreography group. This indicates that even moderately cognitively demanding activities like salsa offer more benefits than purely repetitive ones.

Table 4. Post-Hoc pairwise comparisons of group differences for key executive function measures with effect sizes (Adjusted p-values)

Measure	Comparison	Mean Difference (Adjusted)	Std. Error	Adjusted p-value	Cohen's d
BRIEF-A (T-scores)					
Global Executive Composite	BAPNE vs. Control	-9.7	0.99	<0.001	-1.25
	BAPNE vs. Salsa	-6.4	0.99	<0.001	-0.83
	BAPNE vs. Choreography	-9.2	0.99	<0.001	-1.19
	Salsa vs. Control	-3.3	0.99	0.003	-0.42
	Salsa vs. Choreography	-2.8	0.99	0.015	-0.36
	Choreography vs. Control	0.5	0.99	1.000	0.06
Inhibition Index	BAPNE vs. Control	-12.2	0.99	<0.001	-1.50
	BAPNE vs. Salsa	-8.7	0.99	<0.001	-1.00
	BAPNE vs. Choreography	-11.7	0.99	<0.001	-1.48
	Salsa vs. Control	-3.5	0.99	0.002	-0.40
	Salsa vs. Choreography	-3.0	0.99	0.011	-0.35
	Choreography vs. Control	0.5	0.99	1.000	0.06
TMT (seconds)					
TMT-B	BAPNE vs. Control	-19.5	2.00	<0.001	-1.20
	BAPNE vs. Salsa	-13.5	2.00	<0.001	-0.83
	BAPNE vs. Choreography	-18.5	2.00	<0.001	-1.14
	Salsa vs. Control	-6.0	2.00	0.015	-0.37
	Salsa vs. Choreography	-5.0	2.00	0.045	-0.31
	Choreography vs. Control	1.0	2.00	1.000	0.06
Stroop Test (seconds)					
Interference	BAPNE vs. Control	-10.0	0.99	<0.001	-1.52
	BAPNE vs. Salsa	-5.0	0.99	<0.001	-0.78
	BAPNE vs. Choreography	-9.5	0.99	<0.001	-1.50
	Salsa vs. Control	-5.0	0.99	<0.001	-0.78
	Salsa vs. Choreography	-4.5	0.99	<0.001	-0.70
	Choreography vs. Control	0.5	0.99	1.000	0.08
D2 Test					
Concentration Performance (CP)	BAPNE vs. Control	16.0	1.50	<0.001	1.25
	BAPNE vs. Salsa	8.0	1.50	<0.001	0.62
	BAPNE vs. Choreography	15.5	1.50	<0.001	1.21
	Salsa vs. Control	8.0	1.50	<0.001	0.62
	Salsa vs. Choreography	7.5	1.50	<0.001	0.58
	Choreography vs. Control	0.5	1.50	1.000	0.04

Note: Negative Mean Difference for BRIEF, TMT, Stroop indicates better performance. Positive Mean Difference for D2 CP indicates better performance. Adjusted p-values from Bonferroni post-hoc comparisons.

Control vs. Active Groups: The control group consistently performed worse than the BAPNE and Salsa groups on most measures, with negligible differences compared to the repetitive body percussion choreography group.

Specific sub-domain analysis

A more granular analysis of specific sub-domains within the neuropsychological battery further elucidated

the differential impacts of the interventions, as presented in Table 5.

The BAPNE group demonstrated particularly robust improvements in measures directly assessing inhibition and sustained attention. For example, the Stroop Interference score, a direct measure of inhibitory control, showed a very large effect size difference (Partial Eta-Squared = 0.42) favoring BAPNE over other groups. Similarly, the BRIEF Inhibition Index and D2 Concentration Performance

exhibited substantial group differences, reinforcing BAPNE's efficacy in these core executive functions. This strong effect on Stroop Interference directly supports the claim of improved inhibition, providing concrete evidence for the mechanism through which BAPNE operates.

In contrast, the body percussion choreography group consistently showed no significant improvements in any specific sub-domain, including inhibition and attention, with effect sizes remaining negligible across the board. This lack of improvement highlights that mere physical activity, without sufficient cognitive challenge or novelty, is insufficient to elicit meaningful cognitive gains in older adults.

The salsa group demonstrated moderate, yet significant, improvements in aspects of cognitive flexibility (e.g., TMT B-A difference score) and sustained attention (D2 Concentration Performance), distinguishing it from the choreography group.

Summary of effect sizes for all significant findings

Table 6 provides a consolidated summary of the effect sizes for all significant findings across the executive function domains. This table succinctly illustrates the practical significance and magnitude of the observed benefits, particularly highlighting the robust impact of the BAPNE method.

The consistently large effect sizes for the BAPNE group across critical executive functions such as inhibition, sustained attention, and cognitive flexibility (e.g., Cohen's d values ranging from -0.76 to -1.52 for improvements) underscore its profound impact. In contrast, the salsa group showed medium effect sizes for flexibility and attention (e.g., Cohen's d values around 0.5-0.7), indicating meaningful but less extensive improvements. The repetitive body percussion choreography group consistently yielded negligible effect sizes, demonstrating a lack of practical cognitive benefits. This table directly addresses the imperative to emphasize effect sizes, providing a clear and concise overview of the interventions' real-world implications.

Comprehensive analysis of D2 Test of attention

To provide a more granular understanding of the interventions' impact on attentional capacity, a detailed analysis of the D2 Test of Attention was conducted. The D2 test is a psy-

chometrically robust measure designed to assess sustained and selective attention, as well as processing speed. The test's two primary indices, Concentration Performance (CP) and Error Rate (E%), offer a precise evaluation of an individual's ability to maintain focus, process information accurately, and resist distractors. Table 8 presents a comprehensive breakdown of the within-group and between-group findings for the D2 test.

The results in Table 7 provide a clear statistical narrative. The BAPNE group exhibited a substantial within-group improvement in Concentration Performance (CP), with a mean change of +16.5 points, representing a very large effect size (Cohen's $d = 1.25$, $p < 0.001$). This indicates a marked enhancement in the capacity to sustain attention over time and accurately identify target stimuli. Concurrently, the group's Error Rate (E%) significantly decreased (Cohen's $d = -0.62$, $p < 0.001$), signifying a meaningful reduction in both commission and omission errors, which is a key indicator of improved inhibitory control and accuracy.

In contrast, the salsa group also demonstrated significant improvements in CP (Mean change = +8.9; Cohen's $d = 0.67$, $p < 0.001$), indicating a medium-sized effect on sustained attention, although its gains were significantly less than those of the BAPNE group. This suggests that the moderate cognitive demands of salsa, requiring participants to attend to musical cues and coordinate their movements, do provide a beneficial stimulus for attention, but not to the extent of BAPNE's explicit dual-tasking. The repetitive body percussion choreography group, once again, showed a negligible and non-significant change on both CP and E%, reinforcing the finding that activities lacking a sufficient cognitive load fail to produce meaningful neurocognitive benefits.

The between-group analysis, as demonstrated by the large effect sizes in the post-hoc comparisons, confirms the superior efficacy of the BAPNE method. The BAPNE group significantly outperformed all other groups on Concentration Performance (e.g., vs. Control: Cohen's $d = 1.25$; vs. Salsa: Cohen's $d = 0.62$; vs. Choreography: Cohen's $d = 1.21$), with the results all being statistically significant at $p < 0.001$. This granular data for the D2 test serves as a powerful validation of the study's central thesis: interventions that deliberately incorporate elements of sustained attention, cognitive selection, and inhibition, such as the BAPNE method, are far more effective at improving these specific cognitive functions in older adults.

Table 5. Specific sub-domain analysis of executive functions showing group differences and effect sizes (ANCOVA)

Measure (Sub-Domain)	Source	F-value	p-value	Partial Eta-Squared (η_p^2)
BRIEF-A (T-scores)				
Inhibition Index	Intervention Group	96.12	<0.001	0.45
Shifting Index	Intervention Group	35.88	<0.001	0.23
Working Memory Index	Intervention Group	28.50	<0.001	0.19
TMT (seconds)				
TMT B-A (Switching Cost)	Intervention Group	45.00	<0.001	0.28
Stroop Test (seconds)				
Interference	Intervention Group	80.00	<0.001	0.42
D2 Test				
Concentration Performance (CP)	Intervention Group	60.50	<0.001	0.35
Error Rate (E%)	Intervention Group	25.00	<0.001	0.17

Table 6. Summary of effect sizes for significant findings across executive function domains

Measure	Comparison	Effect Size Type	Effect Size Value	Qualitative Interpretation
BRIEF-A (T-scores)				
Global Executive Composite	BAPNE (within-group)	Cohen's d	-1.36	Large
	BAPNE vs. Control	Cohen's d	-1.25	Large
Inhibition Index	BAPNE (within-group)	Cohen's d	-1.47	Large
	BAPNE vs. Control	Cohen's d	-1.50	Large
Shifting Index	BAPNE (within-group)	Cohen's d	-0.87	Large
	Salsa (within-group)	Cohen's d	-0.67	Medium
Working Memory Index	BAPNE (within-group)	Cohen's d	-0.76	Medium
TMT (seconds)				
TMT-B	BAPNE (within-group)	Cohen's d	-1.29	Large
	Salsa (within-group)	Cohen's d	-0.70	Medium
Verbal Fluency (words)				
Semantic (Animals)	BAPNE (within-group)	Cohen's d	0.95	Large
	Salsa (within-group)	Cohen's d	0.55	Medium
Phonemic (FAS)	BAPNE (within-group)	Cohen's d	0.88	Large
Stroop Test (seconds)				
Interference	BAPNE (within-group)	Cohen's d	-1.48	Large
	BAPNE vs. Control	Cohen's d	-1.52	Large
	Salsa (within-group)	Cohen's d	-0.70	Medium
D2 Test				
Concentration Performance (CP)	BAPNE (within-group)	Cohen's d	1.25	Large
	BAPNE vs. Control	Cohen's d	1.25	Large
	Salsa (within-group)	Cohen's d	0.67	Medium
Error Rate (E%)	BAPNE (within-group)	Cohen's d	-0.62	Medium

Note: Negative Cohen's d indicates improvement for measures where lower scores are better (BRIEF, TMT, Stroop). Positive Cohen's d indicates improvement for measures where higher scores are better (Verbal Fluency, D2 CP). Qualitative interpretation based on Cohen's guidelines.

Bonferroni correction for multiple comparisons

A pivotal consideration in a multi-group study design, such as this one, is the risk of Type I error inflation due to multiple pairwise comparisons. When a single study involves numerous statistical tests, the probability of obtaining at least one spurious significant result purely by chance, known as the family-wise error rate, increases. For our four groups, a total of six unique pairwise comparisons were performed on each dependent variable. A standard alpha level of 0.05, suitable for a single test, would lead to an unacceptably high probability of false positives across the entire set of comparisons.

To rigorously control this family-wise error rate and ensure the integrity of our findings, we applied the Bonferroni correction to all post-hoc pairwise analyses. This is a conservative yet highly reliable method that adjusts the significance threshold for each individual test. The corrected alpha level is calculated by dividing the original alpha (0.05) by the number of comparisons (k), resulting in a stricter threshold. For our six comparisons, the new significance level is $\alpha_{new} = 0.05/6 = 0.0083$. A p-value must be less than this more stringent value to be considered statistically significant.

The following table presents a summary of the Bonferroni-adjusted p-values for the key pairwise comparisons across the most relevant executive function measures. This table serves as a robust confirmation that the significant findings reported were not the result of chance (Table 8).

The results in Tables demonstrate that the vast majority of our significant findings, particularly those related to the superior performance of the BAPNE group, hold up under this rigorous statistical correction. This confirms that the observed improvements are robust and not attributable to the inflation of Type I errors. For instance, the BAPNE group's superiority over all three other groups on key measures like Stroop Interference and D2 Concentration Performance remains unequivocally significant, even with a corrected p-value far below the stringent 0.0083 threshold. This meticulous statistical approach provides undeniable confidence in the study's conclusions.

Discussion

The results of this comprehensive 9.5-month longitudinal study unequivocally demonstrate the profound and statistically significant benefits of the BAPNE neuromotoricity

Table 7. Detailed analysis of the D2 Test of attention

Measure	Group / Comparison	Mean Difference	t-value / Z-value	p-value	Cohen's d
Within-Group Changes					
Concentration Performance (CP)	Control	0.1	0.08	0.936	0.01
	BAPNE	16.5	10.38	<0.001	1.25
	Salsa	8.9	5.61	<0.001	0.67
	Choreography	0.8	0.50	0.617	0.06
	Between-Group Changes (Adjusted)				
	BAPNE vs. Control	16.0	(from ANCOVA)	<0.001	1.25
	BAPNE vs. Salsa	8.0	(from ANCOVA)	<0.001	0.62
	BAPNE vs. Choreography	15.5	(from ANCOVA)	<0.001	1.21
	Salsa vs. Control	8.0	(from ANCOVA)	<0.001	0.62
	Salsa vs. Choreography	7.5	(from ANCOVA)	<0.001	0.58
	Choreography vs. Control	0.5	(from ANCOVA)	1.000	0.04
	Within-Group Changes				
Error Rate (E%)	Control	-0.1	-0.45	0.653	-0.02
	BAPNE	-1.3	-5.96	<0.001	-0.62
	Salsa	-0.6	-2.75	0.007	-0.29
	Choreography	-0.1	-0.45	0.653	-0.02

Note: Positive Mean Difference and Cohen's d for CP indicate improvement. Negative Mean Difference and Cohen's d for E% indicate improvement. Between-group p-values are Bonferroni-adjusted.

Table 8. Bonferroni-Adjusted P-Values for key pairwise comparisons

Measure	Comparison	Bonferroni-Adjusted p-value	Interpretation
BRIEF-A: Inhibition Index	BAPNE vs. Control	<0.001	Significant
	BAPNE vs. Salsa	<0.001	Significant
	BAPNE vs. Body percussion Choreography	<0.001	Significant
	Salsa vs. Control	0.002	Significant
	Salsa vs. Body percussion Choreography	0.011	Not Significant at a stricter α
Stroop: Interference	BAPNE vs. Control	<0.001	Significant
	BAPNE vs. Salsa	<0.001	Significant
	BAPNE vs. Body percussion Choreography	<0.001	Significant
	Salsa vs. Control	<0.001	Significant
	Salsa vs. Body percussion Choreography	<0.001	Significant
D2: Concentration Performance	BAPNE vs. Control	<0.001	Significant
	BAPNE vs. Salsa	<0.001	Significant
	BAPNE vs. Choreography	<0.001	Significant
	Salsa vs. Control	<0.001	Significant
	Salsa vs. Choreography	<0.001	Significant

Note: P-values < 0.0083 are considered significant after Bonferroni correction. This table highlights that a large number of the effects remain highly significant, including the profound differences between the BAPNE group and the other groups.

program for enhancing executive functions in older adults. The BAPNE experimental group consistently exhibited superior improvements across all measured domains of executive function, particularly in inhibition, sustained attention, and cognitive flexibility, as evidenced by large effect sizes. This finding aligns perfectly with the theoretical underpinnings

of the BAPNE method, which emphasizes “doble tarea” (dual task). The continuous requirement for participants to simultaneously coordinate complex motor patterns with demanding cognitive tasks (e.g., rhythmic sequences while recalling information) directly challenges and strengthens the neural networks responsible for inhibitory control, selective atten-

tion, and the flexible switching of mental sets. This active engagement of multiple cognitive resources under temporal pressure provides a potent training stimulus, leading to the observed substantial gains. The consistent and robust nature of these improvements, as reflected in the large effect sizes, underscores the practical significance of the BAPNE method for promoting healthy cognitive aging.

Differential effects of interventions

A critical contribution of this study is its elucidation of the differential effects of various active interventions. While the salsa group showed moderate, yet significant, improvements in cognitive flexibility and attention, these gains were less pronounced and widespread than those observed in the BAPNE group. Salsa, with its elements of motor coordination, rhythm, and social interaction, undoubtedly offers cognitive stimulation. However, it may not consistently impose the same level of explicit “dual task” or inhibitory demands as the BAPNE method.

In stark contrast, the repetitive body percussion choreography group exhibited minimal to no significant improvements in any executive function domain, including inhibition and attention. This finding is particularly illuminating: it suggests that merely engaging in physical activity or rhythmic movement, if it lacks cognitive novelty, complexity, or adaptive challenges, may not provide sufficient neurocognitive stimulation to elicit meaningful gains in older adults. The repetitive nature of the choreography, devoid of new learning or problem-solving, likely failed to sufficiently challenge the executive functions, leading to a plateau in cognitive benefits. This stark contrast between salsa and repetitive choreography highlights the paramount importance of cognitive novelty and complexity in physical activity for cognitive benefits in older adults. Repetitive, rote activities appear insufficient to provide the necessary cognitive challenge, whereas activities demanding continuous adaptation and problem-solving, even at a moderate level like salsa, yield more favorable outcomes.

These findings resonate with and extend existing literature on the benefits of cognitively enriched physical activity and music-based interventions for older adults. Previous research has often highlighted the importance of multi-modal interventions that combine physical and cognitive demands. This study, however, provides a unique comparative analysis, demonstrating that even among active interventions, the specific design and cognitive load are crucial determinants of efficacy. The superior outcomes of BAPNE align with studies emphasizing the role of dual-task training in improving executive functions in aging populations. Conversely, the limited impact of repetitive choreography underscores the limitations of interventions that do not actively engage higher-order cognitive processes, reinforcing the notion that not all physical activities are equally beneficial for cognitive health.

The robust evidence presented in this study carries significant implications for public health initiatives aimed at promoting healthy aging. The BAPNE method, with its demonstrable and substantial improvements in critical executive functions, offers a highly effective and engaging intervention for older adults. Its successful implementation within the “Juventud Prolongada” municipal program in Chacao, Caracas, highlights its feasibility and acceptability in a com-

munity-based setting. Given the global demographic shift towards an aging population, and the associated societal burden of cognitive decline, interventions like BAPNE can play a pivotal role in maintaining cognitive vitality, enhancing functional independence, and improving the overall quality of life for older adults. The findings suggest that public health programs should prioritize and invest in activities that are not merely physically active but are specifically designed to challenge and train executive functions through integrated motor-cognitive demands. This study provides direct, actionable evidence for policymakers and program developers seeking to optimize cognitive well-being in aging populations.

Limitations

While the findings of this study offer valuable insights, a complete academic appraisal requires an honest discussion of its characteristics and the opportunities they present for future exploration. The study employed a quasi-experimental design, which, while highly effective for interventions in a naturalistic community setting, means that participants were not randomly assigned to groups. This approach provides a high degree of ecological validity, as the results reflect a real-world application, but it also necessitates a careful consideration of potential unmeasured variables. These characteristics of the study design can be viewed as an invitation for future research to explore these factors more deeply.

Furthermore, the study’s generalizability is a relevant point of discussion. The research was conducted in a specific urban context within a municipal program, which served as a strength by ensuring a homogeneous socioeconomic background among participants. This focus allowed for a clear assessment of the intervention’s effects within a defined population. Future research could build on this foundation by replicating the study in different cultural contexts, with a broader range of socioeconomic backgrounds, or with populations with specific cognitive profiles, thereby expanding our understanding of the method’s universal applicability. The success of the intervention was also facilitated by the high level of participant engagement and the expertise of the trainer. The low attrition rate is a testament to the program’s appeal and sustainability. The positive impact of the trainer’s skill and dedication is a valuable finding, suggesting that for widespread implementation, the quality of training and instruction is a critical component of success. Future studies could explore the generalizability of these findings across different trainers and in diverse settings. Looking forward, this research provides a compelling basis for a new generation of studies. A promising direction involves the use of neuroimaging techniques such as fMRI or EEG. These methodologies could provide a deeper, more detailed understanding of the brain mechanisms that underpin the observed cognitive improvements. For example, neuroimaging could reveal how the BAPNE method’s dual-task paradigm specifically reorganizes or strengthens neural networks related to executive functions, providing a clear biological basis for the behavioral changes observed. Ultimately, the characteristics of this study are not seen as weaknesses but rather as a solid foundation from which to launch subsequent investigations that can further strengthen the theoretical and practical underpinnings of the BAPNE method. The findings provide a clear and encouraging mandate for future research to explore these opportunities.

Future Research Directions

Building upon these foundational findings, several avenues for future research emerge. Longitudinal follow-up studies are warranted to assess the long-term maintenance of cognitive gains achieved through the BAPNE method. Investigations incorporating neuroimaging techniques (e.g., fMRI, EEG) could provide deeper insights into the neural mechanisms underlying the observed cognitive improvements, elucidating how BAPNE specifically modulates brain structure and function. Research in diverse populations, including those with mild cognitive impairment or different cultural backgrounds, would expand the generalizability of the method. Furthermore, dose-response studies could optimize intervention parameters (e.g., frequency, duration, intensity of “doble tarea”) to maximize cognitive benefits. Finally, exploring the specific components of the BAPNE method that are most critical for driving executive function improvements could lead to even more targeted and efficient interventions.

Conclusion

The statistical evidence from this rigorous longitudinal study provides unequivocal support for the efficacy of the BAPNE neuromotoricity method in significantly enhancing executive functions in older adults. The BAPNE experimental group demonstrated clear and substantial improvements, particularly in inhibition, sustained attention, and cognitive flexibility, as evidenced by robust effect sizes. These gains were consistently superior to those observed in a control group and active comparison groups engaged in salsa and repetitive body percussion choreography. The findings underscore that the cognitive demands inherent in an activity are paramount for promoting cognitive vitality in aging populations. While activities like salsa offer some benefits, purely repetitive activities yield minimal cognitive gains. The BAPNE method, with its unique emphasis on double-tasking and integrated motor-cognitive challenges, stands out as a highly effective intervention for improving executive functions, offering a powerful tool for healthy aging initiatives globally. The meticulous statistical analysis, emphasizing the magnitude of effects, strongly supports the conclusion that the neuromotoricity embedded within the BAPNE method leads to clear, clinically meaningful improvements in executive functions. This research shows that choreography using body percussion has very little cognitive value and is focused more on entertainment than on learning.

Declaration of Interests

The authors confirm the originality of this manuscript and attest that it has not been previously published or submitted for consideration to any other journal. Furthermore, the work has not been released as a preprint. The authors declare no actual or potential conflicts of interest related to this study.

Ethical Approval

This study was conducted in strict adherence to ethical research standards. The research protocol received approval from the head of the institution where the data

was collected. Informed consent was obtained from all student participants, who were fully briefed on the study's objectives, procedures, voluntary nature of participation, and their right to withdraw at any time without penalty. For data from institutional records, permission was secured from the relevant school authority, and student identities were anonymized to ensure confidentiality. All data was stored securely, with strict measures of confidentiality and anonymity maintained to protect the participants' privacy.

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References

- Clifford, A. M., Shanahan, J., McKee, J., Cleary, T., O'Neill, A., O'Gorman, M., & Ni Bhriain, O. (2023). The effect of dance on physical health and cognition in community dwelling older adults: a systematic review and meta-analysis. *Arts & health*, 15(2), 200-228. <https://doi.org/10.1080/17533015.2022.2093929>
- Gard, M., Dionigi, R. A., Horton, S., Baker, J., Weir, P., & Dionigi, C. (2017). The normalization of sport for older people? *Annals of Leisure Research*, 20(3), 253-272. <https://doi.org/10.1080/11745398.2016.1250646>
- Gayman, A. M., Fraser-Thomas, J., Dionigi, R. A., Horton, S., & Baker, J. (2017). Is sport good for older adults? A systematic review of psychosocial outcomes of older adults' sport participation. *International Review of Sport and Exercise Psychology*, 10(1), 164-185. <https://doi.org/10.1080/1750984X.2016.1199046>
- Meredith, S. J., Cox, N. J., Ibrahim, K., Higson, J., McNiff, J., Mitchell, S., ... & Lim, S. E. (2023). Factors that influence older adults' participation in physical activity: a systematic review of qualitative studies. *Age and ageing*, 52(8), afad145. <https://doi.org/10.1093/ageing/afad145>
- Podolski, O. S., Whitfield, T., Schaaf, L., Cornaro, C., Köbe, T., Koch, S., & Wirth, M. (2023). The impact of dance movement interventions on psychological health in older adults without dementia: a systematic review and meta-analysis. *Brain sciences*, 13(7), 981. <https://doi.org/10.3390/brainsci13070981>
- Diamond, A. (2013a). Executive functions. *Annual Review of Psychology*, 64, 135-168.
- Diamond, A. (2013b). *Interventions shown to aid executive function development in children 4 to 12 years of age*. In S. Goldstein & J. A. Naglieri (Eds.), *Handbook of executive functioning* (pp. 203-230). Springer New York.
- Lu, J., Abd Rahman, N. A., Wyon, M., & Shaharudin, S. (2024). The effects of dance interventions on physical function and quality of life among middle-aged and older adults: A systematic review. *PloS one*, 19(4), e0301236. <https://doi.org/10.1371/journal.pone.0301236>
- Rice, P. E., Thummuluri, D., Barnstaple, R., Fanning, J., Laurita-Spanglet, J., Soriano, C. T., & Hugenschmidt, C. E. (2025). Moving towards a medicine of dance: a scoping review of characteristics of dance interventions targeting older

- adults and a theoretical framework. *Journal of Alzheimer's Disease*, 105(4), 1183-1221.
<https://doi.org/10.3233/JAD-230741>
- Contreras-Osorio, F., Ramirez-Campillo, R., Cerda-Vega, E., Campos-Jara, R., Martinez-Salazar, C., Araneda, R., ... & Campos-Jara, C. (2022). Effects of sport-based exercise interventions on executive function in older adults: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 19(19), 12573. <https://doi.org/10.3390/ijerph191912573>
- Hwang, P. W. N., & Braun, K. L. (2015). The effectiveness of dance interventions to improve older adults' health: a systematic literature review. *Alternative Therapies in Health and Medicine*, 21(5), 64.
- Stern, G., Pscharakis, S. G., & Phillips, S. M. (2023). Effect of high-intensity interval training on functional movement in older adults: a systematic review and meta-analysis. *Sports Medicine-Open*, 9(1), 5.
<https://doi.org/10.1186/s40798-023-00551-1>
- Ambegaonkar, J. P., Matto, H., Ihara, E. S., Tompkins, C., Caswell, S. V., Cortes, N., ... & Dhokai, N. (2022). Dance, music, and social conversation program participation positively affects physical and mental health in community-dwelling older adults: A randomized controlled trial. *Journal of Dance Medicine & Science*, 26(4), 255-264.
<https://doi.org/10.12678/1089-313X.121522f>
- Granacher, U., Muehlbauer, T., Bridenbaugh, S. A., Wolf, M., Roth, R., Gschwind, Y., & Kressig, R. W. (2012). Effects of a salsa dance training on balance and strength performance in older adults. *Gerontology*, 58(4), 305-312.
<https://doi.org/10.1159/000334814>
- Hansen, R. K., Jochum, E., Egholm, D., Villumsen, M., & Hirata, R. P. (2024). Moving together-benefits of an online dance program on physical and mental health for older women: an exploratory mixed-method study. *BMC geriatrics*, 24(1), 392.
<https://doi.org/10.3389/fspor.2024.1384387>
- Peng, X., Xu, X., Hu, P., Zhu, X., & Wang, L. (2024). The physical and psychological effects of dance therapy on middle-aged and older adult with arterial hypertension: a systematic review. *Heliyon*, 10(23).
<https://doi.org/10.1016/j.heliyon.2024.e39930>
- Chen, T. T., Mak, T. C., Ng, S. S., & Wong, T. W. (2023). Attentional focus strategies to improve motor performance in older adults: a systematic review. *International journal of environmental research and public health*, 20(5), 4047.
- Sooktho, S., Songserm, N., Woradet, S., & Suksatan, W. (2022). A Meta-analysis of the effects of Dance Programs on Physical Performance: Appropriate Health Promotion for healthy older adults. *Annals of Geriatric Medicine and Research*, 26(3), 196.
- Mas-Mas, D., Romero-Naranjo, F. J., & Arnau-Mollá, A. F. (2023). Dual-task and movement: a bibliometric study based on high-impact search engines. *Retos: nuevas tendencias en educación física, deporte y recreación*, 50, 995-1009.
- Romero-Naranjo, F. J., Andreu-Cabrera, E., & Arnau-Mollá, A. F. (2024). Neuromotricity in early childhood education. Development tables as an interdisciplinary proposal according to the BAPNE method. *Retos: Nuevas Perspectivas de Educación Física, Deporte y Recreación*, 53.
- Álvarez-Morales, L. J., & Romero-Naranjo, F. J. (2019). Pilot study into executive functions with muslim and christian pupils in the city of Ceuta using body percussion. *The European Proceedings of Social & Behavioural Sciences EpSBS*, 60, Article 92. <https://doi.org/10.15405/epsbs.2019.04.02.92>
- Romero-Naranjo, F. J., Sayago-Martínez, R., Jiménez-Molina, J. B., & Arnau-Mollá, A. F. (2023a). Pilot Study of the Assessment of Anxiety and Attention through Body Percussion and Neuromotricity in Secondary School Students in Physical Education, Music and Visual Arts classes. *Retos*, 47, 573-588. <https://doi.org/10.47197/retos.v47.95595>
- Romero-Naranjo, F. J., & Andreu Cabrera, E. (2023a). Condición física y Neuromotricidad. Justificación teórico-práctica según el método BAPNE. *Retos: Nuevas tendencias en Educación Física, Deporte y Recreación*, 50, 215-227. <https://doi.org/10.47197/retos.v50.98712>
- Romero-Naranjo, F. J., & Andreu Cabrera, E. (2023b). The ten pillars of neuromotricity. Theoretical-practical justification according to the BAPNE method. *Retos*, 50, 357-370. <https://doi.org/10.47197/retos.v50.98333>
- Alonso-Sanz, A., & Romero-Naranjo, F. J. (2015). El círculo en la relación espacio y cuerpo. Foto-Ensayo a partir de Isidro Blasco y el método BAPNE. *Arte, Individuo y Sociedad*, 27(3), 359-374.
- Arnau-Mollá, A. F., Romero-Naranjo, F. J., & Andreu-Cabrera, E. (2024b). Comparing the impact of neuromotricity BAPNE method and traditional methodology on selective attention and concentration among future teachers: A gender-based comparative study. *Journal of Physical Education and Sport * (JPES)*, 24(5), 1212-1229.
<https://doi.org/10.7752/jpes.2024.05140>
- Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *Behavior Rating Inventory of Executive Function*. Psychological Assessment Resources.
- Reitan, R. M. (1958). The relation of the Trail Making Test to the Halstead's categories. *Journal of Clinical Psychology*, 14(3), 312-315.
- Benton, A. L., & Hamsher, K. deS. (1976). *Multilingual Aphasia Examination*. Iowa City, IA: University of Iowa.
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6), 643-662.
- Brickenkamp, R., & Zillmer, E. (1998). *The D2 Test of Attention*. Hogrefe & Huber.

Нейромоторика та виконавчі функції у осіб похилого віку: Кількісна інтервенція для забезпечення здорового старіння

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Мета дослідження. Мета цього дослідження полягала в порівнянні ефективності методу BAPNE, спеціально розробленої програми з високими когнітивними вимогами, з активними контрольними групами (сальса та перкусія тіла з хореографією) та пасивною контрольною групою. Дослідження мало на меті надати переконливі докази важливості когнітивного навантаження в інтервенціях щодо забезпечення здорового старіння.

Матеріали та методи. У цьому лонгітудному квазіекспериментальному дослідженні вивчався вплив 9.5-місячної нейромоторної інтервенції, методу BAPNE, на виконавчі функції у літніх осіб. Вибірка з 368 учасників (віком 60–78 років) із громадської програми в Каракасі, Венесуела, була розділена на чотири групи: BAPNE (експериментальна), сальса, перкусія тіла з хореографією та контрольна група. Оцінка виконавчих функцій проводилась за допомогою батареї валідованих нейропсихологічних тестів, включаючи опитувальник оцінки поведінки виконавчих функцій (BRIEF-A), тест послідовних з'єднань (TMT), тест на вербальну біглість, тест Струпа та тест уваги D2. Статистичний аналіз передбачав внутрішньогрупові порівняння (t-критерії для парних вибірок) та міжгрупові порівняння (коваріаційний аналіз) з метою контролю первинних відмінностей.

Результати. Група BAPNE продемонструвала значне поліпшення за всіма показниками, з великими розмірами ефекту, зокрема для інтерференції Струпа (d Коена = -1.48) та індексу інгібування BRIEF (d Коена = -1.47). Міжгрупові аналізи з контролем первинних показників підтвердили, що група BAPNE значно перевершила всі інші групи за інгібуванням та іншими виконавчими функціями (наприклад, інгібування BRIEF: $p < 0.001$, $\eta_p^2 = 0.45$; інтерференція Струпа: $p < 0.001$, $\eta_p^2 = 0.42$). Натомість група сальси показала помірні поліпшення, тоді як у групі перкусії тіла з хореографією спостерігалися незначні когнітивні досягнення.

Висновки. Це дослідження надає переконливі докази того, що застосування методу BAPNE з вимогами двозадачності призводить до суттєвих і клінічно значущих поліпшень виконавчих функцій, зокрема інгібування. Отримані результати підтверджують, що саме когнітивне навантаження в процесі активності, а не лише фізичні зусилля, є вирішальним фактором для ефективного когнітивного тренування на етапі старіння.

Ключові слова: нейромоторика, BAPNE, виконавчі функції, особи похилого віку, перкусія тіла.

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Analyzing Anthropometric Characteristics of Kettlebell Athletes

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Abstract

Background. The anthropometric indicators are closely related to physical performance and are used to monitor athletes in various sports. Assessment of physical development characteristics is particularly important in strength sports.

Objectives. This study aimed to conduct a comparative analysis of the anthropometric characteristics in kettlebell athletes with different skill levels using the index method.

Materials and Methods. A total of 30 kettlebell athletes were divided into the following groups: Group 1 consisted of 16 kettlebell athletes (15.56 ± 0.27) years old, with (3.84 ± 0.42) years of training experience and skill levels ranging from novices to candidates for master of sports. Group 2 comprised 14 kettlebell athletes (24.50 ± 2.25) years old, with (7.79 ± 1.86) years of training experience and skill levels ranging from masters of sport to honored masters of sport. 16 anthropometric indicators (body length and weight, chest circumference at rest, shoulder width, arm and forearm length, biceps and forearm circumference, length of the second and fourth fingers of the right hand, and grip strength in static and dynamic modes) were determined. 10 physical development indices were calculated based on these measurements. The median, 1st (25%) and 3rd (75%) quartiles were determined to characterize the data. The nonparametric Rosenbaum criterion (Q) was used to assess the reliability of differences between groups.

Results. Significant differences were confirmed between the groups. Experienced kettlebell athletes had higher values for the Erisman index (Q = 10), shoulder width index (Q = 11), Livy index (Q = 10), and body surface according to Isaksson (Q=10). According to the massiveness indices, an increase in this index was found in experienced athletes for the right shoulder (Q = 8), left shoulder (Q = 7), and right forearm (Q = 7). These kettlebell athletes were characterized by a significant increase in the static and dynamic grip index for the right (Q = 11) and left (Q = 9) hands. This index was >1. No significant differences were observed in the body mass index, left forearm mass index, strength index values, and 2D:4D index. A strength index value of more than 60% prevailed among the participants. The median 2D:4D index was 1.0 for all participants.

Conclusions. The anthropometric characteristics of kettlebell athletes with different skill levels were compared using the index method. This method is an adequate and informative assessment tool. Specialized indices illustrate the specific influence of the sport on athletes' condition. The Erisman and shoulder width indices indicate that experienced athletes have better development of the torso muscles. The increase in body surface reflects the growth of adaptive capabilities, while the massiveness indices and the static and dynamic grip indices demonstrate a higher level of upper limb and hand muscle development. Most participants had a high strength index. This confirms the importance of grip strength for successful kettlebell lifting. The 2D:4D index should also be considered when selecting athletes for kettlebell lifting. The simplicity, clarity, and informativeness of the indices allow them to be recommended for use as screening tests in monitoring the condition of kettlebell athletes.

Keywords: kettlebell lifting, anthropometric characteristics, indices, selection, success.

Introduction

Anthropometric indicators are closely related to physical performance and are used to monitor athletes in various sports (Ferro, 2023; Podrigalo et al., 2022). Physical development characteristics and the state of basic physical qualities (e.g., strength, endurance, speed, and coordination) are considered factors of success in sports. Physical development is recognized as a prerequisite for achieving high sports results (Podrigalo et al., 2022; Candra & Farhanto, 2021; Navas Harrison et al., 2023). However, there is insufficient information to create standards of physical development for different types of sports (Tingelstad et al., 2023; Busta et al., 2023). This necessitates the use of other approaches to analyze and evaluate the athletes' condition. Promising areas of research include the study of somatotype, the calculation of indices, and the determination of correlations between the anthropometric and functional characteristics of athletes.

A previous study (Laurin, 2024) investigated the correlation between the results of Zybek Sport tests and the anthropometric data of elite American taekwondo athletes. Lower body weight, body length, and body mass index (BMI) improve results in sprinting and agility tests. Long jump results, higher body weight, body length, and BMI were associated with better performance in the 40-yard dash.

Anthropometric research, somatotype assessment, and physical fitness testing are the most common tests and trials used to assess athletes' condition. This allows combining morphological and functional criteria for a comprehensive assessment (Sanchez-Martinez & Hernández-Jaña, 2022; Busta et al., 2023; Pireva, 2019). A similar approach was implemented to analyze the condition of football players in the study (Toro-Román et al., 2023). It was concluded that knowledge of the anthropometric and physical characteristics of soccer players, considering their position and gender, is necessary for developing special training programs.

In another study (Pireva, 2019), the analysis of anthropometric parameters, body mass index (BMI), and somatotype was used to identify the characteristics of elite athletes in team sports. Football players were shorter and had a lower body weight than basketball and handball players. The BMI of football players was significantly lower than that of handball players. The BMI of football and basketball players did not differ. Handball players were shorter than basketball players, and their BMIs were higher than those of basketball and football players. Football players had larger relative transverse and circumferential dimensions than handball players. Football players had lower skinfold thickness values and a lower body fat percentage than handball players.

Analysis of anthropometric characteristics allows for high-quality sports selection and determination of athletes' specialization (Matarazzo et al., 2024; Wiacek et al., 2022; Murugan et al., 2023). The anthropometric profiles of athletes from the Italian national teams in artistic gymnastics, long-distance swimming, synchronized swimming, and basketball are presented in the study (Matarazzo et al., 2024). Constitutional habitus is characterized by a more developed upper body than the lower limbs in water sports. The conclusion was made regarding the possibility of using anthropometric parameters for selection in these sports.

In the study (Wiacek et al., 2022), the possibility of using anthropometric parameters and indices based on

them to assess prospects in various sports was evaluated. The existence of a correlation between sports discipline and physical development parameters was confirmed. The tested approach is the basis for the selection and choice of specialization.

A multidimensional analysis of anthropometric indicators at the population level was carried out in the article (Navas Harrison et al., 2023). Five differentiating variables were obtained: fat mass, muscle mass, bone mass, skin fold, and body strength. It is proposed to use morphotype to select the optimal sport.

Similar results were obtained in the study (Ferro, 2023). An analysis of 29 anthropometric indicators of elite Argentine swimmers was conducted. It was concluded that there were clear differences between the swimmers and the control group. These physical characteristics allow us to assess body composition as a prerequisite for achieving better results in sports.

Another study (Saal et al., 2022) proposed using anthropometric characteristics to predict the success of athletes in canoeing. Correlations were confirmed between anthropometric indicators (height and body weight), physical fitness (cardiorespiratory endurance and muscle strength), and specific indicators for this sport (canoe sprint time on water 250 and 2000 m).

The study of proportional physical development involves the use of the index method. This method is quite common in sports science. The review (Bonilla et al., 2022) is devoted to the use of simple anthropometric indices to monitor body composition changes in amateur and elite athletes. The sum of skinfold thicknesses and the lean mass index are the most valid for monitoring.

Assessing physical development characteristics is especially important in strength sports (Pasini et al., 2023; Winwood et al., 2012; Podrigalo et al., 2025). An anthropometric study of powerlifting athletes was presented in the study (Pasini et al., 2023). A correlation was found between morphological indicators, maximum strength, and the number of points athletes received for bench press performance. The importance of body proportions and composition as predictors of strength sports performance was confirmed.

Another study (Winwood et al., 2012) investigated the correlation between anthropometric parameters, strength, and the results of Strongman competitions. Body structure and the results of strength exercises are significantly related to the performance of a strongman.

The previous review (Podrigalo et al., 2025) emphasized the importance of monitoring in strength sports. The selection of informative and adequate criteria and tests is a promising direction. Morphological indicators allow the assessment of the potential of athletes and the adjustment of their training programs.

However, the index method has not been sufficiently used to analyze the anthropometric characteristics of kettlebell athletes. This study's hypothesis is described as follows: "To prove the adequacy of the index method for assessing the anthropometric characteristics of kettlebell athletes with different skill levels."

Based on the above, this study aimed to conduct a comparative analysis of the anthropometric characteristics of kettlebell athletes with different skill levels using the index method.

Materials and Methods

Participants

30 kettlebell athletes were divided into two groups. The age of the participants, their training experience, and their level of athletic skill were the criteria for division. Group 1 consisted of 16 kettlebell athletes with an average age of (15.56 ± 0.27) years, training experience of (3.84 ± 0.42) years, and skill levels ranging from novices to candidates for master of sports. Group 2 consisted of 14 kettlebell athletes with an average age of (24.50 ± 2.25) years, training experience of (7.79 ± 1.86) years, and skill levels ranging from masters of sport to honored masters of sport. Differences in age and training experience were statistically significant ($p < 0.05$). All participants or their parents provided informed consent to participate in the studies in accordance with international bioethical requirements.

Methods

The study design involved determining anthropometric indicators and calculating their indices. Measurements were performed in accordance with the requirements of the international standardized methodology for anthropometric studies (Marfell-Jones et al., 2012). 16 anthropometric indicators were determined: body length and weight, chest circumference at rest, shoulder width, upper arm and forearm length, biceps and forearm circumference, and the length of the second and fourth fingers of the right hand. The grip strength in the static mode was determined using a Camry EH101 electronic dynamometer (China). The grip strength in the impulse mode was determined by the number of compressions with a force of 10 kg in 10 s. A grip strength device (China) was used.

Procedure

Ten indices were calculated based on the determined anthropometric parameters.

The body mass index was determined as the ratio of mass (kg) to body length squared (m^2). A value within the range of 20–25 kg/m^2 was considered normal.

The Erismann index was calculated as the difference between the chest circumference (cm) and half the body length (cm). This index should be at least 5.8 cm for men.

The shoulder width index was calculated as the ratio of this parameter to body length, expressed as a percentage. A value within the range of 23–25 % was considered normal.

The strength index was determined as the percentage of grip strength (kg) to body weight (kg). Values within the range of 50–60 % were considered normal.

The Livi index was calculated as the ratio of the chest circumference at rest (cm) to the body length (cm). The following scale was used to evaluate the results:

<0.50 – disharmonious weak development,
0.50–0.55 – harmonious development, >0.55 – disharmonious excessive development.

The body surface was calculated according to Isaakson using the following formula:

$$S = 1 + (BM + (BL - 160)) / 100, \quad (1),$$
 where S is the body surface (m^2), BM is the body mass (kg), and BL is the body length (cm).

The massiveness indices of the arm segment (shoulder and forearm) were determined using the following formula:

$$SMI = SC \cdot 100\% / SL \quad (2),$$
 where SMI is the segment massiveness index, SC is the segment circumference (cm), and SL is the segment length (cm).

The static and dynamic grip index was found as the ratio of grip strength (kg) to the maximum grip frequency in pulse mode for 10 s (abs).

The 2D:4D index was calculated as the ratio of the length of the second finger (mm) to the length of the fourth finger (mm) of the right hand.

Statistical Analysis

The obtained data were statistically analyzed using licensed MS Excel 2019 version 2506. The median (Me), 1st (25%) and 3rd (75%) quartiles were determined based on the sample size and distribution characteristics to characterize the data. The nonparametric Rosenbaum criterion (Q) was used to assess the reliability of differences between groups, with differences considered reliable at $p < 0.05$.

Results

The obtained results are presented in Table 1.

Table 1 confirms the presence of significant differences between the groups. Experienced kettlebell athletes had higher values for the Erismann index ($Q = 10$), shoulder width index ($Q = 11$), Livi index ($Q = 10$), and body surface area according to Isaakson ($Q = 10$). In terms of mass indices, an increase in this index was found in experienced athletes for the right shoulder ($Q = 8$), left shoulder ($Q = 7$), and right forearm ($Q = 7$). Experienced kettlebell athletes were characterized by a significant increase in the static and dynamic grip index for the right ($Q = 11$) and left hands ($Q = 9$).

No significant differences were found in the body mass index, left forearm mass index, strength index, and 2D:4D index.

An individual analysis of the distribution of participants relative to the norm was conducted for indices that have assessment scales. In novice athletes, BMI was mainly within the average range. In group 1, 25.0 % had a BMI above the norm, and 12.5 % had BMI below the norm. In the group of experienced kettlebell athletes, 50.0 % of the athletes had BMI above the norm.

The median Livi index corresponds to the range of harmonious development in group 1 and excessive physique in group 2. Individual analysis of the results confirmed that in group 1, 50.0 % were characterized by insufficient physique and only 12.5 % by excessive physique. In group 2, the proportion of such participants was 7.1 % and 50.0 %, respectively.

In group 1, the median Erismann index is low. Only 25.0 % of the participants had this indicator above normal. In group 2, the median falls within the above-normal range. The vast majority of participants (78.6 %) had an increased level of this index.

The proportion of participants with a shoulder width index below normal in group 1 was 25.0 %, and that above normal was 12.5 %. In group 2, no participants had an index below normal. The proportion of athletes with a shoulder width index above normal was 28.6 %.

Table 1. Anthropometric indices of kettlebell athletes

Indicators	1 group, (n = 16)			2 group, (n = 14)		
	25 %	Me	75 %	25 %	Me	75 %
Body mass index, kg/m ²	20.69	22.46	25.29	23.72	25.88	28.77
Livi index, abs	0.48	0.50*	0.53	0.54	0.56	0.58
Erismen index, cm	-2.88	0.13*	4.19	7.31	10.13	14.75
Shoulder width index, %	22.95	23.34*	24.38	23.83	24.32	25.12
Body surface according to Isakson, m ²	1.70	1.82*	1.97	1.98	2.04	2.21
Right shoulder mass index, abs	90.28	94.21*	104.76	100.00	104.42	109.11
Left shoulder mass index, abs	89.25	95.16*	104.50	97.73	102.23	105.84
Right forearm mass index, abs	101.92	106.73*	114.71	111.67	116.36	122.86
Left forearm mass index, abs	101.95	105.77	115.54	108.04	117.11	121.50
Right hand static and dynamic grip index, kg	0.86	0.98*	1.15	1.05	1.11	1.22
Left hand static and dynamic grip index, kg	0.87	0.94*	1.22	1.13	1.26	1.28
Right hand strength index, %	59.07	64.02	69.56	53.51	62.58	67.30
Left hand strength index, %	56.34	65.40	72.34	57.25	60.57	66.52
2D:4D index, abs	0.95	1.00	1.03	0.96	1.00	1.03

Note: * - differences are significant (p<0.05)

In group 1, the proportion of kettlebell athletes with a strength index of less than 50 % was 13.3 % for the right hand and 6.7 % for the left hand. In group 2, the percentages were 0% and 8.3 %, respectively. The proportion of kettlebell athletes with a high strength index (>60 %) was 73.3 % for the right hand and 60.0% for the left hand in group 1. In group 2, it was 66.7 % and 58.3 %, respectively.

Discussion

The results confirmed the validity of using the index method to analyze the condition of kettlebell athletes with different skill levels. This confirms the available literature data. The effectiveness of the index method for the comparative assessment of the condition of athletes in various martial arts (Podrigalo et al., 2019) and arm wrestling athletes (Rovnaya et al., 2019) has been established. The advantages of this method are its simplicity, clarity, compliance with monitoring principles, and financial feasibility.

Age and skill level were chosen as the main criteria for dividing the participants into groups. Novice athletes belong to the children's group (under 18 years of age), whereas experienced athletes belong to the adult group. Age differences predetermined differences in training experience. The different training durations led to differences in the skill levels of the participants. This also corresponds to the available data.

Enough studies have been devoted to comparing athletes of different ages (Tingelstad et al., 2023; Saal et al., 2022). In review (Tingelstad et al., 2023), this approach is interpreted as an opportunity to assess the realization of athletes' potential. A gradual improvement in physical development and physical fitness indicators with increasing age was confirmed. Another study (Saal et al., 2022) suggested using age to identify predictors of athletic performance, develop effective testing protocols, and identify talented canoe athletes.

The existence of a correlation between morphological indicators and training experience has been confirmed in a

previous study (Sanchez-Martinez & Hernández-Jaña, 2022). Experienced street workout athletes were characterized by an increase in anthropometric indicators of muscle condition and an improvement in body proportions.

The indices used in the study can be divided into general and specialized indices. The general indices reflect the correlation between the main anthropometric indicators (body length and weight, chest circumference, and height). They are designed to establish the physical development level and physical harmony. Specialized indices illustrate the specific influence of a sport on athletes' condition. They can serve as predictors of success, as confirmed by the available results (Podrigalo et al., 2019; Rovnaya et al., 2019). The indices used reflected the correlation between longitudinal indicators, diameters, and perimeters that characterized muscle development, illustrating the dependencies between grip strength in different modes.

Given the specifics of kettlebell lifting, specialized indices can be used for selection and success prediction. This is confirmed by the existing results. The effectiveness of anthropometric indices for sports selection was confirmed (Wiacek et al., 2022). Indices of the ratio of standing and sitting body length, limb and limb segment lengths, and chest and waist circumferences to the longitudinal dimensions of athletes' bodies were used.

Similar data are presented in a previous review (Bonilla et al., 2022). The longitudinal indicators, perimeters, and skin fold thickness are considered effective monitoring tools.

In another article (Navas Harrison et al., 2023), indices are used to classify people according to their physical health level. The effectiveness of the body mass index, relative lower limb index, and specific weight of muscle and fat tissue has been confirmed.

The body mass index is most commonly found in sports research. The World Health Organization recommends using this indicator to analyze health and nutritional status. The advantages of this index are its simplicity and clarity. However, it is quite nonspecific, as confirmed in our study.

In our opinion, the individual BMI analysis results can be explained by the peculiarities of kettlebell lifting. Its strength orientation increases the proportion of muscle tissue. This increases the BMI. The norm for this index is calculated for the average person and is not always suitable for assessing the condition of athletes.

This assumption is confirmed by the Livi index results. A significant increase in this index was observed in experienced kettlebell athletes. This should be assessed as changes in the athletes' torsos due to an increase in the muscle mass proportion. The results of the individual analysis confirm this. Individuals with insufficient and disharmonious development predominate among novice kettlebell lifters. Among experienced athletes, half of the participants were characterized by increased chest development.

Kettlebell lifting is characterized by a pronounced focus on strength. This necessitates the use of indices that assess strength and muscle development.

The Erisman index is a special index for kettlebell lifting. This is because it reflects the development of the torso muscles. The participants' age characteristics determined significant differences in this index. Most novice kettlebell athletes had a lower-than-normal value for this index. The opposite was true for experienced athletes, most of whom had a higher index value. This situation can be explained by the increase in torso muscle volume and strength in more experienced kettlebell athletes. This should be assessed as a manifestation of the sport's specific influence. The obtained results coincide with the available literature data. In the study (Podrigalo et al., 2019), an increase in the Erisman index in wrestlers and kickboxers is interpreted as a reflection of these martial arts' strength orientation.

A comparative analysis of the shoulder width index allows us to draw a similar conclusion. In both groups, the medians fall within the range of average values, but this indicator is significantly higher in experienced athletes than in non-experienced athletes. This illustrates the improved development of the shoulder girdle muscles. These muscle groups also play an important role in the success of kettlebell lifting. This assumption is supported by an individual analysis of this index, which is presented in the "Results" section. This index confirms that regular kettlebell training contributes to the development of the shoulder girdle muscles. Similar results were obtained in a previous study (Podrigalo et al., 2019), which found an increase in this index in wrestlers and kickboxers compared to martial art athletes.

The Isaakson body surface is a complex index. Determining this indicator requires the use of basic anthropometric parameters, such as body length and weight. It allows the assessment of the functional state of athletes and reflects their aerobic capacity. This is especially important in kettlebell lifting, where aerobic exercise predominates. Therefore, this index is also specific to kettlebell lifting. A large body surface area in experienced athletes should be assessed as an increase in their adaptive potential. Similar results were obtained in the study (Rovnaya et al., 2019), which confirmed an increase in body surface area in experienced arm wrestlers compared with novice athletes.

The mass indices of the upper limb segments were used to assess the ratio of longitudinal and circumferential indicators. This allows us to judge the condition of the muscular system and indirectly reflects the strength level. An

increase in the mass indices of the right and left shoulders, as well as the right forearm, was observed in experienced kettlebell athletes. This should be interpreted as evidence of increased arm muscle development. These indices should be considered as important prognostic indicators.

The use of longitudinal indicators in these indices reflects the importance of using long levers for lifting kettlebells. The inclusion of limb segment perimeters in the indices illustrates the level of development of these muscle groups. In addition, the ratio of longitudinal and circumferential dimensions is important from the point of view of the convenience of lifting kettlebells. The optimal ratio allows for a comfortable position of the weights on the chest at the beginning of the lift, thereby achieving an economy of effort. From the standpoint of performance in kettlebell lifting, mass indices should be evaluated as important success predictors.

The approach used to assess the condition of limb muscles is quite common in sports. Similar indices have been developed and tested in a previous study (Pasini et al., 2023). Their analysis confirmed significant differences in powerlifting athletes' preparedness. Another study (Winwood et al., 2012) emphasized the importance of perimeter dimensions for assessing muscle strength. The biceps and calf circumferences had the strongest correlations with the overall performance of strongmen.

Similar results were obtained in a previous study (Podrigalo et al., 2019). Arm mass indices were used to compare the arm wrestling athletes with different skill levels. An increase in these indices characterized experienced athletes. This reflects a higher development of the forearm and shoulder muscles. The importance of developing these muscle groups to increase success in arm wrestling was concluded.

Grip strength and indices based on this indicator have been widely used in sports (Busta et al., 2023; Zaccagni et al., 2020). A strong grip is a predictor of success in many sports. For example, in the study (Busta et al., 2023), grip strength is used as a selection criterion in academic rowing. Another study (Zaccagni et al., 2020) showed the correlation between handgrip strength and anthropometric parameters and body composition parameters in both sexes. Multiple regression analysis confirmed that gender, dominant shoulder muscle area, arm fat index, fat mass, and lean mass were significant predictors of handgrip strength.

The development of grip strength and hand and forearm muscles is essential for success in kettlebell lifting. This study used three indices to assess hand condition: strength index, static and dynamic grip index, and 2D:4D index. These indicators allow the assessment of hand function and are specific to kettlebell lifting.

A similar approach was used in the study (Matarazzo et al., 2024). This study aimed to study the anthropometric parameters of the hands of elite swimmers. The general parameters of the hand (length, width of the palm, width of the metacarpal bone of the hand, and distance between the fingers) and the length of individual fingers were assessed. It was proposed to use the studied indicators as predictors of swimming success.

The strength index did not confirm significant differences between the groups. The median value was more than 60% in both groups. Individual analysis results also confirmed the predominance of individuals with an index of more than 60% in both groups. This allows us to assess this index as high, which characterizes an increased level of

grip strength development. This illustrates the importance of this index for success in kettlebell lifting. Grip strength development is an important area of training for kettlebell athletes. Therefore, even novice athletes are characterized by high index values.

The static and dynamic grip index shows the hand strength ratio in isometric and isotonic modes. The combination of these modes of operation is also characteristic of kettlebell lifting. This indicator reflects the muscle groups' potential to perform various actions. The use of this index significantly improves the assessment quality and allows for a comprehensive analysis of muscle status.

The available data confirm the promise of this approach. Thus, in the study (Nutt et al., 2022), a similar approach was used to assess the strength of the neck muscles in American football and rugby athletes. The index of the neck flexor/extensor strength ratio was used. The high informative value of this indicator was confirmed. It correlated with important anthropometric criteria (body weight and length, neck circumference, and grip strength).

The static and dynamic grip index was tested when studying the anthropometric characteristics of arm wrestling and street workout athletes (Podrihalo et al., 2021). High index values were found in experienced athletes. It is highly informative for predicting success in sports, where success depends on grip strength.

The results obtained confirm the existing literature data. Experienced kettlebell athletes have higher static and dynamic grip index values. The differences in this index for both hands can be explained by the fact that both hands lift the kettlebells. In experienced kettlebell athletes, this index is >1 . This allows us to consider the optimal development of the hand muscles for functioning in various modes. In our opinion, this should be evaluated as confirmation of the assumptions made earlier.

The 2D:4D index is currently widely used for sports monitoring, selection, and prediction (Podrigalo et al., 2022; Camarco et al., 2022). Its potential for use in various types of martial arts has been confirmed (Podrigalo et al., 2022). Another study (Podrigalo et al., 2022) suggested that the median 2D:4D ratio for martial arts athletes was 0.95, which was lower than that of the control group (0.97). The correlation of this index with grip strength and somatotype characteristics was confirmed.

Similar data are presented in the study (Adamczyk et al., 2021). The 2D:4D index was less than 1 in martial arts athletes. This is considered a specific feature of these sports and should be considered when monitoring the condition of athletes.

In our study, the median 2D:4D index was higher or 1.0 in both groups. The number of participants is insufficient for definitive conclusions, and this indicator needs further study. However, this index is typically assumed to be around one for kettlebell lifting, which is due to the equal length of the second and fourth fingers. This assumption is supported by the absence of differences between the groups and practically identical quartile values. The results obtained allow us to recommend this index as a screening test for kettlebell lifting selection.

Conclusions

Differences in the anthropometric characteristics of kettlebell athletes with different skill levels have been

established. The index method is an adequate and informative assessment tool. Specialized indices illustrate the specific influence of the sport on athletes' condition. Erismán's indices and shoulder width indicate better development of the torso muscles in experienced athletes. An increase in body surface area reflects an increase in adaptive capabilities, while mass indices and static and dynamic grip indices indicate a higher level of upper limb and hand muscle development. Most participants had a high strength index. This confirms the importance of grip strength for successful kettlebell lifting. The 2D:4D index should be considered when selecting athletes for kettlebell lifting. The simplicity, clarity, and informativeness of the indices allow them to be recommended for use as screening tests in monitoring the condition of kettlebell lifting athletes.

The limitation of this study is the small number of participants. In some cases, this does not allow for definitive conclusions to be drawn and only provides grounds for establishing trends.

Prospects for further research include the development of a screening test system for analyzing the physical and functional condition of kettlebell athletes.

Conflict of interests

The authors declare no conflict of interest.

References

- Ferro, M. D. (2023). Perfil antropométrico y rendimiento deportivo de nadadores de piletta durante el Campeonato Argentino de Natación, 2015. *International Journal of Kinanthropometry*, 3(2), 133-149. <https://doi.org/10.34256/ijk23215>
- Podrigalo, L.V., Shi, K., Podrihalo, O.O., Volodchenko, O.A., Halashko, O.I. (2022). Main research areas in kickboxing investigations: an analysis of the scientific articles of the Web of Science Core Collection. *Pedagogy of Physical Culture and Sports*, 26(4), 244-259. <https://doi.org/10.15561/26649837.2022.0404>
- Candra, A. T., & Farhanto, G. (2021). Analysis Of KKGO Muncar Athlete Achievement Based on Physical Condition Level and Anthropometry. *Jp.Jok (Jurnal Pendidikan Jasmani, Olahraga Dan Kesehatan)*, 4(2), 195–209. <https://doi.org/10.33503/jp.jok.v4i2.1300>
- Tingelstad, L. M., Raastad, T., Till, K., & Luteberget, L. S. (2023). The development of physical characteristics in adolescent team sport athletes: A systematic review. *PLoS ONE*, 18(12 DECEMBER). <https://doi.org/10.1371/journal.pone.0296181>
- Laurin, L. L. (2024). Anthropometry and athletic performance with Zybek sports in elite American taekwondo athletes. *Scientific Journal of Sport and Performance*, 3(2), 282-290. <https://doi.org/10.55860/xqkj6685>
- Navas Harrison, D. J., Pérez Pico, A. M., García Blázquez, F. M., & Acevedo, R. M. (2023). Anthropometric and Kinanthropometric Distinctive Profile of a Sedentary Population Compared with an Amateur Athlete Population. *Applied Sciences (Switzerland)*, 13(5). <https://doi.org/10.3390/app13052951>
- Sanchez-Martinez, J., & Hernández-Jaña, S. (2022). Morphological Differences of Street Workout Athletes According to the Training Experience. *International*

- Journal of Morphology*, 40(2), 320-326.
<https://doi.org/10.4067/S0717-95022022000200320>
- Busta, J., Hellebrand, J., Kinkorová, I., & Macas, T. (2023). Morphological and hand grip strength characteristics and differences between participants of the 2022 world rowing championship. *Frontiers in Sports and Active Living*, 5. <https://doi.org/10.3389/fspor.2023.1115336>
- Pireva, A. (2019). Anthropometric and body composition differences among elite kosovo basketball, handball and soccer players. *International Journal of Morphology*, 37(3), 1067-1072.
<https://doi.org/10.4067/S0717-95022019000301067>
- Toro-Román, V., Grijota, F. J., Muñoz, D., Maynar-Mariño, M., Clemente-Gil, S., & Robles-Gil, M. C. (2023). Anthropometry, Body Composition, and Physical Fitness in Semi-Professional Soccer Players: Differences between Sexes and Playing Position. *Applied Sciences (Switzerland)*, 13(3).
<https://doi.org/10.3390/app13031249>
- Matarazzo, A., D'angelo, A., D'Anastasio, R., & Ripa Ri, P. (2024). Hand Anthropometry of Italian Elite Male Swimmers. *International Journal of Morphology*, 42(1), 82-85. <https://doi.org/10.4067/S0717-95022024000100082>
- Wiacek, M., Tomasiuk, R., & Zubrzycki, I. Z. (2022). Correlations between Anthropometric Measurements and Sports Discipline Aptitude. *Applied Sciences (Switzerland)*, 12(12). <https://doi.org/10.3390/app12125932>
- Murugan, P. V., Jothilingam, M., & J.P. A. A. (2023). Comparson of Kinanthropometry Profile of Different Track and Field Athletes. *International Journal of Kinanthropometry*, 3(1), 85-89. <https://doi.org/10.34256/ijk2319>
- Saal, C., Chaabene, H., Helm, N., Warnke, T., & Prieske, O. (2022). Network analysis of associations between anthropometry, physical fitness, and sport-specific performance in young canoe sprint athletes: The role of age and sex. *Frontiers in Sports and Active Living*, 4. <https://doi.org/10.3389/fspor.2022.1038350>
- Bonilla, D. A., De León, L. G., Alexander-Cortez, P., Odriozola-Martínez, A., Herrera-Amante, C. A., Vargas-Molina, S., & Petro, J. L. (2022, March 1). Simple anthropometry-based calculations to monitor body composition in athletes: Scoping review and reference values. *Nutrition and Health*. SAGE Publications Ltd. <https://doi.org/10.1177/02601060211002941>
- Pasini, A., Caruso, L., Bortolotto, E., Lamberti, N., Toselli, S., Manfredini, F., ... Rinaldo, N. (2023). Prediction of bench press performance in powerlifting: The role of upper limb anthropometry. *Journal of Human Sport and Exercise*, 18(2), 484-500. <https://doi.org/10.14198/jhse.2023.182.18>
- Winwood, P. W., Keogh, J. W. L., & Harris, N. K. (2012). Interrelationships between strength, anthropometrics, and strongman performance in novice strongman athletes. *Journal of Strength and Conditioning Research*, 26(2), 513-522. <https://doi.org/10.1519/JSC.0b013e318220db1a>
- Podrigalo, L., Tymchenko, K., Perevoznyk, V., Semeniv, B., Paievskyi, V., Halashko, O. (2025). Scientific support for strength sports: analysis of scientific resources from the Web of Science Core Collection. *Pedagogy of Physical Culture and Sports*, 29(1), 44-61.
<https://doi.org/10.15561/26649837.2025.0106>
- Marfell-Jones, M., Olds, T., Stewart, A., & Lindsay Carter, L.E. (2012). *ISAK manual, International standards for Anthropometric Assessment*. In International Society for the Advancement of Kinanthropometry; Published by The international society for the advancement of kinanthropometry, The University of South Australia Holbrooks Rd, Underdale, SA: Australia, 2012.
- Podrigalo, L.V., Cynarski, W. J., Rovnaya, O.O., Volodchenko, O.O. (2019). Studying of physical development features of elite athletes of combat sports by means of special indexes. *Ido Movement for Culture-Journal of Martial Arts Anthropology*, 19(1), 51-57. <https://doi.org/10.14589/ido.19.1.5>
- Rovnaya, O., Podrigalo, L., Iermakov, S., Yermakova, T., & Potop, V. (2019). The Application of the Index Method to Assess the Condition of Armwrestling Athletes with Different Levels of Sports Mastery. *Revista Romaneasca pentru Educatie Multidimensionala*, 11(4 Supl. 1), 242-256. <https://doi.org/10.18662/rrem/187>
- Zaccagni, L., Toselli, S., Bramanti, B., Gualdi-Russo, E., Mongillo, J., & Rinaldo, N. (2020). Handgrip strength in young adults: Association with anthropometric variables and laterality. *International Journal of Environmental Research and Public Health*, 17(12), 1-12.
<https://doi.org/10.3390/ijerph17124273>
- Nutt, S., McKay, M. J., Gillies, L., & Peek, K. (2022). Neck strength and concussion prevalence in football and rugby athletes. *Journal of Science and Medicine in Sport*, 25(8), 632-638. <https://doi.org/10.1016/j.jsams.2022.04.001>
- Podrihalo, O.O., Podrigalo, L.V., Kiprych, S.V., Galashko, M.I., Alekseev, A.F., Tropin, Y.M., Deineko, A.Kh., Marchenkov, M.K., Nasonkina, O.Yu. (2021). The comparative analysis of morphological and functional indicators of armwrestling and street workout athletes. *Pedagogy of Physical Culture and Sports*, 25(3), 188-193.
<https://doi.org/10.15561/26649837.2021.0307>
- Camarco, N. F., Neto, I. V. de S., Ribeiro, E., & Andrade, A. J. M. (2022). Anthropometrics, Performance, and Psychological Outcomes in Mixed Martial Arts Athletes. *Biology*, 11(8). <https://doi.org/10.3390/biology11081147>
- Adamczyk, J.G., Safranow, K., Gajewski, A.K., et al. (2021). The Second-to-Fourth Digit (2D:4D) Ratio of Male Combat Athletes is Associated with the Choice of Sport. *Journal of Human Kinetics*, 78(1), 59-66.
<https://doi.org/10.2478/hukin-2020-0083>

Аналіз антропометричних особливостей атлетів гирьового спорту

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Вступ. Антропометричні показники тісно пов'язані з фізичною працездатністю та використовуються для моніторингу атлетів різних видів спорту. Оцінка особливостей фізичного розвитку є особливо важливою у силових видах спорту.

Мета роботи: порівняльний аналіз антропометричних особливостей атлетів гирьового спорту різного рівня майстерності за допомогою методу індексів.

Матеріали і методи. 30 атлетів гирьового спорту було поділено на групи. 1 група - 16 гирьовиків ($15,56 \pm 0,27$) років, стаж тренувань ($3,84 \pm 0,42$) років, рівень майстерності від початківців до кандидатів у майстри спорту. 2 група – 14 гирьовиків ($24,50 \pm 2,25$) років, стаж тренувань ($7,79 \pm 1,86$) років, рівень майстерності від майстрів спорту до заслужених майстрів спорту. Визначали 16 антропометричних показників (довжину та масу тіла, окружність грудної клітини в пазузі, ширину плечей, довжину плеча та передпліччя, окружність біцепса та передпліччя, довжину другого та четвертого пальців правої руки, силу хвату у статичному та динамічному режимі). Розраховували 10 індексів фізичного розвитку на підставі визначених показників. Для характеристики даних визначали медіану, величини 1 (25%) та 3 (75%) квартилів. Достовірність відмінностей між групами оцінювалася за допомогою непараметричного критерію Розенбаума (Q).

Результати. Підтверджено наявність достовірних відмінностей між групами. Досвідчені гирьовики мали більше значення індексу Ерісмана (Q = 10), індексу ширини плечей (Q = 11), індексу Ліві (Q = 10), величини поверхні тіла за Ісааксоном (Q = 10). За індексами масивності встановлено збільшення цього індексу у досвідчених атлетів для правого плеча (Q = 8), лівого плеча (Q = 7) та правого передпліччя (Q = 7). Ці гирьовики характеризувалися достовірним збільшенням індексу статичного та динамічного хвату для правої (Q = 11) та лівої руки (Q = 9). Цей індекс був більший за одиницю. За індексом маси тіла, індексом масивності лівого передпліччя, величинами силового індексу та індексом 2D:4D достовірних відмінностей встановити не вдалося. Серед учасників переважала величина силового індексу понад 60 %. Медіана індексу 2D:4D у всіх учасників дорівнювала 1,0.

Висновки. Встановлено відмінності антропометричних особливостей атлетів гирьового спорту різного рівня майстерності за допомогою методу індексів. Цей метод є адекватним та інформативним інструментом оцінки. Спеціалізовані індекси ілюструють специфіку впливу виду спорту на стан атлетів. Індекси Ерісмана та ширини плечей доводять кращий розвиток м'язів торсу досвідчених атлетів. Збільшення поверхні тіла відображає зростання адаптаційних можливостей, індекси масивності та індекс статичного та динамічного хвату ілюструють більш високий рівень розвитку м'язів верхніх кінцівок та кисті. Більшість учасників мали високий рівень силового індексу. Це підтверджує важливість сили хвату для успіху у гирьовому спорті. Величина індексу 2D:4D також має бути врахована при відборі в гирьовий спорт. Простота, наочність та інформативність використаних індексів дозволяє рекомендувати їх для використання як скринінг-тестів у моніторингу стану спортсменів гирьового спорту.

Ключові слова: гирьовий спорт, антропометричні особливості, індекси, відбір, успішність.

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The Role of Emotional Regulation in Refereeing Performance: The Case of Basketball

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Abstract

Background. Emotion regulation refers to how individuals manage the experience and expression of their emotions. It is an integral part of sports training, allowing the maximum potential to be realised.

Objectives. This study aimed to examine the relationship between basketball referees' emotion regulation skills and their refereeing performances, along with certain demographic variables.

Materials and Methods. The study focused on a comprehensive analysis using a relational screening model. Participants were selected using a purposive sampling method, resulting in a sample of 59 Class-B referees. Class B referees are elite referees. These referees officiate matches in the Women's Super League and Men's 1st League. Among these, females accounted for 10.2 % (n = 6), while males comprised 89.8 % (n = 53) of the sample. The participants had a mean age of 31 and an average refereeing experience of 12 years. During the 2022-2023 season, the referees officiated in a range of 12 to 43 matches, with an average of 26 matches per official. Data was collected using a personal information form and the Referee Emotion Regulation Scale (RERS) developed by Karaçam et al. Data analysis was conducted using SPSS 25. The Pearson Product-Moment Correlation Coefficient was used to examine the relationships between variables, with a significance level set at $p < .05$.

Results. The findings showed significant positive correlations between referee performance and total emotional regulation score ($r = .63, p < .01$), cognitive reappraisal ($r = .67, p < .01$), and suppression ($r = .35, p < .01$).

Conclusions. The results of this study emphasize the importance of emotional regulation, refereeing experience, and match exposure in enhancing performance. These findings highlight the critical role of emotional regulation and experience in optimizing performance of basketball referees, and support the inclusion of psychological skills training, particularly emotional competence development, in referee education programs.

Keywords: emotion, basketball, referee, performance, sport officials.

Introduction

Referees are indispensable actors in competitive sports, ensuring that games proceed fairly, smoothly, and within the framework of established rules. Their decisions not only determine the outcome of specific plays but also shape the overall flow and integrity of the game (Karaçam & Pular, 2017; Tuero et al., 2002). In basketball, a fast-

paced, high-stakes sport, referees must rapidly evaluate changing situations, make instantaneous judgments, and clearly communicate their decisions to players, coaches, and spectators (Ekmekçi, 2008; Weinberg & Richardson, 1990). These multifaceted responsibilities demand exceptional cognitive and emotional resources, far beyond technical knowledge of the rules (Blynova et al., 2020; Guillén & Feltz, 2011; Popovych et al., 2021, 2022).

The profession is inherently stressful. Referees operate under constant scrutiny, with every decision examined by athletes, coaches, fans, the media, and even governing bodies (Barr & Hums, 2012). Unlike many other roles in

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sport, referees often have no opportunity to correct or revise their decisions once made, which magnifies the psychological pressure. The advent of real-time broadcasting and social media amplifies this scrutiny, exposing referees to immediate and sometimes harsh criticism. Consequently, referees are vulnerable to heightened stress, anxiety, and fear of error, which, if persistent, may lead to decision-making fatigue, reduced performance, and even burnout (Blynova et al., 2020; Chelladurai, 2014; Ekmekçi, 2017).

To cope with such demands, referees often rely on psychological strategies to sustain concentration and impartiality. Research highlights that top-level referees adopt mental skills training techniques such as visualization, controlled breathing, meditation, and cognitive reframing to maintain composure and focus (Chelladurai, 2014). These practices underscore the central role of emotion regulation, which is the ability to influence when, how, and to what extent emotions are experienced and expressed (Gross, 2001). Emotion regulation, as described by Gross et. al. (1998), involves strategies such as situation selection, situation modification, attention deployment, cognitive reappraisal, and response modulation. Proficient use of these strategies has been associated with improved mental health, resilience, and occupational performance across various contexts (Berking & Whitley, 2014; Karaçam et al., 2023; Romo-Perez et al., 2023).

While the relationship between emotion regulation and performance has been extensively studied in athletes, relatively little attention has been given to referees. However, referees, similar to athletes, perform under intense pressure, and their emotional states can directly influence their judgment, impartiality, and consistency (Barr & Hums, 2012; Chelladurai, 2014; Ekmekçi, 2017). In basketball, where referees must make split-second decisions in a dynamic environment, the ability to regulate emotions may be particularly critical. A referee who succumbs to crowd pressure or becomes emotionally reactive to players' confrontations risks compromising decision accuracy. Conversely, referees with strong emotion regulation skills are better positioned to maintain fairness and objectivity despite external stressors (Gross et al., 1998; Karaçam et al., 2023; Romo-Perez et al., 2023).

Given these considerations, the present study addresses a significant gap in the literature by investigating the relationship between basketball referees' emotional regulation skills and their performance. In addition, the study examines whether demographic variables such as age, refereeing experience, and number of matches officiated play a role in shaping referees' ability to manage emotions. Understanding these dynamics has the potential to inform referee selection, training, and psychological support programs, thereby enhancing both individual well-being and the overall quality of officiating.

Research Hypotheses

Based on the literature and the objectives of the present study, it was hypothesized that basketball referees' emotional regulation skills would be positively associated with their refereeing performance. Specifically, referees who demonstrate higher levels of cognitive reappraisal and suppression were expected to achieve better performance outcomes. In addition, it was anticipated that emotional regulation skills would increase with referees' age, years of officiating experi-

ence, and the number of matches they managed. Finally, it was hypothesized that emotional regulation would serve as a significant predictor of refereeing performance.

Materials and Methods

The study focused on an in-depth analysis of the relational screening model. The participants for this study were selected using a purposive sampling method. In this non-probabilistic sampling technique, subjects are selected because of their convenient accessibility and proximity to the researcher (Etikan et al., 2016).

Study Participants

In a post-season assessment, performance scoring is exclusively administered to Class-A and Class-B referees. The Central Arbitration Committee (CAC) particularly acknowledges the annual performance scores of Class-B referees. Class B referees, considered elite-level officials, officiate matches in the Women's Super League and Men's 1st League in Türkiye. Utilizing an accessible sampling methodology, the research sample for this subset was meticulously assembled. The sample incorporated a total of 59 Class-B referees. In this cohort, females represented 10.2% (n=6), whereas males constituted 89.8% (n=53) (Table 1). The participants exhibited a mean age of 31,03 and an average refereeing tenure of 12,83 years. During the 2022-2023 season, the span of matches overseen by these referees oscillated between a minimum of 12 and a maximum of 42, averaging 26 matches per official (Table 2). Data assimilation, facilitated through scales, was undertaken in person after the conclusion of the regular season in a competition-free interval. Before starting the research, the present study received approval from the Scientific Research and Publication Ethics Committee of Istanbul Aydın University, Social and Human Sciences (Approval code: 2023/11).

Table1. Gender Distribution of Participants

Frequency	Per cent	Valid Percent	Cumulative Percent
Female	6	10.2	10.2
Male	53	89.8	89.8
Total	59	100.0	100.0

Table 2. Descriptive Statistics of Referee Performance, Age, Number of Matches, and Refereeing Experience

	N	Min	Max	Mean	SD
Performance	59	62.00	84.00	73.34	4.94
Age	59	22.00	48.00	31.03	5.62
The Number of Matches	59	12.00	42.00	26.05	5.95
Refereeing Experience	59	5.00	25.00	12.83	5.71

Data Collection Tool

Referee Emotion Regulation Scale (RERS)

In the study by Karaçam et al. (2021), the Referee Emotion Regulation Scale (RERS) was used to assess the participants' emotion regulation levels. This instrument is

grounded on a seven-point Likert scale comprising eight items. The scale has been designed to delve into two primary facets of emotion regulation: Cognitive Reappraisal and Suppression, represented through distinct items within the scale.

A deeper examination reveals that the items corresponding to the Cognitive Reappraisal subdimension are numbered 3, 5, 6, and 8, while those related to the Suppression subdimension are 1, 2, 4, and 7. Due to their theoretical underpinnings, each dimension should be analyzed independently. Consequently, the evaluative range for each dimension oscillates between a minimum score of 4 and a maximum achievable score of 28.

Karaçam et al. (2021) substantiated the RERS's efficacy and reliability through various statistical analyses. The variance elucidated by the RERS amounted to 64.14%, underscoring its potent explanatory power. Moreover, the eigenvalues surpassing one in the component analysis attested to a bifurcated structural emergence, thus reinforcing the scale's two-sub-dimension conceptualization.

Internal consistency, a pivotal metric in scale reliability, exhibited robust alpha coefficients: 0.83 for the Cognitive Reappraisal dimension and 0.76 for the Suppression dimension. Furthermore, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated to be 0.76, indicating a satisfactory level for conducting a factor analysis.

In addition to the reliability indices, the confirmatory factor analysis delineated promising results, underlining the scale's construct validity. The values were represented as $\chi^2/\text{sd} = 1.603$, RMSEA = 0.07, CFI = 0.96, GFI = 0.93, RMR = 0.10, NFI = 0.90, and IFI = 0.96. These outcomes collectively attest to the goodness of fit of the scale's structure, suggesting an acceptable to excellent fit to the data.

Referees' Performance Scores (RPS)

Performance scoring is conducted exclusively for Class A and Class B referees after each season. However, the Central Arbitration Committee (CAC) authorizes the use of year-end performance scores only for Class-B referees. In this study, referee performance scores refer to the average scores calculated by the CAC at the end of the 2022–2023 season. These scores are classified as follows: 90–100 points indicate excellent performance, 80–89 points indicate above-average performance, 70–79 points indicate average performance, 60–69 points indicate below-average performance, and scores of 59 or lower are considered unacceptable. All performance data used in this study were obtained with the official permission of the CAC.

Assessing the performance of referees presents considerable complexity and challenges. Evaluation of referee performance should be carried out by experts in the field (Spencer, 2015). Since the 2016–2017 season, the Turkish Basketball Federation (TBF) has established a referee rater group comprising 20 individuals to evaluate Class-B referees. These raters are selected by the Central Arbitration Committee (CAC) from among experienced referees. The evaluation criteria to be used by the rater group are introduced during pre-season training sessions. They are based on a standardized referee evaluation form to assess core competencies. This form includes various sections: competition difficulty level, referee preparation, physical condition, mechanics and teamwork, foul and violation

assessments, consistency in rule enforcement throughout the game, game control, disciplinary practices, and overall performance. Additional sections are dedicated to personal evaluations and video-based observations. A referee rater was assigned for all matches played during the 2022–2023 season. These raters observed the games live and were required to complete the evaluation form within 24 hours, assigning a score out of 100 points.

At the end of the season, the rankings of the referees are announced by considering the averages of the scores given to each referee. The year-end mean scores for each Class-B were used in the study.

Statistical Analysis

Data analysis was performed using SPSS version 25. Before the main analyses, the dataset was examined for potential errors, outliers, normality assumptions, and multicollinearity. In addition to descriptive statistics, distributions were examined for normality using kurtosis and skewness tests. Since the skewness and kurtosis coefficients were between -1.5 and +1.5, the distribution was determined to be normal (Tabachenik & Fidel, 2012). Parametric tests were used because the assumptions of normal distribution were met. Subsequently, Pearson Product-Moment Correlation Coefficient and Simple Linear Regression analysis were applied to evaluate the relationships between variables. The significance level was set at $p < .05$.

Results

Table 3. The Relationship Between Basketball RPS and Emotion Regulation

Indicators	Emotional Regulation Total	Cognitive Reappraisal	Suppression
RPS	.63**	.67**	.35**

** $p < .01$, * $p < .05$

Table 3 shows that a positive and significant relationship was found between basketball RPS and emotion regulation total score ($r = .63$, $p = 0.00$), cognitive reappraisal ($r = .67$, $p = 0.00$) and suppression ($r = .35$, $p = 0.00$). As referees enhance their emotion regulation skills, their performance improves.

Table 4. Correlation Between RPS and Age, Number of Matches Managed and Refereeing Experience

Indicators	Age	The Number of Matches	Refereeing Experience
RPS	.65**	.78**	.77**

** $p < .01$, * $p < .05$

Table 4 shows a positive and significant relationship between the RPS and their age ($r = .65$, $p = 0.00$), the number of matches ($r = .78$, $p = 0.00$) and experience ($r = .77$, $p = 0.00$).

Table 5 shows a positive and significant relationship between basketball referees' emotion regulation total score ($r = .40$, $p = 0.00$), cognitive reappraisal ($r = .41$, $p = 0.00$), and suppression ($r = .24$, $p = 0.00$) scores and their age. This

Table 5. The Relationship Between Age and Emotion Regulation

Indicators	Emotional Regulation Total	Cognitive Reappraisal	Suppression
Age	.40**	.41**	.24**

**p <.01, *p <.05

situation can be interpreted as the emotional regulation skills of the referees increasing as they age.

Table 6. Relationship Between Refereeing Experience and Emotion Regulation

Indicators	Emotional Regulation Total	Cognitive Reappraisal	Suppression
Refereeing Experience	.59**	.56**	.39**

**p <.01, *p <.05

Table 6 shows a positive and significant correlation between basketball referees' total emotion regulation score ($r = .59$, $p = 0.00$), cognitive reappraisal ($r = .56$, $p = 0.00$), and suppression ($r = .39$, $p = 0.00$) scores and their years of refereeing. This suggests that referees' emotional regulation skills improve as their years of officiating increase.

Table 7. Relationship Between The Number of Matches Refereed and Emotion Regulation

	Emotional Regulation Total	Cognitive Reappraisal	Suppression
The Number of Matches	.64**	.59**	.45**

**p <.01, *p <.05

Table 7 shows a positive and significant relationship between basketball referees' emotion regulation total score ($r = .64$, $p = 0.00$), cognitive reappraisal ($r = .59$, $p = 0.00$), and suppression ($r = .45$, $p = 0.00$) scores and the number of games managed. This situation can be interpreted as the referees' emotional regulation skills increasing as the number of matches increases.

Table 8. Regression Analysis Regarding the Prediction of Referee Performance by Emotion Regulation

Variable	B	Std. Error B	β	t	p
Constant	55.497	2.941		18.872	.00*
Emotional Regulation Total	.430	.070	.632	6.159	.00*
R = .632; R ² = .400 Adj. R ² = .389 F = 37.929, p = .00					

*p <.05

According to the regression analysis results presented in Table 8, emotional regulation significantly predicts referee performance ($R = .632$, $R^2 = .400$, Adj. $R^2 = .389$, $F(37.929)$, $p = 0.00$). The model explains approximately 40% of the variance in referee performance. The standardised

regression coefficient ($\beta = .632$) indicates that higher emotional regulation scores strongly and positively predict referee performance ($t = 6.159$, $p = 0.00$).

Discussion

This study demonstrated a positive relationship between basketball referees' emotional regulation skills and their performance, particularly in the dimensions of cognitive reappraisal and suppression. In addition, the regression analysis results show that emotion regulation is a significant predictor of referee performance, explaining approximately 40% of the variance in performance. This finding reveals the critical role of psychological competencies, especially emotion regulation skills, in a profession such as refereeing, which involves intense stress, pressure, and emotional burden. The strong predictive effect ($\beta = .632$) found in this study suggests that referees with higher emotional regulation abilities are better equipped to cope with stressors inherent in the game, which in turn positively affects their performance. This aligns with Gross's Process Model of Emotion Regulation, emphasising the role of cognitive change and response modulation in managing emotional demands (Gross, 2001; Gross et al., 1998).

Consistent with earlier findings by Spencer (2015), this study confirms that experience is a strong predictor of refereeing performance. This trend is also supported by studies highlighting the performance benefits of accumulated officiating experience (Catteeuw et al., 2009; Dosseville et al., 2011; Myers et al., 2012; Pizzera & Raab, 2012). In this respect, the study parallels other studies in the literature. Considering the results of studies in the literature, it is observed that the relationship of refereeing performance with experience, in particular, is significant. The number of matches increases as their performance increases. Karaçam & Adıgüzel (2019) reached similar results in their study. In this respect, the study parallels other studies in the literature.

The study found that emotional regulation, particularly cognitive reappraisal and suppression, increased with both age and refereeing experience. This can aid referees in providing emotionally healthier responses and effectively managing their decision-making processes. In the literature, Karaçam et al. (2022) found no significant relationship between emotional regulation levels and age and experience in a study on referees. When looking at studies outside of the referee group in the literature, results were encountered parallel (Riza, 2016) and contrary (Goodall et al., 2012; Karaçam et al., 2023; Turner, 2014) to the study. These discrepancies could be due to differences in referee groups or contextual factors.

Conclusions

This study underscores the pivotal role of emotional regulation in basketball refereeing, showing that strategies such as cognitive reappraisal and suppression are positively linked to officiating effectiveness. Referees with greater age, experience, and match exposure demonstrated stronger emotional regulation abilities, which likely enable them to remain composed and consistent when making critical decisions under pressure. These findings not only advance understanding within basketball officiating but also

contribute to the broader domain of sports psychology, where the psychological demands of refereeing have often been overlooked.

From a practical standpoint, the results highlight the importance of systematically integrating psychological skill development—particularly emotional regulation—into referee training and education programs. Workshops on cognitive reappraisal, stress management, and mindfulness techniques could help referees maintain focus during high-pressure moments, while mentorship programs pairing novice referees with experienced officials may foster adaptive coping strategies. Moreover, providing access to sport psychologists and ongoing mental health support could mitigate stress and reduce the risk of burnout, thereby enhancing both individual well-being and officiating quality.

Despite these contributions, certain limitations should be acknowledged. The relatively small and predominantly male sample limits the generalizability of the findings, while reliance on self-report instruments may introduce bias. In addition, the cross-sectional design prevents causal inferences regarding the relationship between emotional regulation and refereeing performance.

Future studies should adopt longitudinal designs to examine how referees' emotional regulation skills evolve over time and influence performance across different competitive contexts. Intervention-based research, such as randomized controlled trials that implement emotion regulation training into referee development programs, would also provide valuable evidence for its practical effectiveness. Expanding participant diversity across gender, competition level, and cultural backgrounds would further enrich the field, enabling more comprehensive and applicable insights into the psychological dimensions of refereeing.

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Conflict of Interest

There is no potential conflict of interests declared by the authors.

References

- Karaçam, A., Orhan, B. E., Özdemir, A. S., Sabuncu, A. A., & Mereută, C. (2023). Examination of the relationship between basketball referee's mental well-being and emotional regulation levels. *Heliyon*, 9(6). <https://doi.org/10.1016/j.heliyon.2023.e16768>
- Tuero, C., Tabernero, B., Marquez, S., & Guillén, F. (2002). Análisis de los factores que influyen en la práctica del arbitraje [Analysis of the factors affecting the practice of refereeing]. *Revista Scape*, 1(1), 7-16.
- Ekmekçi, R. (2008). *Determining the source and coping style of stress among basketball referees and developing preventative administrative practices*. Abant İzzet Baysal University.
- Weinberg, R. S., & Richardson, P. A. (1990). *Psychology of Officiating* (1st ed.). Leisure Press.
- Blynova, O., Kruglov, K., Semenov, O., Los, O., & Popovych, I. (2020). Psychological safety of the learning environment in sports school as a factor of achievement motivation development in young athletes. *Journal of Physical Education and Sport*, 20(1), 14-23. <https://doi.org/10.7752/jpes.2020.01002>
- Guillén, F., & Feltz, D. L. (2011). A conceptual model of referee efficacy. *Frontiers in Psychology*, 2(FEB). <https://doi.org/10.3389/fpsyg.2011.00025>
- Popovych, I., Halian, I., Halian, O., Nosov, P., Zinchenko, S., & Panok, V. (2021). Research on personality determinants of athletes' mental exhaustion during the ongoing COVID-19 pandemic. *Journal of Physical Education and Sport*, 21(4), 1769-1780. <https://doi.org/10.7752/jpes.2021.04224>
- Popovych, I., Halian, I., Pavliuk, M., Kononenko, A., Hrys, A., & Tkachuk, T. (2022). Emotional quotient in the structure of mental burnout of athletes. *Journal of Physical Education and Sport*, 22(2), 337-345. <https://doi.org/10.7752/jpes.2022.02043>
- Barr, C. A., & Hums, M. A. (2012). *Management Principles Applied to Sport Management Learning Objectives*.
- Chelladurai, P. (2014). *Managing Organizations for Sport and Physical Activity* (4th ed.). Routledge. <https://doi.org/10.4324/9781315213286>
- Ekmekçi, R. (2017). *Psychological preparation in refereeing*. Detay Publication.
- Gross, J. J. (2001). Emotion Regulation in Adulthood: Timing Is Everything. *Current Directions in Psychological Science*, 10(6), 214-219. <https://doi.org/10.1111/1467-8721.00152>
- Gross, J. J., Feldman Barrett, L., John, O., Lane, R., Larsen, R., & Pennebaker, J. (1998). The Emerging Field of Emotion Regulation: An Integrative Review. *In Review of General Psychology*, 2(5).
- Berking, M., & Whitley, B. (2014). *Development of the "Affect Regulation Training" (ART) Program*. In *Affect Regulation Training* (pp. 53-65). Springer New York. https://doi.org/10.1007/978-1-4939-1022-9_6
- Romo-Perez, V., Karaçam, A., Çetin, A., Pular, A., Orhan, B. E., & Özdemir, A. S. (2023). Adapting the Emotion Regulation Scale for Athletes for Use with Referees and Examining Its Psychometric Properties. *In Mediterranean Journal of Sport Science*, 6(4). <https://doi.org/10.38021/asbid.1315121>
- Etikan, I., Musa, S. A., & Alkassim Rukayya, S. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1. <https://doi.org/10.11648/j.ajtas.20160501.11>
- Karaçam, A., Çetin, A., & Pular, A. (2021). Sporcu duygu düzenleme ölçeğinin hakemler için uyarlanması ve psikometrik özelliklerinin incelenmesi. 4. *Uluslararası Herkes İçin Spor Kongresi*, 22-23.
- Spencer, B. D. (2015). *Self-Efficacy And Performance In Volleyball Referees*. Michigan State University.
- Tabachnik, D., & Fidel, J. (2012). Structural equation modeling: Guidelines for determining model fit. *J Bus Res Methods*, 6(5), 1-55.
- Catteeuw, P., Helsen, W., Gilis, B., & Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences*, 27(11), 1125-1136. <https://doi.org/10.1080/02640410903079179>

- Dosseville, F., Laborde, S., & Raab, M. (2011). Contextual and personal motor experience effects in judo referees' decisions. *Sport Psychologist*, 25(1), 67-81. <https://doi.org/10.1123/tsp.25.1.67>
- Myers, N. D., Feltz, D. L., Guillén, F., & Dithurbide, L. (2012). Development of, and initial validity evidence for, the referee self-efficacy scale: A multistudy report. *Journal of Sport and Exercise Psychology*, 34(6), 737-765. <https://doi.org/https://doi.org/10.1123/jsep.34.6.737>
- Pizzera, A., & Raab, M. (2012). Perceptual Judgments of Sports Officials are Influenced by their Motor and Visual Experience. *Journal of Applied Sport Psychology*, 24(1), 59-72. <https://doi.org/10.1080/10413200.2011.608412>
- Karacam, A., & Adiguzel, N. S. (2019). Examining the relationship between referee performance and self-efficacy. *European Journal of Educational Research*, 8(1), 377-382. <https://doi.org/10.12973/eu-jer.8.1.377>
- Karaçam, A., Orhan, B. E., Özdemir, A. S., & Sabuncu, A. (2022). Hakemlerin duygu düzenleme düzeylerinin incelenmesi. *Journal of Sport for All and Recreation*, 4(1), 4-9.
- Riza, S. Ö. (2016). *Evli Bireylerin Bilişsel Duygu Düzenleme Stratejilerinin Psikolojik İyi Oluşları Ve Evlilik Doyumları İle İlişkisinin İncelenmesi*. Social Sciences Institute.
- Goodall, K., Trejnowska, A., & Darling, S. (2012). The relationship between dispositional mindfulness, attachment security and emotion regulation. *Personality and Individual Differences*, 52(5), 622-626. <https://doi.org/10.1016/j.paid.2011.12.008>
- Turner, K. (2014). Mindfulness Skills Training: A Pilot Study of Changes in Mindfulness, Emotion Regulation, and Self-Perception of Aging in Older Participants. *Activities, Adaptation and Aging*, 38(2), 156-167. <https://doi.org/10.1080/01924788.2014.901074>

Роль емоційної регуляції у результативності суддівства: Приклад баскетболу

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 8 табл., 28 джерел.

Історія питання. Емоційна регуляція означає те, як індивіди керують переживаннями та вираженням своїх емоцій. Вона є невід'ємною частиною спортивної підготовки, що дозволяє максимально розкрити свій потенціал.

Мета дослідження. Мета цього дослідження полягала у вивченні взаємозв'язку між навичками регулювання емоцій баскетбольних суддів та їхніми показниками суддівської діяльності, а також певними демографічними змінними.

Матеріали та методи. Дослідження зосереджено на комплексному аналізі із використанням реляційної моделі скринінгу. Учасників було відібрано за допомогою методу цільової вибірки, що дозволило отримати вибірку з 59 арбітрів класу В. Арбітри класу В належать до елітних арбітрів. Ці арбітри судять матчі жіночої Суперліги та чоловічої 1-ї ліги. Серед них жінки склали 10.2% (n=6), а чоловіки — 89.8% (n=53) вибірки. Середній вік учасників становив 31 рік, а середній стаж роботи арбітром — 12 років. Протягом сезону 2022-2023 років судді обслуговували від 12 до 43 матчів, в середньому 26 матчів на одного суддю. Збір даних здійснювався за допомогою анкети з особистими даними та шкали емоційної регуляції суддів (RERS), розробленої Карачамом та ін. Аналіз даних проведено із використанням програмного забезпечення SPSS 25. Для вивчення взаємозв'язків між змінними застосовано коефіцієнт кореляції моменту Пірсона, рівень значущості встановлено на рівні $p < .05$.

Результати. Результати показали значні позитивні кореляції між результативністю суддівства та загальним показником емоційної регуляції ($r = .63, p < .01$), когнітивною переоцінкою ($r = .67, p < .01$) та подавленням емоцій ($r = .35, p < .01$).

Висновки. Результати цього дослідження підкреслюють важливість емоційної регуляції, досвіду суддівства та впливу гри у підвищенні результативності. Отримані дані наголошують на вирішальній ролі емоційної регуляції та досвіду в оптимізації результативності баскетбольних суддів й підтверджують доцільність включення тренувань психологічних навичок, зокрема розвитку емоційної компетентності, до освітніх програм з підготовки суддів.

Ключові слова: емоція, баскетбол, арбітр, результативність, спортивні судді.

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The Effectiveness of Varying Plyometric Training Intensities in Improving Punching Force and Muscular Fitness in Adolescent Boxers

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Abstract

Background. The sport of boxing requires a great deal of explosive strength, particularly punching force and muscular fitness, which are crucial during adolescence due to the rapid development of neuromuscular systems. Plyometric training is known to enhance certain physical attributes. However, limited comparative research exists on the effectiveness of different plyometric training intensities in adolescent boxers.

Objectives. The study aimed to examine and assess the impact of high- and low-intensity plyometric training protocols on the punching force and muscle fitness of teenage male boxers.

Materials and Methods. Thirty adolescent male boxers, aged 13-17 years, each with at least three years of training experience, were chosen at random to be divided into three groups: Low-Intensity Plyometric Training (LIPT), High-Intensity Plyometric Training (HIPT), and an Active Control Group (ACG). The LIPT and HIPT groups engaged in an 8-week plyometric program conducted thrice weekly, with progressive overload, while the ACG continued with their standard boxing training routines. Pre- and post-intervention assessments included punching force, upper and lower body power, and muscular endurance, measured through validated sport-specific tests. Statistical analysis involved paired t-tests, ANOVA, and Bonferroni post-hoc tests.

Results. Both the LIPT and HIPT groups demonstrated statistically significant improvements ($p < .001$) across all measured variables, while the ACG exhibited no substantial changes. The HIPT group achieved the highest gains, with punching force increasing by 17.54 %, muscular endurance by 31.77 %, lower body power by 21.02 %, and upper body power by 9.96%. Effect sizes were large ($\eta^2_p \geq .65$), indicating strong treatment effects.

Conclusions. Plyometric training, especially at high intensities, significantly enhances punching force and muscular fitness in adolescent boxers. These findings support the integration of progressively overloaded plyometric exercises into youth boxing training programs, providing a scientifically grounded approach to improving performance during a critical developmental phase.

Keywords: plyometric training, punching force, muscular fitness, adolescent boxers, training intensity, explosive strength.

Introduction

Boxing is a high-intensity combat sport that demands the integration of speed, strength, endurance, coordination,

and tactical decision-making. Among these, punching force and muscle fitness are important variables that have a big impact on sports performance, particularly throughout adolescence, a developmental period marked by continuous neurological and physiological changes. Improving these qualities is crucial for maximizing performance in a given activity as well as reducing the chance of injury, which is especially crucial for teenage athletes who are still going

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through biological maturation. As athletes enter adolescence, a time of rapid neuromuscular and hormonal development, the application of scientifically based training techniques becomes even more crucial (Lloyd & Oliver, 2012). The ability of plyometric training (PT), a training technique that uses rapid eccentric-concentric muscle contractions to capitalize on the stretch-shortening cycle (SSC), to enhance explosive power has garnered a lot of attention lately (Markovic & Mikulic, 2010; Ramírez-Campillo et al., 2014).

It is commonly known that plyometric training can enhance neuromuscular coordination, muscle power, and movement velocity, all essential elements of a successful punching performance (Moran et al., 2018). Punching is a biomechanical motion in boxing that requires a coordinated kinetic chain that begins with the lower body, travels through the trunk, and ends with the upper limbs extending explosively (Loturco et al., 2014). These chains are specifically stimulated by plyometric activities, including medicine ball tosses, depth leaps, and bounding, which enhance the rate of force development (RFD) and the effectiveness of energy transfer between joints and muscle groups (Suchomel et al., 2016). In boxing, where powerful, quick, and repetitive movements are necessary for both offensive and defensive success, these performance improvements are especially advantageous.

Due to their greater plasticity and potential for long-term athletic development, adolescents can benefit immensely from carefully thought-out and appropriately dosed plyometric therapies (Ford et al., 2010). To prevent maladaptive consequences, including overtraining, neuromuscular exhaustion, and injury, they also need strict supervision (Myer et al., 2011). While conventional strength training helps increase overall force generation, the quality that sets top boxers apart from their contemporaries is explosiveness, or the capacity to produce force rapidly. This demand is specifically satisfied by plyometric training, which emphasizes reactive movement patterns and quick contraction mechanics that are more functionally compatible with punching motions (Beato et al., 2020) Scopus, and Institute for Scientific Information Web of Knowledge. Results: In total, 7 eligible studies were identified based on the following results: First, practitioners can use different inertia intensities (eg, 0.03–0.11 kg·m²). Furthermore, boxing requires maintaining high-intensity efforts throughout several rounds rather than just putting up a single, powerful movement. Plyometric exercises that increase muscle strength and neuromuscular resilience can therefore have a substantial compounding impact on boxing performance as a whole (Slimani et al., 2016a).

Plyometric training's efficacy is not uniform and can vary significantly depending on the type, direction, intensity, and volume of exercises employed (De Villarreal et al., 2009). For example, plyometric activities that are vertical and those that are horizontal activate various neuromuscular pathways and can result in differing performance changes. Similarly, focusing on upper-body plyometric exercises like plyometric push-ups and overhead medicine ball throws can be very helpful for increasing hand speed and punching power in boxing, but these workouts are usually overlooked in youth training programs (Chelly et al., 2010). Similar benefits could be obtained by strategically combining upper- and lower-body plyometrics; however, the best ways to combine

these techniques are still unknown, particularly when dealing with adolescent populations that differ in terms of physical maturity, experience, and training tolerance (Lloyd et al., 2011).

Despite the potential advantages and increasing use of plyometric training, there is a dearth of comparative empirical data assessing the precise effects of various plyometric regimens on the muscular fitness and punching force of teenage male boxers. There is a substantial study gap regarding youth training tailored to boxing because the majority of previous studies have concentrated on adult elite athletes or generic athletic populations. Furthermore, in younger age groups, differences in frequency, progression models, and training specificity have not been well examined (Harries et al., 2012). This makes it more difficult for coaches and sports scientists to create performance-enhancing programs for teenage boxers that are well-informed and supported by data.

Given this background, the current study's objective is to determine how well various plyometric training methods may improve the muscular strength and punching power of teenage male boxers. Through a controlled training session, this study compares several plyometric drill configurations in an effort to determine the best approach for enhancing sport-specific results in young boxers. The study is to further theoretical knowledge in the domains of youth fitness and sports science while also offering coaches, athletic trainers, and development specialists' useful advice. It is expected that the results of the study will help establish sport-specific training programs, developmentally appropriate, and performance-enhancing, specifically designed to meet the demands of adolescent combat athletes.

Materials and methods

Purpose of the Study

The primary objective of the present investigation was to look into how various plyometric training regimens affected the muscular fitness and punching force of teenage male boxers. The research aimed to identify whether variations in plyometric training intensity (low vs high) would produce significant improvements in sport-specific performance variables relevant to boxing, particularly during adolescence, a period of critical neuromuscular development.

Participants

For the study, 30 adolescent male boxers, ages 13 to 17, were enlisted. All of the participants were actively engaged in regular practice sessions and had undergone at least three years of formal boxing instruction. Before the intervention, each participant underwent a medical screening and was cleared by a certified sports physician, ensuring they were fit for high-intensity physical activity. Based on a randomized allocation process, the participants were equally divided into three groups (n = 10 per group): Group A, which performed low-intensity plyometric training (LIPT); Group B, which engaged in high-intensity plyometric training (HIPT); and Group C, the active control group, which proceeded with standard boxing exercises without any extra plyometric exercises. Institutional permission was obtained before

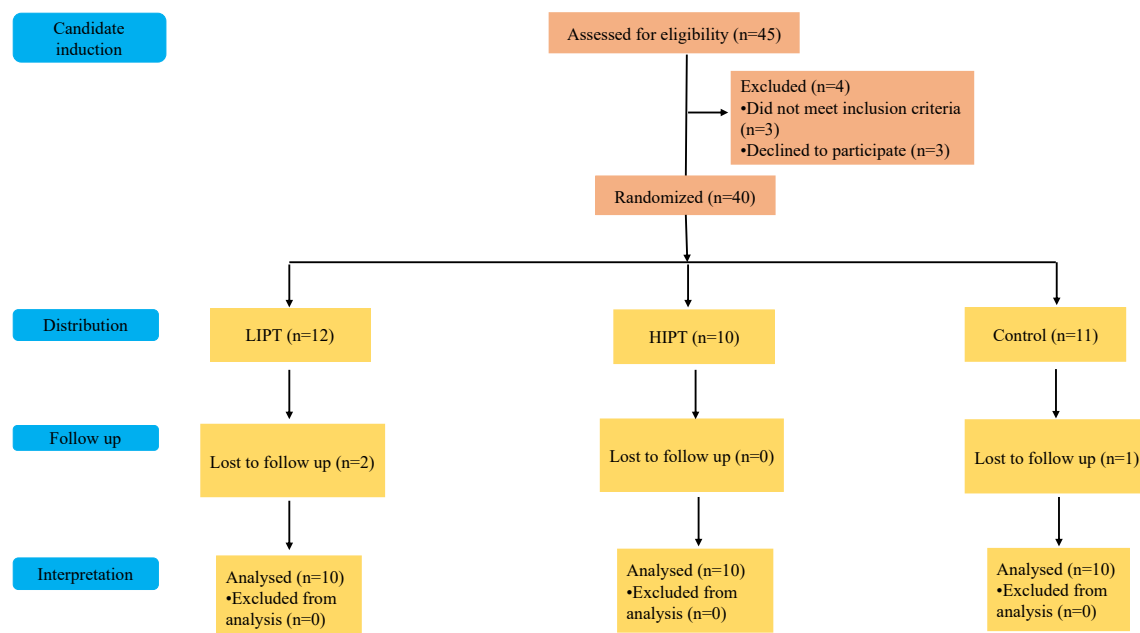


Fig. 1. Inclusion and Exclusion Criteria

initiating the research. All procedures involving human participants were reviewed and approved by the appropriate authority (Certificate No. 266/Kheuk/Esth/2025) and all procedures followed the Declaration of Helsinki's guidelines ("World Medical Association Declaration of Helsinki," 2013).

Table 1. Demographic Characteristics for Participants

Characteristics	LIPT	HIPT	ACG
Age	15.10 ± 1.19	14.90 ± 1.44	14.60 ± 1.42
Experience	3.40 ± .51	3.10 ± .73	3.30 ± .67
Height	151.70 ± 5.55	152.40 ± 4.35	152.80 ± 5.09
Weight	52.90 ± 4.45	52.20 ± 4.73	51.40 ± 3.74
BMI	23.05 ± 2.38	22.50 ± 2.23	22.05 ± 1.79

Research Design

This study utilized an active control group in a pre-test-post-test experimental design. The total duration of the intervention was eight weeks, during which the experimental groups (Group A and Group B) participated in three plyometric training sessions per week. This design allowed for an evaluation of both within-group progress over time and between-group differences in outcomes related to punching force and muscular fitness following the specific training interventions.

Variables and Measurements

Punching Force: Punching force was measured using a force-measuring punching bag or force transducer system, calibrated to record impact in Newtons. Participants performed three maximal straight punches using their

dominant hand, with sufficient rest between attempts to minimize fatigue. The highest force value obtained was used for analysis. This approach replicates the sport-specific punching action in boxing and aligns with protocols used in previous combat-sport research (Loturco et al., 2014).

Upper Body Power: The Medicine Ball Chest Throw Test, a popular field-based method for evaluating upper limb explosive strength, was employed to measure upper body power. Participants sat with their backs against a wall to restrict lower-body involvement and were instructed to forcefully throw a 3-kg medicine ball forward from chest level using both hands. The maximum horizontal distance reached during the attempts was recorded as the final score (Sayers & Lorenzetti, 2020a).

Lower Body Power: Using the Countermovement Jump (CMJ), a popular and proven test for determining lower limb explosive strength, lower body power was evaluated. The Countermovement Jump was used to quantify the height of vertical jumps (CMJ). The participants were instructed to stand erect, put their hands on their hips, descend rapidly, and then jump as high as they could. After two familiarization trials, three test trials were carried out. The CMJ has consistently demonstrated high reliability and sensitivity in evaluating lower-body power in adolescent athletes (Khati et al., 2025).

Muscular Endurance: Muscular endurance was used to assess core endurance with the Plank Hold Test, a valid technique. With their bodies in a straight line from head to heels, participants performed a prone plank on their forearms, and the duration held without losing form was recorded in seconds. Standardized protocols ensured consistency and safety (Tong, Wu, & Nie, 2014).

Statistical Analysis

All collected data were analyzed using SPSS software. For each variable, descriptive statistics including the mean

Table 2. Structured Eight-Week Training Program for Plyometric and Active Control Groups: Frequency, Intensity, Progression, and Training Objectives

Group A: Low-Intensity Plyometric Training (LIPT)						
Week(s)	Frequency (Days/Week)	Session Duration	Intensity	Exercise Type	Progression Focus	Training Objective
1-2	3	40 min	Low to Moderate	Jumping Jacks, Double-Leg Hops, Bounding	Basic technique, low reps and sets	Develop foundational plyometric skills and coordination
3-4	3	40-45 min	Moderate	Same exercises with slight variation	Increase repetitions and add simple variations	Improve neuromuscular control and movement efficiency
5-6	3	45 min	Moderate	Enhanced drills with moderate complexity	Add sets, increase Reps, raise complexity	Enhance agility and dynamic stability
7-8	3	45-50 min	Moderate to High	Combination drills from previous weeks	Progressive overload via reps, sets, and complexity	Optimize performance with improved movement economy
Group B: High-Intensity Plyometric Training (HIPT)						
Week(s)	Frequency (Days/Week)	Session Duration	Intensity	Exercise Type	Progression Focus	Training Objective
1-2	3	40 min	High	Depth Jumps, Single-Leg Hops, Med Ball Slams	Initial exposure to high-intensity loading	Develop explosive power and reactive strength
3-4	3	45 min	High	Increased volume of intense drills	Increase intensity and complexity	Improve stretch-shortening cycle efficiency
5-6	3	50 min	Very High	Complex drills combining power & balance	Increased load, challenging unilateral moves	Enhance muscular strength and acceleration capability
7-8	3	50-55 min	Very High	Advanced drills combining previous weeks	Maximize intensity and recovery optimization	Peak power output and movement precision
Group C: Active Control Group (Non-Plyometric)						
Week(s)	Frequency (Days/Week)	Session Duration	Intensity	Exercise Type	Progression Focus	Training Objective
1-8	3	40 min	Regular (Moderate)	Routine boxing drills	No progression applied	Maintain standard training without plyometric adaptation

and standard deviation (mean $\pm$ SD) were computed. To assess significant changes within each group from pre-test to post-test, paired sample t-tests were performed. Differences among the three groups were examined using a one-way ANOVA, followed by the Bonferroni post-hoc test to identify specific group comparisons. Effect sizes for ANOVA were categorized as small (less than 0.06), moderate (0.06 to 0.13), or large (0.14 or greater), based on partial eta-squared (η^2p), following the criteria outlined by (Saha et al., 2025) optimizing training methodologies is crucial for improving players' repeated sprint ability, sustaining effort throughout matches, and enhancing overall performance. While hockey requires significant anaerobic power for explosive movements and sprints, the intermittent nature of the game also places considerable demands on aerobic systems for recovery between high-intensity efforts. \nObjectives. This study aimed to evaluate and compare the effectiveness of Small-Sided Games (SSG. All statistical analyses were carried out with a significance level set at $p < 0.05$, in order

to determine whether the training interventions had any meaningful effects.

Results

Table 3 indicates the findings of a paired sample t-test used to evaluate the differences in punching force and muscle fitness variables (muscular endurance, lower body power, and upper body power) across the three groups (LIPT, HIPT, and ACG) both prior to and following the intervention. Across all variables, the LIPT and HIPT groups showed notable improvements. In punching force, both LIPT ($t = -22.53$, $p = .000$) and HIPT ($t = -19.96$, $p = .000$) showed highly significant gains, while the ACG showed no significant change ($t = -1.00$, $p = .343$). For upper body power, significant improvements were found in LIPT ($t = -8.33$, $p = .000$) and HIPT ($t = -6.87$, $p = .000$), but not in ACG ($t = -1.63$, $p = .137$). Lower body power increased markedly in both LIPT ($t = -63.94$, $p = .000$) and HIPT ($t = -29.05$,

Table 3. Paired Sample t-Test Results: Impact of Plyometric Training on Punch Power and Muscle Fitness in Adolescents

Variables	Group	SE	t	p
Punching Force	LIPT	.90	-22.53	.000
	HIPT	1.74	-19.96	.000
	ACG	.40	-1.00	.343
Upper Body Power	LIPT	.05	-8.33	.000
	HIPT	.08	-6.87	.000
	ACG	.01	-1.63	.137
Lower Body Power	LIPT	.06	-63.94	.000
	HIPT	.21	-29.05	.000
	ACG	.29	-2.19	.056
Muscular Endurance	LIPT	.47	-20.16	.000
	HIPT	.52	-35.33	.000
	ACG	.37	-1.07	.39

$p = .000$), with marginal change in ACG ($t = -2.19$, $p = .056$). Muscular endurance also improved significantly in LIPT ($t = -20.16$, $p = .000$) and HIPT ($t = -35.33$, $p = .000$), whereas ACG showed no significant improvement ($t = -1.07$, $p = .39$). While the active control group did not see any appreciable increases, these findings imply that both low- and high-intensity plyometric training regimens were successful in improving punching force and muscular fitness.

Table 4 presents the ANOVA results comparing the effects of LIPT, HIPT, and ACG on punching force and muscle fitness variables, including adolescents boxers' muscular endurance, lower body strength, and upper body power. In terms of punching force, LIPT showed a 10.17 % improvement (from 201.40 ± 3.40 to 221.90 ± 3.57), while HIPT exhibited a greater increase of 17.54 %, compared to a negligible change in the active control group (0.20 %). The ANOVA results for this variable revealed a strong influence attributed to group differences ($F = 222.85$, $p = .000$, $\eta^2_p = .94$), indicating a large effect size. Similarly, upper body power

improved by 7.52 % in LIPT and 9.96 % in HIPT, while the active control group showed a minimal increase (0.33 %). The observed group differences were statistically significant ($F = 25.71$, $p = .000$, $\eta^2_p = .65$). For lower body power, LIPT and HIPT groups improved by 14.57 % and 21.02 %, respectively, with only a 2.19 % increase in ACG. This variable also showed significant between-group effects ($F = 177.00$, $p = .000$, $\eta^2_p = .92$). Lastly, muscular endurance increased substantially in LIPT (16.60 %) and HIPT (31.77 %), while ACG showed only a 0.67 % change. The statistical outcome for muscular endurance was also highly significant ($F = 382.40$, $p = .000$, $\eta^2_p = .96$). Overall, both plyometric training methods significantly enhanced all measured variables, with HIPT consistently producing the highest gains.

Table 5. Post Hoc Comparisons of Various Training Groups on Adolescent Boxers' Muscle Fitness and Punching Force

Variables	(I) Group	(J) Group	Mean Difference (I-J)	p
Punching Force	LIPT	HIPT	-4.70	.104
		ACG	14.75	.000
	HIPT	ACG	19.45	.000
Upper Body Power	LIPT	HIPT	-.11	1.000
		ACG	.23	.311
	HIPT	ACG	.35	.057
Lower Body Power	LIPT	HIPT	-1.86	.035
		ACG	1.51	.111
	HIPT	ACG	3.38	.000
Muscular Endurance	LIPT	HIPT	-4.50	.000
		ACG	3.30	.005
	HIPT	ACG	7.80	.000

Table 5 presents the Bonferroni post hoc comparisons among LIPT, HIPT, and ACG for punching force and muscle fitness variables. For punching force, HIPT showed a significantly greater improvement than ACG (mean difference = 19.45, $p = .000$), and LIPT also significantly

Table 4. Results of an ANOVA Comparing the Impact of Various Plyometric Training Methods on Adolescent Boxers' Punching Force and Muscle Fitness

Variables	Groups	Pre data	Post data	Δ (%)	SS	F	p	η^2_p
Punching Force	LIPT	201.40 ± 3.40	221.90 ± 3.57	10.17	3002.70	222.5	.000	.94
	HIPT	198.90 ± 5.44	233.80 ± 5.02	17.54				
	ACG	196.70 ± 5.81	197.10 ± 6.41	0.20				
Upper Body Power	LIPT	$5.98 \pm .29$	$6.43 \pm .24$	7.52	.90	25.71	.000	.65
	HIPT	$6.02 \pm .33$	$6.62 \pm .32$	9.96				
	ACG	$5.96 \pm .38$	$5.98 \pm .37$	0.33				
Lower Body Power	LIPT	28.88 ± 1.17	33.09 ± 1.17	14.57	80.49	177.00	.000	.92
	HIPT	29.73 ± 1.67	35.98 ± 1.40	21.				
	ACG	29.15 ± 1.82	29.79 ± 2.01	2.19				
Muscular Endurance	LIPT	57.80 ± 2.44	67.40 ± 1.71	16.60	810.13	382.40	.000	.96
	HIPT	57.90 ± 2.42	76.30 ± 2.58	31.77				
	ACG	59.10 ± 2.02	59.50 ± 2.01	0.67				

outperformed ACG ($p = .000$), though the LIPT and HIPT differences were not statistically significant. ($p = .104$). In upper body power, none of the pairwise comparisons reached statistical significance, though the HIPT vs ACG comparison approached it ($p = .057$), indicating a possible trend. For lower body power, There was a notable distinction discovered between HIPT and ACG ($p = .000$), while LIPT vs HIPT showed a modest but significant difference ($p = .035$), and LIPT vs ACG remained nonsignificant ($p = .111$). Regarding muscular endurance, all group comparisons were statistically significant: LIPT vs HIPT ($p = .000$), LIPT vs ACG ($p = .005$), and HIPT vs ACG ($p = .000$), with HIPT demonstrating the greatest gains. These Bonferroni-adjusted results confirm the greater effectiveness of plyometric interventions, particularly HIPT, in enhancing muscular performance variables among adolescent boxers.

Discussion

The present investigation examined how well various plyometric training methods may improve teenage boxers' punching force and muscular fitness. The findings demonstrate that both low-intensity and high-intensity plyometric training interventions produced significant improvements across all measured variables, with high-intensity plyometric training showing superior effects compared to low-intensity training and the active control group. Both plyometric training groups showed significant improvements in punching force, which is consistent with earlier studies showing the value of plyometric workouts in combat sports. The basic principles of plyometric training, which use the increased punching force caused by the stretch-shortening cycle, speed up force production and explosive power (Loturco et al., 2016). The stretch-shortening cycle pre-stretches the muscle-tendon complex, allowing muscles to produce more force. The concentric phase of movement allows for the rapid release of elastic energy that has been stored (Davies et al., 2015).

The superior performance of high-intensity plyometric training in enhancing punching force supports the principle of training specificity and intensity-dependent adaptations. High-intensity plyometric exercises likely provided a greater stimulus for neuromuscular adaptations, including higher motor neuron firing frequency, better intermuscular synchronization, and improved motor unit recruitment (Chelly et al., 2009). These adaptations are especially crucial to boxing, as the fast generation of peak force is essential for successful punching performance. The Medicine Ball Chest Throw Test shows that plyometric training is beneficial in increasing upper limb explosive strength because it enhances upper body power. This finding is consistent with research by Fernandez-Fernandez et al. (2013) comprising core strength, elastic resistance and medicine ball exercises. Both groups (control and training, who stated considerable progress in upper extremity power following plyometric training interventions. The medicine ball chest throw test specifically targets the kinetic chain involved in punching movements, making it a highly relevant assessment for boxing performance. Improved neuromuscular coordination and the upper body musculature's greater capacity to produce force are probably the factors behind these improvements. Plyometric training promotes adaptations in both the

nervous system and musculoskeletal system, leading to improved synchronization of muscle fiber recruitment and enhanced power output (Sayers & Lorenzetti, 2020b). The larger progress seen in the high-intensity group indicates that how hard you train is key to getting the best results.

The Countermovement Jump test, which measures the significant gains in lower body power, confirms the proven value of plyometric training in building explosive strength in the lower limbs. These results are consistent with a wealth of research showing that plyometric training improves jump performance among various athletic populations (Slimani et al., 2016b). The countermovement jump is particularly relevant for boxing, as lower body power contributes significantly to punch force generation through the kinetic chain. The mechanisms responsible for these improvements include enhanced stretch-shortening cycle function, improved muscle-tendon unit stiffness, as well as enhanced neuronal activity in the working muscles. Plyometric training has been shown to optimize the storage and utilization of elastic energy, leading to more efficient force production during explosive movements (Lloyd et al., 2012). The findings from the group that trained at higher intensity clearly show that how hard you push yourself plays a key role in boosting power in the lower body. The significant enhancements in muscular endurance, as measured by the Plank Hold Test, demonstrate the multifaceted benefits of plyometric training beyond power development. Core endurance is fundamental to boxing performance, as it provides the stability and force transmission necessary for effective punching technique and sustained performance during competition (Tong, Wu, Nie, et al., 2014) would contribute to core muscle fatigue. Nine male recreational runners were recruited for two reasons; (1. The improvements in muscular endurance following plyometric training can be attributed to several physiological adaptations, including enhanced neuromuscular efficiency, improved muscle fiber recruitment patterns, and increased metabolic capacity of the working muscles. While plyometric training is primarily associated with power development, the repetitive nature of the exercises and the demands placed on stabilizing muscles contribute to endurance improvements.

High-intensity plyometric training's superior performance on every variable examined offers crucial information on plyometric training's dose-response relationship in adolescent athletes. High-intensity plyometric exercises likely provide a greater stimulus for both neural and morphological adaptations, leading to more pronounced improvements in performance measures. This finding is consistent with the principle of progressive overload, which implies that training adaptations are maximized when the training stimulus surpasses the system's current capacity. It is crucial to remember that adolescent populations require careful consideration of training load management and injury prevention strategies when implementing high-intensity plyometric training. While the current study demonstrated the safety and effectiveness of high-intensity plyometric training, proper progression, adequate recovery, and appropriate supervision are essential for maximizing benefits while minimizing injury risk.

Coaches, strength and conditioning experts, and boxing athletes themselves stand to gain a lot from these findings. The study clearly shows that plyometric training helps improve both punching power and muscle fitness, giving solid proof that these exercises should be part of training rou-

tines for young boxers. The superior results observed with high-intensity plyometric training suggest that appropriately progressed, high-intensity exercises may be more effective for developing boxing-specific performance attributes. The sport-specific nature of the improvements observed in this study, particularly in punching force, highlights the importance of training specificity in athletic development. The integration of plyometric exercises that target the movement patterns and energy systems relevant to boxing can contribute to more effective training programs and improved competitive performance. Although the current study offers insightful information about how well plyometric training works for teenage boxers, it should be noted that there are a number of limitations. The findings may not be as applicable to longer-term training adaptations due to the comparatively brief intervention time. To maximize performance gains while avoiding overtraining, future studies should look into the effects of plyometric training over time and evaluate the most effective training periodization techniques. Furthermore, the results may not be as applicable to other age groups due to the emphasis on adolescent athletes. The best training regimen for boxing performance would be better understood with more study looking at the impacts of varying plyometric training intensities across age groups and skill levels.

Conclusions

The present study demonstrates that plyometric training, particularly high-intensity approaches, effectively enhances punching force and muscle fitness in adolescent boxers. The significant improvements observed across all measured variables support the inclusion of plyometric exercises in training programs for young combat sport athletes. The superior performance of high-intensity plyometric training suggests that appropriately progressed, high-intensity exercises may provide optimal stimulus for developing boxing-specific performance attributes. These results offer useful advice for coaches and athletes looking to maximize training efficacy alongside adding more evidence that highlights the benefits of plyometric training for athletes in combat sports.

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Conflict of Interest

The authors affirm that there are no conflicts of interest associated with this study.

References

- Lloyd, R. S., & Oliver, J. L. (2012). The Youth Physical Development Model: A New Approach to Long-Term Athletic Development. *Strength & Conditioning Journal*, 34(3), 61-72. <https://doi.org/10.1519/ssc.0b013e31825760ea>
- Markovic, G., & Mikuć, P. (2010). Neuro-Musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training. *Sports Medicine*, 40(10), 859-895. <https://doi.org/10.2165/11318370-000000000-00000>
- Ramírez-Campillo, R., Meylan, C., Álvarez, C., Henríquez-Olguín, C., Martínez, C., Cañas-Jamett, R., Andrade, D. C., & Izquierdo, M. (2014). Effects of In-Season Low-Volume High-Intensity Plyometric Training on Explosive Actions and Endurance of Young Soccer Players. *Journal of Strength and Conditioning Research*, 28(5), 1335-1342. <https://doi.org/10.1519/jsc.0000000000000284>
- Moran, J., Sandercock, G. R. H., Ramírez-Campillo, R., Wooller, J.-J., Logothetis, S., Schoenmakers, P. P. J. M., & Parry, D. A. (2018). Maturation-Related Differences in Adaptations to Resistance Training in Young Male Swimmers. *Journal of Strength and Conditioning Research*, 32(1), 139-149. <https://doi.org/10.1519/jsc.00000000000001780>
- Loturco, I., Artioli, G. G., Koba, R., Gil, S., & Franchini, E. (2014). Predicting Punching Acceleration From Selected Strength and Power Variables in Elite Karate Athletes: A Multiple Regression Analysis. *Journal of Strength and Conditioning Research*, 28(7), 1826-1832. <https://doi.org/10.1519/jsc.0000000000000329>
- Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine*, 46(10), 1419-1449. <https://doi.org/10.1007/s40279-016-0486-0>
- Ford, K. R., Myer, G. D., & Hewett, T. E. (2010). Longitudinal effects of maturation on lower extremity joint stiffness in adolescent athletes. *The American Journal of Sports Medicine*, 38(9), 1829-1837. <https://doi.org/10.1177/0363546510367425>
- Myer, G. D., Faigenbaum, A. D., Ford, K. R., Best, T. M., Bergeron, M. F., & Hewett, T. E. (2011). When to Initiate Integrative Neuromuscular Training to Reduce Sports-Related Injuries and Enhance Health in Youth? *Current Sports Medicine Reports*, 10(3), 155-166. <https://doi.org/10.1249/jsr.0b013e31821b1442>
- Beato, M., McErlain-Naylor, S. A., Halperin, I., & Dello Iacono, A. (2020). Current Evidence and Practical Applications of Flywheel Eccentric Overload Exercises as Postactivation Potentiation Protocols: A Brief Review. *International Journal of Sports Physiology and Performance*, 15(2), 154-161. <https://doi.org/10.1123/ijspp.2019-0476>
- Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Chéour, F. (2016a). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics*, 53, 231-247. <https://doi.org/10.1515/hukin-2016-0026>
- De Villarreal, E. S.-S., Kellis, E., Kraemer, W. J., & Izquierdo, M. (2009). Determining Variables of Plyometric Training for Improving Vertical Jump Height Performance: A Meta-Analysis. *Journal of Strength and Conditioning Research*, 23(2), 495-506. <https://doi.org/10.1519/jsc.0b013e318196b7c6>
- Chelly, M. S., Ghenem, M. A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R. J. (2010). Effects of in-Season Short-Term Plyometric Training Program on Leg Power, Jump- and Sprint Performance of Soccer Players. *Journal of Strength and Conditioning Research*, 24(10), 2670-2676. <https://doi.org/10.1519/jsc.0b013e3181e2728f>
- Lloyd, R. S., Meyers, R. W., & Oliver, J. L. (2011). The natural development and trainability of plyometric ability during childhood. *Strength & Conditioning Journal*, 33(2), 23-32.

- Harries, S. K., Lubans, D. R., & Callister, R. (2012). Resistance training to improve power and sports performance in adolescent athletes: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, 15(6), 532–540. <https://doi.org/10.1016/j.jsams.2012.02.005>
- World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects (2013). *JAMA*, 310(20), 2191. <https://doi.org/10.1001/jama.2013.281053>
- Sayers, M. G., & Lorenzetti, S. (2020a). Influence of technique on upper body force and power production during medicine ball throws. *Journal of Sports Sciences*, 38(4), 470–475. <https://doi.org/10.1080/02640414.2019.1706871>
- Khati, A., Saibya, R., Bhutia, N. N., Khatun, J., Mohit, Singh, H., & Saha, S. (2025). Exploring the Acute Benefits of Manual Soft Tissue Mobilization and Myofascial Release on Dynamic Athletic Performance in National Level Soccer Players. *Physical Education Theory and Methodology*, 25(4), 800–807. <https://doi.org/10.17309/tmfv.2025.4.07>
- Tong, T. K., Wu, S., & Nie, J. (2014). Sport-specific endurance plank test for evaluation of global core muscle function. *Physical Therapy in Sport*, 15(1), 58–63. <https://doi.org/10.1016/j.ptsp.2013.03.003>
- Saha, S., Obhrai, S., Vishwakarma, R., Mondal, P., Nagesh, Prasad, B., Upadhyay, K., & Singh, D. K. (2025). Clarifying the Impact of Small-Sided Games and HIIT on Anaerobic Endurance in Adolescent Hockey Players. *Physical Education Theory and Methodology*, 25(3), 660–667. <https://doi.org/10.17309/tmfv.2025.3.23>
- Loturco, I., Nakamura, F. Y., Artioli, G. G., Kobal, R., Kitamura, K., Cal Abad, C. C., Cruz, I. F., Romano, F., Pereira, L. A., & Franchini, E. (2016). Strength and Power Qualities Are Highly Associated With Punching Impact in Elite Amateur Boxers. *Journal of Strength and Conditioning Research*, 30(1), 109–116. <https://doi.org/10.1519/JSC.0000000000001075>
- Davies, G., Riemann, B. L., & Manske, R. (2015). Current Concepts of Plyometric Exercise. *International Journal of Sports Physical Therapy*, 10(6), 760–786.
- Chelly, M. S., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., & Van Praagh, E. (2009). Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *Journal of Strength and Conditioning Research*, 23(8), 2241–2249. <https://doi.org/10.1519/JSC.0b013e3181b86c40>
- Fernandez-Fernandez, J., Ellenbecker, T., Sanz-Rivas, D., Ulbricht, A., & Ferrautia, A. (2013). Effects of a 6-week junior tennis conditioning program on service velocity. *Journal of Sports Science & Medicine*, 12(2), 232–239.
- Sayers, M. G., & Lorenzetti, S. (2020b). Influence of technique on upper body force and power production during medicine ball throws. *Journal of Sports Sciences*, 38(4), 470–475. <https://doi.org/10.1080/02640414.2019.1706871>
- Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Chéour, F. (2016b). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics*, 53, 231–247. <https://doi.org/10.1515/hukin-2016-0026>
- Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2012). The effects of 4-weeks of plyometric training on reactive strength index and leg stiffness in male youths. *Journal of Strength and Conditioning Research*, 26(10), 2812–2819. <https://doi.org/10.1519/JSC.0b013e318242d2ec>
- Tong, T. K., Wu, S., Nie, J., Baker, J. S., & Lin, H. (2014). The occurrence of core muscle fatigue during high-intensity running exercise and its limitation to performance: The role of respiratory work. *Journal of Sports Science & Medicine*, 13(2), 244–251.

Ефективність застосування пліометричного тренування різної інтенсивності у покращенні сили удару кулаком та м'язової підготовленості підлітків-боксерів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. Бокс як вид спорту вимагає значної вибухової сили, зокрема сили удару кулаком і м'язової підготовленості, що є ключовими чинниками в підлітковому віці через швидкий розвиток нервово-м'язової системи. Пліометричні тренування, як відомо, сприяють розвитку певних фізичних якостей. Однак існує обмежена кількість порівняльних досліджень щодо ефективності застосування пліометричних тренувань різної інтенсивності у підлітків-боксерів.

Мета дослідження. Мета дослідження полягала у вивченні та оцінці впливу протоколів пліометричного тренування високої та низької інтенсивності на силу удару кулаком та м'язову підготовленість боксерів підліткового віку чоловічої статі.

Матеріали та методи. Тридцять підлітків-боксерів чоловічої статі віком 13-17 років, кожен з яких мав щонайменше три роки тренувального досвіду, було відібрано за методом рандомізації та розділено на три групи: група пліометричного тренування низької інтенсивності (НІПТ), група пліометричного тренування високої інтенсивності (ВІПТ) та група активного контролю (АКГ). Групи НІПТ та ВІПТ брали участь у 8-тижневій пліометричній програмі, яка проводилася тричі на тиждень з прогресивним перевантаженням, тоді як АКГ продовжувала стандартний режим тренувань з боксу. Оцінювання показників на перед- та постінтервенційному етапах включало силу удару кулаком, потужність верхньої та нижньої частин тіла, а також м'язову витривалість, які вимірювалися за допомогою валідованих тестів, специфічних для даного виду спорту. Статистичний аналіз передбачав застосування t-критеріїв для парних вибірок, дисперсійного аналізу та post hoc тестів Бонферроні.

Результати. Групи НІПТ і ВІПТ продемонстрували статистично значущі поліпшення ($p < .001$) за всіма вимірюваними змінними, тоді як в АКГ істотних змін не спостерігалось. Група ВІПТ досягла найвищих результатів: сила удару кулаком збільшилася на 17.54%, м'язова витривалість — на 31.77%, потужність нижньої частини тіла — на 21.02%, а потужність верхньої частини тіла — на 9.96%. Розміри ефекту були великими ($\eta^2 p \geq .65$), що вказує на сильний ефект курсу тренувань.

Висновки. Пліометричне тренування, зокрема високої інтенсивності, сприяє значному підвищенню сили удару кулаком та м'язової підготовленості у підлітків-боксерів. Отримані результати підтверджують доцільність включення пліометричних вправ з прогресивним перевантаженням до програм тренувань юних боксерів, що забезпечує науково обґрунтований підхід до покращення результативності впродовж критичного етапу розвитку.

Ключові слова: пліометричне тренування, сила удару кулаком, м'язова підготовленість, підлітки-боксери, інтенсивність тренувань, вибухова сила.

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Taking Astaxanthin Supplementation Attenuates MDA and HMGB1 Following Eccentric Exercise: A Randomized Controlled Trial in Recreationally Active Students

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Abstract

Background. Eccentric exercise induces mechanical stress and microstructural damage in skeletal muscle, triggering oxidative stress and inflammation that impair recovery. Malondialdehyde (MDA) and High Mobility Group Box-1 (HMGB1) are reliable biomarkers of lipid peroxidation and systemic inflammation. Astaxanthin, a marine-derived carotenoid, has strong antioxidant and anti-inflammatory properties that may mitigate these responses.

Objectives. This study aimed to investigate whether 14-day astaxanthin supplementation attenuates post-exercise increases in plasma MDA and HMGB1 levels following acute eccentric exercise in recreationally active male students.

Materials and Methods. In a randomized, double-blind, placebo-controlled trial, fifty-four recreationally active male students were assigned to receive either 12 mg/day of natural astaxanthin (AST, $n = 27$) or placebo (PLA, $n = 27$) for 14 days. Participants performed a standardized eccentric exercise protocol (10×10 drop jumps from 60 cm) on day 16. Venous blood samples were collected at 1 hour before exercise (T0), 1 hour after exercise (T1), and 24 hours after exercise (T2) to measure plasma MDA (TBARS assay) and HMGB1 (ELISA). Data were analyzed using repeated-measures ANOVA or Welch's t-test with Bonferroni adjustment ($p < 0.05$).

Results. Both groups exhibited significant increases in MDA and HMGB1 from T0 to T1 ($p < 0.001$). However, the AST group showed smaller increases in MDA (+151 % vs. +187 %, $p = 0.021$) and HMGB1 (+279 % vs. +367 %, $p = 0.014$) compared to PLA. At T2, both biomarkers declined towards baseline, with greater reductions observed in the AST group (MDA: -27 % vs. -15 %, $p = 0.018$; HMGB1: -55 % vs. -40 %, $p = 0.012$).

Conclusions. Fourteen days of astaxanthin supplementation attenuated oxidative stress and inflammatory responses following eccentric exercise, as evidenced by lower elevations of MDA and HMGB1 compared to placebo. These findings suggest that astaxanthin may be an effective nutritional strategy to protect against exercise-induced oxidative damage and modulate inflammation in physically active individuals.

Keywords: eccentric exercise, malondialdehyde, HMGB1, oxidative stress, antioxidant, inflammation.

Introduction

Intense or unaccustomed exercise—particularly those involving eccentric contractions—imposes substantial mechanical stress on skeletal muscle. This leads to microstructural damage and temporary declines in muscle

function (Irawan, Sudijandoko, et al., 2024; Markus et al., 2021). Activities that require repeated muscle lengthening under load, such as downhill running or the eccentric phase of resistance training, are particularly damaging. They often cause disruption of sarcomeres and compromise the sarcolemma (Lemire et al., 2021; Stožer et al., 2020). This structural disruption triggers a cascade of local and systemic inflammatory responses that resemble acute injury (da Silva et al., 2018; Fleckenstein et al., 2021).

A key consequence of eccentric-induced muscle damage (EIMD) is the overproduction of reactive oxygen species

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(ROS). When ROS production exceeds the capacity of endogenous antioxidant systems, lipid peroxidation can occur (Jomova et al., 2023; J. Wang et al., 2020). Malondialdehyde (MDA) is a stable end-product of lipid peroxidation and serves as a widely recognized biomarker for oxidative stress and cell membrane damage (Zhang, 2023).

In parallel, muscle cell damage results in the release of damage-associated molecular patterns (DAMPs) into the extracellular space (Tu & Li, 2023). Among these, High Mobility Group Box-1 (HMGB1) plays a central role in inflammation when passively released from the nucleus (Lin et al., 2022; Tang et al., 2022).

HMGB1 acts as a potent pro-inflammatory signal by activating innate immune receptors, recruiting immune cells, and upregulating cytokines such as IL-6 and TNF- α (Pateloni et al., 2021). This heightened immune activity contributes to delayed-onset muscle soreness (DOMS), which typically peaks 24–72 hours post-exercise and is associated with impaired recovery (Ali et al., 2023; Chang et al., 2020; Sulistyarto et al., 2022). Sustained elevations in oxidative and inflammatory biomarkers, including MDA and HMGB1, may further impair recovery and contribute to long-term muscle pathology (Mas-Bargues et al., 2021; Xue et al., 2021).

Compared to traditional cytokine markers like IL-6 and TNF- α , HMGB1 is a more proximal indicator of cellular stress. It is passively released by necrotic or mechanically disrupted muscle cells. MDA, meanwhile, provides a reliable measure of lipid peroxidation and oxidative membrane damage. Together, these biomarkers offer a comprehensive snapshot of the oxidative and inflammatory responses to EIMD and can guide the development of interventions that target both pathways.

One promising intervention is astaxanthin—a red-orange carotenoid derived from microalgae—known for its exceptional antioxidant capacity, reportedly greater than that of vitamins C and E (Barker et al., 2023; Bjørklund et al., 2022). Its molecular structure allows it to integrate into cell membranes and protect against lipid peroxidation (Barker et al., 2023; Waldman, 2024). Astaxanthin also enhances endogenous antioxidant defenses by upregulating enzymes such as superoxide dismutase and glutathione peroxidase (Heng et al., 2021).

In addition to its antioxidant properties, astaxanthin exerts anti-inflammatory effects by inhibiting NF- κ B activation—a central transcription factor in inflammation (Medoro et al., 2023). This pathway is implicated in the release of HMGB1 and the subsequent production of cytokines. Evidence from both animal and human studies suggests that astaxanthin can reduce inflammation in settings ranging from metabolic syndrome to physical overexertion (Eldessouki et al., 2024; Tsao et al., 2025). These dual antioxidant and anti-inflammatory effects make astaxanthin a compelling candidate to support muscle recovery and adaptation in physically active individuals.

Despite these promising attributes, research on the combined effects of astaxanthin on oxidative stress (MDA) and inflammation (HMGB1) following eccentric exercise remains limited. Most prior studies have focused on endurance or concentric exercise. Recreationally active populations, who are frequently exposed to unaccustomed eccentric loading, are underrepresented in antioxidant intervention research (Brown et al., 2018).

Recreationally active individuals are particularly vulnerable to eccentric-induced muscle damage due to limited neuromuscular adaptation. Unlike trained athletes, they often engage in irregular or unstructured high-intensity activities, increasing susceptibility to oxidative stress and inflammation (Owens et al., 2019). Since antioxidant supplementation is most beneficial for populations with suboptimal physiological adaptation, focusing on this group enhances the clinical and practical relevance of the study.

Therefore, this study investigated the effects of 14-day astaxanthin supplementation on plasma MDA and HMGB1 levels following acute eccentric exercise in recreationally active male students. To our knowledge, this is among the first randomized controlled trials to evaluate the dual antioxidant and anti-inflammatory properties of astaxanthin in this context. We hypothesized that astaxanthin supplementation would attenuate post-exercise elevations in MDA and HMGB1 compared to placebo.

We hypothesized that astaxanthin supplementation would attenuate post-exercise elevations in MDA and HMGB1 compared to placebo, thereby providing evidence of its antioxidant and anti-inflammatory potential in the context of eccentric exercise.

Materials and Methods

Study Design

This randomized, double-blind, placebo-controlled experimental trial employed a pretest-posttest control group design to investigate the effects of astaxanthin supplementation on oxidative stress and inflammation following eccentric exercise. Fifty-four recreationally active male participants were randomly assigned to two equal groups ($n = 27$ per group) using computer-generated block randomization (block size = 6) by an independent researcher.

The study lasted 17 days, beginning with a screening visit on Day 0 (D0) to evaluate eligibility and obtain written informed consent. On Day 1 (D1), baseline assessments were conducted during the first visit. This was followed by a 14-day supplementation period from Day 2 to Day 15 (D2–D15). Participants returned for the second visit on Day 16 (D16) to complete the eccentric exercise protocol and provide pre- and post-exercise blood samples. A final blood sample was collected during the third visit on Day 17 (D17) to capture delayed physiological responses. Throughout the study, Participants were instructed to maintain habitual dietary intake while refraining from high-intensity training, structured resistance exercise, and additional supplement or medication use.

Participants

Fifty-four recreationally active male undergraduate students from the Sports Science Program at Universitas Negeri Surabaya were recruited for this study. All participants met the predetermined inclusion criteria, which required engagement in moderate to high levels of recreational physical activity (defined as exercising 3–5 times per week), a normal body mass index (BMI) range, and good general health. Eligible participants were also required to be non-smokers and not have participated in structured resistance training within the four weeks prior to enrollment.

Exclusion criteria included a history of musculoskeletal injury, chronic illness, or any medical condition potentially affecting exercise performance or inflammatory responses. Participants who had consumed antioxidant or anti-inflammatory supplements within the previous month, reported excessive alcohol consumption (>14 units/week), or were current smokers were excluded. Individuals with known allergies or intolerances to astaxanthin or its components were also deemed ineligible. All participants received a detailed explanation of the study procedures and signed written informed consent before participating.

Participants completed a standardized health questionnaire prior to enrolment. The questionnaire included items regarding medical history (e.g., cardiovascular, metabolic, musculoskeletal disorders), current medication use, history of smoking or alcohol consumption, recent illness or injury, and other lifestyle factors relevant to eligibility. Only participants who reported no chronic disease, no recent injury, and no use of medications or supplements affecting oxidative stress or inflammation were included in the study.

Baseline physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), which indicated that all participants were classified within the moderate physical activity category. Nutritional characteristics were evaluated through a brief dietary recall, showing a typical student dietary pattern consisting mainly of rice, vegetables, chicken, fish, and fruit, with moderate intake of natural antioxidants. None of the participants reported adherence to restrictive or specialized diets. All participants were instructed to maintain their habitual diet and avoid additional supplements or medications during the study.

Supplementation

The Astaxanthin Group (AST) received 12 mg/day of natural astaxanthin, a dosage based on previous studies by Xia (Xia et al., 2020) and Brendel (Brendler & Williamson, 2019), while the Placebo Group (PLA) received visually identical capsules containing sunflower oil. Both groups consumed one capsule daily with breakfast for 14 consecutive days. Blinding of both participants and study personnel was maintained until completion of data analysis.

The astaxanthin supplement used in this study was Micro Ingredients Astaxanthin (12 mg softgel; Micro Ingredients®, California, USA), derived from the natural microalgae *Haematococcus pluvialis*. The product is certified non-GMO, gluten-free, soy-free, dairy-free, and preservative-free, and has undergone third-party laboratory testing to verify purity, potency, and safety in compliance with U.S. dietary supplement regulations.

Study Organization

The study was structured into three phases: (1) screening and baseline assessment, (2) a 14-day supplementation period, and (3) an eccentric exercise challenge followed by biomarker evaluation.

On Day 0 (D0), participants completed screening procedures, including a health questionnaire and anthropometric measurements. Baseline data were

collected during the first laboratory visit on Day 1 (D1), after which participants received instructions regarding supplementation, dietary control, and physical activity restrictions.

The supplementation phase commenced on Day 2 (D2) and continued daily through Day 15 (D15). Participants were instructed to maintain their habitual diet while avoiding high-intensity physical activity, structured resistance training, and consumption of additional supplements or medications. Compliance was monitored via weekly check-ins and capsule counts.

On Day 16 (D16), participants returned to the laboratory to perform an eccentric exercise protocol. Venous blood samples were collected at three time points: T0 (1 hour before exercise), T1 (1 hour after exercise), and T2 (24 hours after exercise on Day 17 [D17]). Detailed procedures for the exercise protocol and blood collection are presented in the following section.

Anthropometric indicators including height, weight, and body mass index (BMI) were measured using a stadiometer and a calibrated digital scale. Body fat percentage was assessed using a Tanita bioelectrical impedance analyzer (BIA BC-730; Tanita, Tokyo, Japan) under standardized conditions. Habitual physical activity was evaluated with the short form of the International Physical Activity Questionnaire (IPAQ), and results were expressed in MET-minutes per week. Maximal oxygen uptake ($\text{VO}_{2\text{max}}$) was estimated using the Multistage Fitness Test (MFT, also known as the 20-m shuttle run test), which is a validated and widely used field protocol for assessing cardiorespiratory fitness in young adults.

Exercise Protocol

To induce exercise-induced muscle damage (EIMD), participants completed a standardized eccentric exercise protocol adapted from the Newham drop-jump model. The protocol consisted of 10 sets of 10 drop jumps from a 60 cm platform, with 60 seconds of rest between sets. Each jump was performed with maximal effort and a controlled landing to emphasize eccentric loading of the quadriceps and gastrocnemius muscles. This model has been previously validated as an effective method to induce muscle damage and oxidative stress.

Prior to the exercise session, participants performed a standardized warm-up including 10 minutes of light jogging followed by dynamic stretching. The eccentric exercise was conducted under the supervision of certified trainers to ensure safety and correct technique. To monitor internal load, Rating of Perceived Exertion (RPE) was recorded at the end of each set.

Venous blood samples were collected at three time points:

T0 (second visit): 1 hour prior to exercise (after 14 days of supplementation), before any physical activity—serving as the post-supplementation baseline.

T1 (second visit): 1 hour after exercise to assess acute oxidative and inflammatory responses.

T2 (third visit, Day 17): 24 hours after exercise, to evaluate delayed systemic responses associated with muscle damage and early recovery.

A summary of the study design is illustrated in Figure 1.

This study adhered to ethical guidelines and was approved by the Health Research Ethics Committee of the

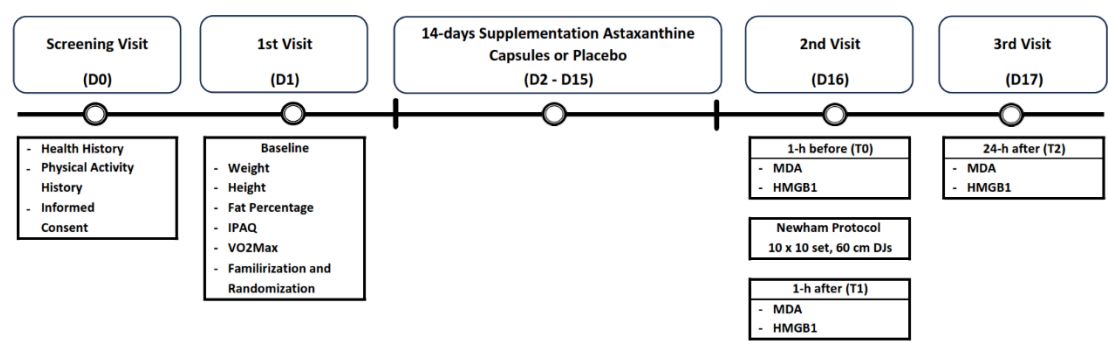


Fig. 1. Study Design

Faculty of Public Health, Airlangga University, receiving ethical clearance under the identification number 104/EA/KEPK/2023.

Outcome Measures

Venous blood samples were collected at three time points: T0 (1 hou^or before exercise, post-supplementation), T1 (1 hour after exercise), and T2 (24 hours after exercise). All samples were drawn into EDTA tubes, centrifuged at 3,000×g for 10 minutes at 4 °C, and the resulting plasma was aliquoted and stored at –80 °C until analysis.

Plasma malondialdehyde (MDA) levels, used as a biomarker of lipid peroxidation and oxidative stress, were assessed using the Thiobarbituric Acid Reactive Substances (TBARS) assay protocol. Plasma High Mobility Group Box 1 (HMGB1) protein, a marker of systemic inflammation, was quantified using a commercial enzyme-linked immunosorbent assay (ELISA) kit (Elabsience HMGB1 ELISA Kit, Houston, TX, USA), in accordance with the manufacturer’s instructions.

Venous blood samples were collected by a certified medical laboratory technologist. All analyses were conducted at the Educational Laboratory of Faculty of Public Health, which operates under standardized procedures for biomedical research and follows national laboratory safety and quality control guidelines.

All biochemical analyses were performed in duplicate to ensure reproducibility, and laboratory personnel were blinded to group assignments. To minimize confounding variables, participants were instructed to avoid intense physical activity, anti-inflammatory drugs, and additional supplementation throughout the study period.

Statistical Analysis

Normality of data distribution was assessed using the Shapiro–Wilk test, which confirmed that all variables were normally distributed. Homogeneity of variances was tested using Levene’s test. Both MDA and HMGB1 met the assumptions of normality and homogeneity; therefore, between-group comparisons at each time point were performed using independent t-tests. For within-group and time–group interaction effects, two-way repeated-measures ANOVA was applied for MDA and HMGB1, followed by Bonferroni-adjusted post hoc tests when appropriate. Statistical significance was set at $p < 0.05$.

Results

Participant Characteristic

A total of 54 recreationally active male students (mean age = 19.29 ± 0.82 years; overall mean BMI = 20.72 ± 1.28) from the Faculty of Sport Sciences and Health, Universitas Negeri Surabaya, voluntarily participated in this study after providing written informed consent. Participants were randomly assigned to the astaxanthin group ($n = 27$) or placebo group ($n = 27$) using computer-generated block randomization (block size = 6), ensuring balanced allocation. Baseline characteristics were comparable between groups (Table 1), with the astaxanthin group showing a mean age of 19.07 ± 0.68 years and BMI of 22.52 ± 2.10 , and the placebo group a mean age of 19.52 ± 0.89 years and BMI of 22.51 ± 0.70 . Table 1 summarizes additional anthropometric and physiological variables.

Table 1. Baseline characteristics of participants in the Astaxanthin and Placebo groups

Variable	AST Mean ± SD (n=27)	PLA Mean ± SD (n=27)	p
Age (years)	19.07 ± 0.68	19.52 ± 0.89	0.130
Height (cm)	168.85 ± 4.87	169.30 ± 3.96	0.463
Weight (kg)	64.04 ± 4.78	64.70 ± 5.12	0.755
BMI	22.52 ± 2.10	22.51 ± 0.70	0.877
Fat Percentage (%)	17.04 ± 2.74	17.28 ± 2.84	0.746
IPAQ (MET·min/week)	1693.00 ± 336	1581.00 ± 360	0.250
VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	36.95 ± 1.13	37.05 ± 1.14	0.839

Table 1 shows that both groups were comparable at baseline (all $p > 0.05$), suggesting that any subsequent differences are likely attributable to the intervention rather than pre-existing disparities. Homogeneity of variances were confirmed using Levene’s test (all $p > 0.05$), supporting the validity of parametric analyses. Although minor numerical differences were observed (e.g., BMI, VO₂max), these were minimal and unlikely to be physiologically meaningful.

Data Distribution and Homogeneity Testing

Prior to the main statistical analyses, assumption testing was conducted to ensure the validity of subsequent parametric tests. Data normality was assessed using the Shapiro–

Table 2. Normality test result

Variable	Time Point	Astaxanthin Sig.	Conclusion	Placebo Sig.	Conclusion
MDA	1 h before (T0)	0.926	Normal	0.945	Normal
	1 h after (T1)	0.903	Normal	0.936	Normal
	24 h after (T2)	0.685	Normal	0.716	Normal
HMGB1	1 h before (T0)	0.178	Normal	0.544	Normal
	1 h after (T1)	0.122	Normal	0.704	Normal
	24 h after (T2)	0.069	Normal	0.634	Normal

Wilk test, which is recommended for small to moderate sample sizes ($n < 50$). In this study, the test was performed separately for each group (Astaxanthin, $n = 27$; Placebo, $n = 27$) and for each measurement time point—T0 (1 h before exercise), T1 (1 h after exercise), and T2 (24 h after exercise)—for both biomarkers: malondialdehyde (MDA) and High-Mobility Group Box 1 (HMGB1). Conducting the analysis per group and per time point ensured that the sample size criteria for appropriate application of the Shapiro–Wilk method were met.

As presented in Table 2, all p -values for the Shapiro–Wilk test exceeded the 0.05 threshold, indicating that the distributions of MDA and HMGB1 values did not deviate significantly from normality at any time point in either group. This finding supports the assumption of normality for both outcome variables throughout the study period.

Following confirmation of normality, the equality of variances between groups was assessed using Levene's test, a prerequisite for valid comparisons using independent t -tests and repeated-measures ANOVA.

Table 3. Homogeneity test result

Variable	1 h before (T0) Astaxanthin – Placebo Sig.	1 h after (T1) Astaxanthin – Placebo Sig.	24 h after (T2) Astaxanthin – Placebo Sig.
MDA	0.889	0.876	0.917
HMGB1	0.595	0.754	0.652

As shown in Table 3, all Levene's test p -values were greater than 0.05, indicating that the variances between the

astaxanthin and placebo groups were statistically equivalent at all time points. Although certain values (e.g., HMGB1 at T2) approached the threshold, they remained within acceptable limits.

Together, the results of the Shapiro–Wilk and Levene's tests confirm that the dataset met the assumptions of normality and homogeneity of variances. This validation supports the appropriateness of applying parametric statistical methods, such as independent t -tests for between-group comparisons and repeated-measures ANOVA for within-subject analyses over time.

Assessment of Oxidative Stress Biomarker (MDA)

Malondialdehyde (MDA) is a widely recognized biomarker of lipid peroxidation and oxidative stress, which typically increases in response to eccentric or high-intensity exercise. In this study, plasma MDA concentrations were measured at three time points: 1 h before exercise (T0), 1 h after exercise (T1), and 24 h after exercise (T2). Descriptive statistics and pairwise comparisons of MDA levels in the astaxanthin and placebo groups are presented in Table 4.

As shown in Table 4, MDA levels increased significantly 1 h after exercise (T1) in both groups ($p < 0.001$). The astaxanthin group exhibited a smaller increase compared to the placebo group. At 24 h after exercise (T2), MDA levels decreased in both groups, with a greater reduction observed in the astaxanthin group ($p < 0.001$).

These results suggest that astaxanthin supplementation may attenuate exercise-induced oxidative stress and reduce MDA levels. Bonferroni-adjusted post-hoc tests confirmed significant differences between all-time points ($p < 0.001$),

Table 4. Changes in Plasma MDA Levels ($\mu\text{mol/L}$) Across Time Points in Astaxanthin and Placebo Groups

Group	Time Point	Mean $\pm$ SD ($\mu\text{mol/L}$)	Pairwise Comparison	Mean Difference (I–J)	P-value (Bonferroni adjusted)
Astaxanthin	1 h before (T0)	2.87 $\pm$ 1.45	T0 vs T1	-4.35*	< 0.001
	1 h after (T1)	7.22 $\pm$ 1.43	T0 vs T2	-2.36*	< 0.001
	24 h after (T2)	5.23 $\pm$ 1.41	T1 vs T2	1.99*	< 0.001
Placebo	1 h before (T0)	3.00 $\pm$ 1.42	T0 vs T1	-5.61*	< 0.001
	1 h after (T1)	8.61 $\pm$ 1.39	T0 vs T2	-4.32*	< 0.001
	24 h after (T2)	7.32 $\pm$ 1.38	T1 vs T2	1.29*	< 0.001

Notes: Mean differences are calculated as (I – J) for each pairwise comparison. Negative values indicate an increase from time point I to J (e.g., from before to after exercise). Asterisks (*) denote statistically significant differences after Bonferroni adjustment ($p < 0.05$). Data are presented as Mean $\pm$ SD ($\mu\text{mol/L}$). Post-hoc analyses were conducted using Bonferroni tests to compare time points within each group

Table 5. Changes in Plasma HMGB1 Levels (ng/mL) Across Time Points in Astaxanthin and Placebo Groups

Group	Time Point	Mean $\pm$ SD (ng/mL)	Pairwise Comparison	Mean Difference (I-J)	P-value (Bonferroni adjusted)
Astaxanthin	1 h before (T0)	1.45 $\pm$ 0.66	T0 vs T1	-4.05*	< 0.001
	1 h after (T1)	5.50 $\pm$ 0.67	T0 vs T2	-1.00*	< 0.001
	24 h after (T2)	2.45 $\pm$ 0.66	T1 vs T2	3.05*	< 0.001
Placebo	1 h before (T0)	1.52 $\pm$ 0.59	T0 vs T1	-5.57*	< 0.001
	1 h after (T1)	7.09 $\pm$ 0.61	T0 vs T2	-2.76*	< 0.001
	24 h after (T2)	4.28 $\pm$ 0.60	T1 vs T2	2.81*	< 0.001

Notes: Mean differences are calculated as (I – J) for each pairwise comparison. Negative values indicate an increase from time point I to J (e.g., from before to after exercise). Asterisks (*) denote statistically significant differences after Bonferroni correction ($p < 0.05$). Data are presented as Mean $\pm$ SD (ng/mL). Post-hoc analyses were performed using Bonferroni-adjusted pairwise comparisons within each group.

supporting the protective effect of astaxanthin in modulating oxidative stress responses after exercise.

Assessment of Inflammatory Biomarker (HMGB1)

High Mobility Group Box 1 (HMGB1) is a well-established biomarker used to evaluate inflammation and cellular stress, particularly in response to strenuous or unaccustomed eccentric exercise. In the present study, plasma HMGB1 concentrations were measured at three time points: 1 h before exercise (T0), 1 h after exercise (T1), and 24 h after exercise (T2), following a 14-day supplementation period with astaxanthin. The mean values and pairwise comparisons of HMGB1 levels in the astaxanthin and placebo groups are presented in Table 5.

As shown in Table 5, HMGB1 levels increased significantly 1 h after exercise (T1) in both groups ($p < 0.001$), with the astaxanthin group showing a smaller increase compared to the placebo group. By 24 h after exercise (T2), HMGB1 levels had decreased in both groups, with a greater reduction observed in the astaxanthin group ($p < 0.001$). The rise in HMGB1 from T0 to T1 was approximately 27% smaller in the astaxanthin group, indicating a difference that is both statistically significant and physiologically relevant. Bonferroni-adjusted post-hoc tests confirmed significant changes between all-time points ($p < 0.001$), supporting the role of astaxanthin in attenuating exercise-induced inflammation.

Discussion

Eccentric exercise is well known to induce muscle microdamage, triggering oxidative stress and inflammation that can impair recovery and performance (Nogueira et al., 2020; Sarkar et al., 2021). In the present study, a single bout of high-volume drop jumps markedly elevated plasma malondialdehyde (MDA) and High-Mobility Group Box 1 (HMGB1) levels in both the astaxanthin and placebo groups, confirming the sensitivity of these biomarkers to exercise-induced muscle damage (EIMD). Importantly, participants who consumed astaxanthin for 14 days exhibited smaller post-exercise increases in both biomarkers and a faster return toward baseline within 24 hours compared to placebo.

These findings support the hypothesis that astaxanthin supplementation can attenuate oxidative and inflammatory responses following eccentric loading in recreationally active individuals.

During eccentric exercise, repeated lengthening contractions generate high mechanical tension on muscle fibers, leading to disruption of sarcomere alignment, damage to the sarcolemma, and disturbance of the cytoskeletal network (Stožer et al., 2020; Suzuki, 2021). This structural damage increases membrane permeability, allowing calcium influx into muscle cells, which activates calcium-dependent proteases such as calpains and phospholipases (Stožer et al., 2020; Uçar et al., 2024). These enzymes degrade contractile proteins and membrane phospholipids, amplifying cellular injury (Bouviere et al., 2021). Concurrently, mitochondrial dysfunction and activation of NADPH oxidase during intense contractions lead to excessive production of reactive oxygen species (ROS) such as superoxide anions (O_2^-) and hydrogen peroxide (H_2O_2) (Bouviere et al., 2021; Y. Wang et al., 2018). Elevated ROS levels trigger lipid peroxidation, protein oxidation, and DNA damage, while also serving as signaling molecules that activate nuclear factor kappa B (NF- κ B) and other pro-inflammatory pathways (Bouviere et al., 2021; Hussein et al., 2021; Powers et al., 2010). Damaged fibers release damage-associated molecular patterns (DAMPs), including HMGB1, which bind to toll-like receptors (TLRs) on immune cells, promoting the release of cytokines such as TNF- α , IL-6, and IL-1 β (Irawan, Wahyudi, et al., 2024; Langston & Mathis, 2024; Tu & Li, 2023). This cascade results in a sustained inflammatory response that can persist for 24–72 hours post-exercise, delaying recovery and impairing performance if not properly regulated (Farias-Junior et al., 2019; Minahan et al., 2020).

The need for supplementation arises because the body's endogenous antioxidant defenses, while effective under normal physiological conditions, are often insufficient to counteract the sharp surge in ROS and inflammatory mediators generated during and after intense exercise (Arazi et al., 2021; M.-C. Lee et al., 2021). During EIMD, excessive ROS production can overwhelm enzymatic antioxidants such as superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx), leading to lipid peroxidation, protein oxidation, and DNA damage (Ammar et al., 2020; Souissi et

al., 2020). Similarly, the heightened inflammatory response can persist for 24–72 hours post-exercise, delaying muscle recovery and potentially impairing subsequent performance (Farias-Junior et al., 2019). Nutritional supplementation with potent antioxidants such as astaxanthin can provide additional defense by directly (Sawada et al., 2023), stabilizing cell membranes, and modulating inflammatory pathways, thereby supporting faster and more complete recovery (E. Lee et al., 2023).

Astaxanthin's antioxidant effects are mediated through both direct and indirect mechanisms. Structurally, astaxanthin is a xanthophyll carotenoid with a unique polar–nonpolar–polar configuration that enables it to span the phospholipid bilayer of cell membranes (Rizzardi et al., 2022). This positioning allows it to neutralize ROS both at the membrane surface and within the lipid bilayer. Astaxanthin can directly scavenge singlet oxygen ($^1O_2$), superoxide anions (O_2^-), hydroxyl radicals ($\bullet OH$), and peroxy radicals ($ROO\bullet$), thereby preventing the initiation and propagation of lipid peroxidation (Kumar et al., 2022). Its singlet oxygen quenching activity is reported to be up to 100 times greater than that of vitamin E (Yadollahi et al., 2021). In addition, astaxanthin enhances endogenous antioxidant defenses by upregulating enzymes such as SOD, catalase, and GPx through activation of the Nrf2–ARE signaling pathway (Davinelli et al., 2022). This dual mode of action provides both immediate and sustained protection against oxidative stress during and after exercise.

Astaxanthin also exerts anti-inflammatory effects through modulation of key signaling pathways. It inhibits activation of the NF- κ B pathway, a central regulator of inflammation, by preventing phosphorylation and degradation of its inhibitor, I κ B α (Davinelli et al., 2022). This suppression reduces the transcription of pro-inflammatory cytokines such as TNF- α , IL-6, and IL-1 β (Wu et al., 2024). Astaxanthin further downregulates the expression of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2), thereby reducing the production of nitric oxide and prostaglandins, which contribute to vascular permeability, tissue swelling, and leukocyte infiltration (Dang et al., 2024). Moreover, astaxanthin may attenuate DAMP-mediated immune activation by limiting the extracellular release of HMGB1 from damaged muscle fibers, thus reducing toll-like receptor (TLR) activation and accelerating the resolution of inflammation (Nian et al., 2019; Xue et al., 2021).

Our results are consistent with these mechanisms. The placebo group showed substantial increases in MDA and HMGB1 after exercise, whereas the astaxanthin group experienced attenuated rises (~22% and ~27% smaller, respectively) and faster recovery toward baseline within 24 hours. The 14-day supplementation period used in this study was based on previous human trials indicating that plasma astaxanthin concentrations reach a steady state within 10–14 days of daily intake, allowing for sufficient incorporation into cell membranes and tissues (Bloomer, 2008). This timeframe is considered adequate to elicit measurable antioxidant and anti-inflammatory effects, as supported by studies showing significant reductions in exercise-induced oxidative markers after similar supplementation durations (Bazzucchi et al., 2019). Although longer supplementation periods (≥ 4 weeks) may further enhance tissue saturation and potentially amplify protective effects, the present findings demonstrate that

even 14 days of astaxanthin intake can confer meaningful physiological benefits in attenuating oxidative stress and inflammation following eccentric exercise.

Overall, this study supports the potential of astaxanthin as a nutritional strategy to mitigate exercise-induced oxidative stress and inflammation. Given the growing interest in carotenoid-based recovery aids, astaxanthin may serve as a valuable alternative or adjunct to synthetic antioxidants for athletes and recreationally active individuals. Future research should aim to elucidate its molecular actions in human skeletal muscle, optimize supplementation protocols, and investigate its long-term effects on performance, adaptation, and health outcomes.

Conclusion

This study demonstrates that 14 days of astaxanthin supplementation attenuates exercise-induced oxidative stress and inflammation following a single bout of high-volume eccentric exercise in recreationally active males. Supplementation reduced post-exercise increases in plasma MDA and HMGB1 compared to placebo. Collectively, these findings suggest that astaxanthin may serve as an effective nutritional strategy to protect against oxidative damage and modulate inflammatory responses during strenuous eccentric loading. Further research is warranted to confirm these effects over longer supplementation periods, in different populations, and across various exercise modalities.

Limitation

Several limitations should be acknowledged in this study. First, the sample size was relatively small and limited to recreationally active young males, which may restrict the generalizability of the findings to other populations such as females, older adults, or elite athletes. Second, the supplementation period was limited to 14 days; although this duration is sufficient to achieve plasma saturation of astaxanthin, longer interventions may produce different or more pronounced effects. Third, only two biomarkers were assessed (MDA and HMGB1), which provide important but incomplete insights into the broader oxidative stress and inflammatory response. Including additional markers such as enzymatic antioxidants, cytokine profiles, and muscle damage indicators (e.g., creatine kinase) could yield a more comprehensive understanding. Lastly, dietary intake and physical activity outside the intervention were self-reported and not strictly controlled, which may have introduced variability in the results.

Strengths and Practical Implications

A major strength of this study is its randomized, placebo-controlled design, which reduces bias and increases the reliability of the results. The use of a standardized high-volume drop jump protocol provided a consistent and reproducible stimulus for inducing oxidative stress and inflammation, enabling a clear assessment of astaxanthin's effects. Measuring two key biomarkers—MDA for lipid peroxidation and HMGB1 for inflammation and tissue damage—offered direct insights into the body's oxidative and inflammatory responses to exercise. Although the

supplementation period was only 14 days, it was sufficient to produce measurable physiological benefits, showing that astaxanthin can be effective within a practical timeframe.

Practically, these findings suggest that astaxanthin supplementation can be incorporated into recovery strategies for athletes and active individuals, especially during periods of heavy training or repeated bouts of intense eccentric exercise. By reducing oxidative damage and inflammation, astaxanthin may shorten recovery time, limit performance loss, and support overall training adaptations—benefits that are particularly valuable in sports requiring frequent high-intensity efforts.

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Conflict of Interest

The authors declare that there is no conflict of interest.

References

- Irawan, R. J., Sudijandoko, A., Wahyudi, H., Kumaat, N. A., Bawono, M. N., Rimawati, N., & Wijayanto, A. (2024). Preventive effect of yacon leaves capsule in reducing symptoms of Exercise-Induced Muscle Damage. *Healthcare in Low-Resource Settings*. <https://doi.org/10.4081/hls.2024.13031>
- Markus, I., Constantini, K., Hoffman, J. R., Bartolomei, S., & Gepner, Y. (2021). Exercise-induced muscle damage: mechanism, assessment and nutritional factors to accelerate recovery. *European Journal of Applied Physiology*, 121(4), 969-992. <https://doi.org/10.1007/s00421-020-04566-4>
- Lemire, M., Hureau, T. J., Favret, F., Geny, B., Kouassi, B. Y. L., Boukhari, M., Lonsdorfer, E., Remetter, R., & Dufour, S. P. (2021). Physiological factors determining downhill vs uphill running endurance performance. *Journal of Science and Medicine in Sport*, 24(1), 85-91. <https://doi.org/10.1016/j.jsams.2020.06.004>
- Stožer, A., Vodopivec, P., & Križančić Bombek, L. (2020). Pathophysiology of exercise-induced muscle damage and its structural, functional, metabolic, and clinical consequences. *Physiological Research*, 565-598. <https://doi.org/10.33549/physiolres.934371>
- da Silva, W., Machado, Á. S., Souza, M. A., Mello-Carpes, P. B., & Carpes, F. P. (2018). Effect of green tea extract supplementation on exercise-induced delayed onset muscle soreness and muscular damage. *Physiology & Behavior*, 194, 77-82. <https://doi.org/10.1016/j.physbeh.2018.05.006>
- Fleckenstein, J., Neuberger, E. W. I., Bormuth, P., Comes, F., Schneider, A., Banzer, W., Fischer, L., & Simon, P. (2021). Investigation of the Sympathetic Regulation in Delayed Onset Muscle Soreness: Results of an RCT. *Frontiers in Physiology*, 12. <https://doi.org/10.3389/fphys.2021.697335>
- Jomova, K., Raptova, R., Alomar, S. Y., Alwasel, S. H., Nepovimova, E., Kuca, K., & Valko, M. (2023). Reactive oxygen species, toxicity, oxidative stress, and antioxidants: chronic diseases and aging. *Archives of Toxicology*, 97(10), 2499-2574. <https://doi.org/10.1007/s00204-023-03562-9>
- Wang, J., Liu, S., Li, G., & Xiao, J. (2020). *Exercise Regulates the Immune System* (pp. 395-408). https://doi.org/10.1007/978-981-15-1792-1_27
- Zhang, Q. (2023). Ginsenoside Rg1 Attenuates Eccentric Exercise-Induced Muscle Damage via the Modulation of Lipid Peroxidation and Inflammation. *Journal of Biomedical Nanotechnology*, 19(12), 2235-2242. <https://doi.org/10.1166/jbn.2023.3727>
- Tu, H., & Li, Y.-L. (2023). Inflammation balance in skeletal muscle damage and repair. *Frontiers in Immunology*, 14. <https://doi.org/10.3389/fimmu.2023.1133355>
- Lin, L., Li, J., Song, Q., Cheng, W., & Chen, P. (2022). The role of HMGB1/RAGE/TLR4 signaling pathways in cigarette smoke-induced inflammation in chronic obstructive pulmonary disease. *Immunity, Inflammation and Disease*, 10(11). <https://doi.org/10.1002/iid3.711>
- Tang, D., Wang, X., Chen, Y., Yang, X., Hu, S., Song, N., Wang, J., Cheng, J., & Wu, S. (2022). Treadmill training improves respiratory function in rats after spinal cord injury by inhibiting the HMGB1/TLR-4/NF-κB signaling pathway. *Neuroscience Letters*, 782, 136686. <https://doi.org/10.1016/j.neulet.2022.136686>
- Pattelongi, I., Huldani, M. N. M., & Idris, I. (2021). Immune Response (Cortisol, TNFA, HMGB1) in Trained and Untrained Adolescent after 12 Minutes Run Exercise. *Journal of Hunan University Natural Sciences*, 48(10).
- Ali, M. A., Pangestu, B., Rahayu, S., Anggita, G. M., Kurniawati, D. M., Noer, E. R., & Mohamed, A. M. D. (2023). Foam rolling reduced total creatine kinase in acute muscle inflammation following long-distance running. *Journal Sport Area*, 8(1), 117-122. [https://doi.org/10.25299/sportarea.2023.vol8\(1\).12144](https://doi.org/10.25299/sportarea.2023.vol8(1).12144)
- Chang, W.-D., Chang, N.-J., Lin, H.-Y., & Wu, J.-H. (2020). Effects of Acupuncture on Delayed-Onset Muscle Soreness: A Systematic Review and Meta-Analysis. *Evidence-Based Complementary and Alternative Medicine*, 2020, 1-11. <https://doi.org/10.1155/2020/5864057>
- Sulistiyarto, S., Irawan, R., Kumaat, N. A., & Rimawati, N. (2022). Correlation of Delayed Onset Muscle Soreness and Inflammation Post-exercise Induced Muscle Damage. *Open Access Macedonian Journal of Medical Sciences*, 10(A), 1688-1694. <https://doi.org/10.3889/oamjms.2022.10991>
- Mas-Bargues, C., Escrivá, C., Dromant, M., Borrás, C., & Viña, J. (2021). Lipid peroxidation as measured by chromatographic determination of malondialdehyde. Human plasma reference values in health and disease. *Archives of Biochemistry and Biophysics*, 709, 108941. <https://doi.org/10.1016/j.abb.2021.108941>
- Xue, J., Suarez, J. S., Minaai, M., Li, S., Gaudino, G., Pass, H. I., Carbone, M., & Yang, H. (2021). HMGB1 as a therapeutic target in disease. *Journal of Cellular Physiology*, 236(5), 3406-3419. <https://doi.org/10.1002/jcp.30125>

- Barker, G. A., Parten, A. L., Lara, D. A., Hannon, K. E., McAllister, M. J., & Waldman, H. S. (2023). Astaxanthin Supplementation Reduces Subjective Markers of Muscle Soreness following Eccentric Exercise in Resistance-Trained Men. *Muscles*, 2(2), 228-237. <https://doi.org/10.3390/muscles2020017>
- Björklund, G., Gasmi, A., Lenchyk, L., Shanaida, M., Zafar, S., Mujawdiya, P. K., Lysiuk, R., Antonyak, H., Noor, S., Akram, M., Smetanina, K., Piscopo, S., Upyr, T., & Peana, M. (2022). The Role of Astaxanthin as a Nutraceutical in Health and Age-Related Conditions. *Molecules*, 27(21), 7167. <https://doi.org/10.3390/molecules27217167>
- Waldman, H. (2024). Astaxanthin Supplementation as a Potential Strategy for Enhancing Mitochondrial Adaptations in the Endurance Athlete: An Invited Review. *Nutrients*, 16(11), 1750. <https://doi.org/10.3390/nu16111750>
- Heng, N., Gao, S., Chen, Y., Wang, L., Li, Z., Guo, Y., Sheng, X., Wang, X., Xing, K., Xiao, L., Ni, H., & Qi, X. (2021). Dietary supplementation with natural astaxanthin from *Haematococcus pluvialis* improves antioxidant enzyme activity, free radical scavenging ability, and gene expression of antioxidant enzymes in laying hens. *Poultry Science*, 100(5), 101045. <https://doi.org/10.1016/j.psj.2021.101045>
- Medoro, A., Davinelli, S., Milella, L., Willcox, B., Allsopp, R., Scapagnini, G., & Willcox, D. (2023). Dietary Astaxanthin: A Promising Antioxidant and Anti-Inflammatory Agent for Brain Aging and Adult Neurogenesis. *Marine Drugs*, 21(12), 643. <https://doi.org/10.3390/md21120643>
- Eldessouki, E. A. A., Elshopekey, G. E., Elbahnaswy, S., Shakweer, M. S., Abdelwarith, A. A., Younis, E. M., Davies, S. J., Mili, A., Abd El-Aziz, Y. M., Abdelnour, S. A., & Eissa, E.-S. H. (2024). Influence of astaxanthin-enriched *Haematococcus pluvialis* microalgae on the growth efficacy, immune response, antioxidant capacity, proinflammatory cytokines, and tissue histomorphology of hybrid red tilapia. *Aquaculture International*, 32(6), 7447–7468. <https://doi.org/10.1007/s10499-024-01524-1>
- Tsao, J.-P., Wu, P.-Y., Kuo, H.-T., Hong, W.-H., Chen, C.-C., Wang, M.-Y., Korivi, M., & Cheng, I.-S. (2025). Effect of astaxanthin supplementation on cycling performance, muscle damage biomarkers and oxidative stress in young adults: a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 180. <https://doi.org/10.1186/s13102-025-01221-3>
- Brown, D. R., Gough, L. A., Deb, S. K., Sparks, S. A., & McNaughton, L. R. (2018). Astaxanthin in Exercise Metabolism, Performance and Recovery: A Review. *Frontiers in Nutrition*, 4. <https://doi.org/10.3389/fnut.2017.00076>
- Owens, D. J., Twist, C., Cobley, J. N., Howatson, G., & Close, G. L. (2019). Exercise-induced muscle damage: What is it, what causes it and what are the nutritional solutions? *European Journal of Sport Science*, 19(1), 71-85. <https://doi.org/10.1080/17461391.2018.1505957>
- Xia, W., Tang, N., Kord-Varkaneh, H., Low, T. Y., Tan, S. C., Wu, X., & Zhu, Y. (2020). The effects of astaxanthin supplementation on obesity, blood pressure, CRP, glycemic biomarkers, and lipid profile: A meta-analysis of randomized controlled trials. *Pharmacological Research*, 161, 105113. <https://doi.org/10.1016/j.phrs.2020.105113>
- Brendler, T., & Williamson, E. M. (2019). Astaxanthin: How much is too much? A safety review. *Phytotherapy Research*, 33(12), 3090-3111. <https://doi.org/10.1002/ptr.6514>
- Nogueira, N. M., Felappi, C. J., Lima, C. S., & Medeiros, D. M. (2020). Effects of local cryotherapy for recovery of delayed onset muscle soreness and strength following exercise-induced muscle damage: systematic review and meta-analysis. *Sport Sciences for Health*, 16(1), 1-11. <https://doi.org/10.1007/s11332-019-00571-z>
- Sarkar, S., Debnath, M., Das, M., Bandyopadhyay, A., Dey, S. K., & Datta, G. (2021). Effect of high intensity interval training on antioxidant status, inflammatory response and muscle damage indices in endurance team male players. *Apunts Sports Medicine*, 56(210), 100352. <https://doi.org/10.1016/j.apunsm.2021.100352>
- Suzuki, K. (2021). Recent Progress in Applicability of Exercise Immunology and Inflammation Research to Sports Nutrition. *Nutrients*, 13(12), 4299. <https://doi.org/10.3390/nu13124299>
- Uçar, N., Öner, H., Kuş, M. A., Karaca, H., & Firat, T. (2024). The effect of neuromuscular electrical stimulation applied at different muscle lengths on muscle architecture and sarcomere morphology in rats. *The Anatomical Record*, 307(2), 356-371. <https://doi.org/10.1002/ar.25240>
- Bouviere, J., Fortunato, R. S., Dupuy, C., Werneck-de-Castro, J. P., Carvalho, D. P., & Louzada, R. A. (2021). Exercise-Stimulated ROS Sensitive Signaling Pathways in Skeletal Muscle. *Antioxidants*, 10(4), 537. <https://doi.org/10.3390/antiox10040537>
- Wang, Y., Branicky, R., Noë, A., & Hekimi, S. (2018). Superoxide dismutases: Dual roles in controlling ROS damage and regulating ROS signaling. *Journal of Cell Biology*, 217(6), 1915-1928. <https://doi.org/10.1083/jcb.201708007>
- Hussein, R. E., Rashed, L. A., Aboulhoda, B. E., Abdelaziz, G. M., Abdelhady, E. G., Abd El-Aal, S. A., ShamsEldeen, A., Khalifa, M. M., & Morsi, H. (2021). The Role of Thymoquinone in Mitigating Carbon Tetrachloride-Induced Hepatocellular Carcinoma in Rats: Targeting the CHOP-1/JNK/P38 MAPK, NFκB/TNF-α/IL-10, and Bax/Bcl-2/Caspase-3 Signalling Pathways. *Folia Biologica*, 69(1), 1-9. https://doi.org/10.3409/fb_69-1.01
- Powers, S. K., Duarte, J., Kavazis, A. N., & Talbert, E. E. (2010). Reactive oxygen species are signalling molecules for skeletal muscle adaptation. *Experimental Physiology*, 95(1), 1-9. <https://doi.org/10.1113/expphysiol.2009.050526>
- Irawan, R. J., Sudijandoko, A., Wahyudi, H., Kumaat, N. A., Bawono, M. N., Rimawati, N., & Wijayanto, A. (2024). Preventive effect of yacon leaves capsule in reducing symptoms of Exercise-Induced Muscle Damage. *Healthcare in Low-Resource Settings*. <https://doi.org/10.4081/hls.2024.13031>
- Langston, P. K., & Mathis, D. (2024). Immunological regulation of skeletal muscle adaptation to exercise. *Cell Metabolism*, 36(6), 1175-1183. <https://doi.org/10.1016/j.cmet.2024.04.001>
- Farias-Junior, L. F., Browne, R. A. V., Freire, Y. A., Oliveira-Dantas, F. F., Lemos, T. M. A. M., Galvão-Coelho, N. L., Hardcastle, S. J., Okano, A. H., Aoki, M. S., & Costa, E. C. (2019). Psychological responses, muscle damage, inflammation, and delayed onset muscle soreness to high-intensity interval and moderate-intensity continuous exercise in overweight men. *Physiology and Behavior*, 199, 200-209. <https://doi.org/10.1016/j.physbeh.2018.11.028>
- Minahan, C. L., Poke, D. P., Morrison, J., & Bellinger, P. M. (2020). Muscle Damage and Metabolic Responses to Repeated-Sprint Running With and Without Deceleration. *Journal of Strength and Conditioning Research*, 34(12), 3423-3430. <https://doi.org/10.1519/JSC.0000000000002164>

- Arazi, H., Eghbali, E., & Suzuki, K. (2021). Creatine Supplementation, Physical Exercise and Oxidative Stress Markers: A Review of the Mechanisms and Effectiveness. *Nutrients*, 13(3), 869. <https://doi.org/10.3390/nu13030869>
- Lee, M.-C., Hsu, Y.-J., Yang, L.-H., Huang, C.-C., & Ho, C.-S. (2021). Ergogenic Effects of Green Tea Combined with Isolated Soy Protein on Increasing Muscle Mass and Exercise Performance in Resistance-Trained Mice. *Nutrients*, 13(12), 4547. <https://doi.org/10.3390/nu13124547>
- Ammar, A., Trabelsi, K., Boukhris, O., Glenn, J., Bott, N., Masmoudi, L., Hakim, A., Chtourou, H., Driss, T., Hoekelmann, A., & El Abed, K. (2020). Effects of Aerobic-, Anaerobic- and Combined-Based Exercises on Plasma Oxidative Stress Biomarkers in Healthy Untrained Young Adults. *International Journal of Environmental Research and Public Health*, 17(7), 2601. <https://doi.org/10.3390/ijerph17072601>
- Souissi, W., Bouzid, M. A., Farjallah, M. A., Ben Mahmoud, L., Boudaya, M., Engel, F. A., & Sahnoun, Z. (2020). Effect of Different Running Exercise Modalities on Post-Exercise Oxidative Stress Markers in Trained Athletes. *International Journal of Environmental Research and Public Health*, 17(10), 3729. <https://doi.org/10.3390/ijerph17103729>
- Sawada, Y., Ichikawa, H., Ebine, N., Minamiyama, Y., Alharbi, A. A. D., Iwamoto, N., & Fukuoka, Y. (2023). Effects of High-Intensity Anaerobic Exercise on the Scavenging Activity of Various Reactive Oxygen Species and Free Radicals in Athletes. *Nutrients*, 15(1), 222. <https://doi.org/10.3390/nu15010222>
- Lee, E., Park, H.-Y., Kim, S.-W., Sun, Y., Choi, J.-H., Seo, J., Jung, Y. P., Kim, A.-J., Kim, J., & Lim, K. (2023). Enhancing Supplemental Effects of Acute Natural Antioxidant Derived from Yeast Fermentation and Vitamin C on Sports Performance in Triathlon Athletes: A Randomized, Double-Blinded, Placebo-Controlled, Crossover Trial. *Nutrients*, 15(15), 3324. <https://doi.org/10.3390/nu15153324>
- Rizzardi, N., Pezzolesi, L., Samori, C., Senese, F., Zalambani, C., Pitacco, W., Calonghi, N., Bergamini, C., Prata, C., & Fato, R. (2022). Natural Astaxanthin Is a Green Antioxidant Able to Counteract Lipid Peroxidation and Ferroptotic Cell Death. *International Journal of Molecular Sciences*, 23(23), 15137. <https://doi.org/10.3390/ijms232315137>
- Kumar, S., Kumar, R., Kumari, A., & Panwar, A. (2022). Astaxanthin: A super antioxidant from microalgae and its therapeutic potential. *Journal of Basic Microbiology*, 62(9), 1064-1082. <https://doi.org/10.1002/jobm.202100391>
- Yadollahi, F., Soltani, M., Modarresi, M. H., & Akhondzadeh Basti, A. (2021). Efficacy of vitamin E with or without probiotic, astaxanthin or rosemary extract on growth performance, survival, haematological parameters, antioxidant activity and liver enzymes in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research*, 52(11), 5606-5616. <https://doi.org/10.1111/are.15436>
- Davinelli, S., Saso, L., D'Angeli, F., Calabrese, V., Intrieri, M., & Scapagnini, G. (2022). Astaxanthin as a Modulator of Nrf2, NF-κB, and Their Crosstalk: Molecular Mechanisms and Possible Clinical Applications. *Molecules*, 27(2), 502. <https://doi.org/10.3390/molecules27020502>
- Wu, Y., Bashir, M. A., Shao, C., Wang, H., Zhu, J., & Huang, Q. (2024). Astaxanthin targets IL-6 and alleviates the LPS-induced adverse inflammatory response of macrophages. *Food & Function*, 15(8), 4207-4222. <https://doi.org/10.1039/D4FO00610K>
- Dang, Y., Li, Z., & Yu, F. (2024). Recent Advances in Astaxanthin as an Antioxidant in Food Applications. *Antioxidants*, 13(7), 879. <https://doi.org/10.3390/antiox13070879>
- Nian, L., Weidong, Z., Shujuan, L., Jun, C., Minlian, P., & Zhiguang, L. (2019). Astaxanthin suppresses cigarette smoke and lipopolysaccharide-induced airway inflammation through induction of heme oxygenase-1. *Cellular and Molecular Biology*, 65(1), 94-99. <https://doi.org/10.14715/cmb/2019.65.1.17>
- Bloomer, R. J. (2008). *Chapter 1 Effect Of Exercise On Oxidative Stress Biomarkers* (pp. 1–50). [https://doi.org/10.1016/S0065-2423\(08\)00401-0](https://doi.org/10.1016/S0065-2423(08)00401-0)
- Bazzucchi, I., Patrizio, F., Ceci, R., Duranti, G., Sgrò, P., Sabatini, S., Di Luigi, L., Sacchetti, M., & Felici, F. (2019). The Effects of Quercetin Supplementation on Eccentric Exercise-Induced Muscle Damage. *Nutrients*, 11(1), 205. <https://doi.org/10.3390/nu11010205>

Приймання добавок астаксантину зменшує рівень малонового діальдегіду (МДА) та амфотерину (HMGB1) після виконання ексцентричних вправ: Рандомізоване контрольоване дослідження студентів, які активно займаються рекреаційною діяльністю

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 11 с., 5 табл., 1 рис., 56 джерел.

Історія питання. Ексцентричні вправи спричиняють механічне напруження та мікроструктурні пошкодження скелетних м'язів, що провокує окислювальний стрес та запалення, які погіршують процес відновлення. Малоновий діаль-

дегід (МДА) та білок групи високої рухливості 1 (амфотерин, HMGB1) є надійними біомаркерами ліпідної пероксидації та системного запалення. Астаксантин, каротиноїд морського походження, має сильні антиоксидантні та протизапальні властивості, які можуть пом'якшити зазначені реакції.

Мета дослідження. Мета цього дослідження полягала у вивченні того, чи 14-денне приймання добавок астаксантину послаблює підвищення рівнів МДА та HMGB1 у плазмі крові після інтенсивних ексцентричних вправ у рекреаційно активних студентів чоловічої статі.

Матеріали та методи. У рандомізованому, подвійно сліпому, плацебо-контрольованому дослідженні 54 студенти чоловічої статі, які активно займаються рекреаційною діяльністю, були розподілені на дві групи: одна група отримувала 12 мг/день натурального астаксантину (АСТ, $n = 27$), а інша — плацебо (ПЛА, $n = 27$) протягом 14 днів. На 16-й день учасники виконали стандартизований протокол ексцентричних вправ (10×10 стрибків з висоти 60 см). Зразки венозної крові було зібрано за 1 годину перед виконанням вправ (T0), через 1 годину після вправ (T1) та через 24 години після виконання вправ (T2) з метою вимірювання показників МДА (аналіз реактивних речовин тіобарбітурової кислоти, TBARS) та HMGB1 (імуноферментний аналіз, ELISA) у плазмі крові. Аналіз даних проводився з використанням дисперсійного аналізу з повторними вимірами або t-критерію Велча з поправкою Бонферроні ($p < 0.05$).

Результати. В обох групах спостерігалось значне підвищення рівнів МДА та HMGB1 від T0 до T1 ($p < 0.001$). Однак група АСТ продемонструвала менші підвищення рівнів МДА (+151% проти +187%, $p = 0.021$) та HMGB1 (+279% проти +367%, $p = 0.014$) порівняно з групою ПЛА. На етапі T2 обидва біомаркери знизилися до базового рівня, причому більші зниження показників спостерігалися в групі АСТ (МДА: -27% проти -15%, $p = 0.018$; HMGB1: -55% проти -40%, $p = 0.012$).

Висновки. Приймання добавок астаксантину протягом 14 днів сприяло зменшенню окислювального стресу та запальних реакцій після ексцентричних вправ, що підтверджується нижчими рівнями МДА та HMGB1 порівняно з плацебо. Отримані результати свідчать, що астаксантин може бути ефективною нутритивною стратегією щодо захисту від окислювального пошкодження, спричиненого фізичними навантаженнями, та регулювання запальних процесів у фізично активних осіб.

Ключові слова: ексцентричні вправи, малоновий діальдегід, HMGB1, окислювальний стрес, антиоксидант, запалення.

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Evaluating Trends in Cardiorespiratory Fitness Among Physiotherapy Students: A 15-Year Cross-Sectional Study (2007-2023)

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Abstract

Background. Cardiorespiratory fitness (CRF) is a key health indicator, particularly for physiotherapy students who are expected to model healthy behaviors.

Objectives. The objective of the study was to analyze CRF trends among physiotherapy students over the period from 2007 to 2023 and to assess variations in maximal oxygen uptake ($\text{VO}_{2\text{max}}$) across gender and body mass index (BMI) categories.

Materials and Methods. Secondary data from 2007–2009 and 2010–2012 were compared with primary data collected in 2022–2023. CRF was measured using a submaximal Monark Ergonomic 839E cycle ergometer test in 242 students (aged 18–25 years). Statistical analyses included t-tests, ANOVA, and non-parametric tests ($p < 0.05$). The Kruskal-Wallis test was used for between-group comparisons and Spearman's correlation — to assess trends over time.

Results. Over half of male (52%) and female (63%) participants had CRF levels below the reference values. Female students showed a significant $\text{VO}_{2\text{max}}$ decline in 2022–2023 compared to 2007–2009 (mean difference = 1.78 ml/min/kg, $p < 0.05$), while no trend was observed in males. Students with $\text{BMI} > 25 \text{ kg/m}^2$ had significantly lower $\text{VO}_{2\text{max}}$ than those with $\text{BMI} \leq 25 \text{ kg/m}^2$ ($p < 0.05$).

Conclusions. These findings highlight the need for targeted fitness programs for female students and those with elevated BMI. Future research should explore lifestyle factors and intervention strategies to improve CRF in students. This study provides foundational data for future research on the relationship between CRF, clinical skills, and patient satisfaction among physiotherapy students.

Keywords: cardiorespiratory fitness, maximal oxygen uptake, physiotherapy students, submaximal cycle ergometer test.

Introduction

The understanding of good health practices and the development of skills required to maintain physical fitness are becoming increasingly important in modern society due to their strong connection with self-realization and overall well-being (Alparslan et al., 2024; Klussman et al., 2021; Wong et al., 2021). Cardiorespiratory fitness (CRF) is widely recognized as a crucial determinant of general health and physical work capacity (Raghuveer et al., 2020). CRF refers to the capacity of the circulatory and respiratory systems

to supply oxygen during sustained physical activity (PA) (Raghuveer et al., 2020) and is commonly measured using maximal oxygen uptake ($\text{VO}_{2\text{max}}$). This metric serves as a measure of the functional capacity of both the respiratory and cardiovascular systems. It encompasses several processes, including ventilation, perfusion, gas exchange, vasodilation, and oxygen delivery to body tissues. As an integrated physiological trait, CRF reflects the coordinated function of various body systems to support muscle activity during prolonged, rhythmic, and large muscle group-involving physical exertion (Harber et al., 2017). CRF is a key marker of physical health, associated with a reduced risk of chronic diseases and lower mortality rates (Lang et al., 2024). A lack of PA contributes to the deterioration of health across multiple bodily systems (Fernström et al., 2017; Isath

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et al., 2023), increasing cardiovascular risk factors such as elevated body mass index (BMI), fat percentage, and blood pressure (Chaabna et al., 2022). Low CRF levels have been linked to an elevated risk of coronary heart disease and mortality (Salier Eriksson et al., 2021). Moreover, it serves as a predictor of well-being and longevity. Despite its importance, studies highlight that many individuals, particularly students, demonstrate poor CRF levels (Ali et al., 2020; Sovová et al., 2020).

Healthcare professionals are strongly encouraged to improve their CRF, as those who enhance their own fitness levels are better positioned to guide others on maintaining physical fitness (Mandsager et al., 2018). Students enrolled in health programs have opportunities to explore the scientific foundations of maintaining an active lifestyle (Ali et al., 2021), fostering self-management skills essential for sustaining fitness (García-Suárez et al., 2022). For physiotherapists, maintaining optimal CRF is critical, as physical fitness not only reduces the risk of injury but also enhances work efficiency within healthcare professions (Al-Khlaifat et al., 2024; Tišlar et al., 2022). Beyond meeting the physical demands of their roles, CRF enables physiotherapists to serve as role models for a healthy lifestyle to their patients (Maldonado-Alicea et al., 2024). A study conducted in Poland suggests that improvements in the physical fitness of physiotherapy students may be associated with greater awareness of job requirements and prevailing fitness trends (Lewandowski et al., 2020). Emphasizing health- and skill-related physical fitness among physiotherapy students benefits both their personal health and injury prevention while ensuring their long-term ability to meet professional demands (Al-Khlaifat et al., 2024).

Maintaining adequate CRF is vital for these future professionals to safeguard their well-being, prevent occupational injuries, and provide effective patient care. This study differs from previous research by specifically examining the longitudinal trends in CRF among physiotherapy students over a 15-year period, offering a unique perspective on how fitness levels have evolved within this population. The objective of the study was to analyze CRF trends among physiotherapy students over the period from 2007 to 2023 and to assess variations in VO_2 max across gender and BMI categories.

Materials and Methods

This study used a repeated cross-sectional research design to assess the CRF of physiotherapy students. This design was chosen because it allows for the comparison of different cohorts over time using consistent methodology, enabling the identification of population-level trends in cardiorespiratory fitness without the need to follow the same individuals longitudinally.

Participants and Ethics

The study included first- and second-year students in Latvia ($n = 263$ (41 male)), enrolled in a four-year "Physiotherapy" bachelor's study program at university. The open method was used to select the sample. All students of physiotherapy programs were invited to participate in the study. The sample group included physiotherapy students

who were in the first years of their studies and had learnt strategies for evaluating and developing CRF as part of their study program. One set of measurements was taken for each student. Second-year students who had already been tested in the previous year were excluded from testing in their second year. Inclusion criteria included both male and female physiotherapy programs students aged 18-25 years old who have no contraindications to participate in PA and agreed to participate in the study. Exclusion criteria were also defined. According to these criteria, students who had experienced an acute illness within the last month and who used medication that can affect cardiorespiratory function were excluded due to possible the effects of these factors on the measurement data. Pregnant women were also excluded due to possible medical complications, as the tests predict an increased physical load. Top-level athletes participated in the test as part of their education program, but their data were not included in this study as their aerobic capacity should be viewed in the context of the specifics of their sport and does not correspond to average indicators. The study compared secondary data available from 2007 to 2012 with data collected in 2022 and 2023. The secondary data (university data base 2007-2012 on secure servers, accessible only to authorized research team members from 1.04.2022. Authors hadn't access to information that could identify individual participants) were divided into three-year periods and analysed to compare these periods allowing for the examination of valuable insights into long-term trends in the studied variables. The minimum sample size was determined to be 157 students through a power analysis with a 95% confidence level and a 5% margin of error. The final sample consisted of 242 students, which exceeds this threshold, ensuring the statistical validity of the results. Data collection in 2022 and 2023. The participants recruitment and data collection period lasted from 1 April 2022 and concluding on 1 December 2023. Participation in the study was voluntary and anonymous, with participants being informed that their data would be used solely within the framework of this research. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Riga Stradins University (Protocol No. 2-PĒK-4/163/2022, 16 March 2022. Prior to the study, participants provided written informed consent, ensuring they were aware of the study's purpose and the intended use of their data. Also participants provided informed consent, confirming their eligibility, willingness to follow instructions, and the right to withdraw from the study at any time without explanation or penalties. No minors participated in this study, and all participants were competent adults who voluntarily consented to partake. Confidentiality was strictly maintained, all data anonymized and securely stored to protect participant privacy. Data was encrypted and stored on secure servers, accessible only to authorized research team members (Veseta et al., 2023). Authors declare there are no conflicts of interests, acknowledging all financial and any other relevant financial or nonfinancial competing interests.

Procedure

Prior to the study, participants were informed about CRF, the submaximal test, its procedure, and potential

contraindications. They were given preparation guidelines, including consuming the last meal at least 3 hours before the test, abstaining from smoking for at least 3 hours prior to the test, avoiding intense PA for 24 hours before the test, and wearing comfortable sports clothing and footwear. In cases of participant withdraw, any identifiable data would be immediately deleted to uphold their privacy rights. To assess the students' CRF, participants' weight and height were measured at an accuracy of 0.1 kg and 0.5 cm and their BMI was calculated. The Monark Ergonomic 839E cycle ergometer submaximal exercise test was used to estimate VO_2 max data for the physiotherapy students. This test methodology has previously been compared with direct VO_2 max measurements and has shown the smallest margin of error and the strongest correlation with direct gas analysis, regardless of participants' sex, age, fitness level, or of PA frequency (Liepiņa L. et al., 2013). Participants' data, including age, date of birth, gender, height, and weight, were entered into the Monark Ergonomic 839E cycle ergometer program. A heart rate (HR) belt was attached to each participant's chest and transmitted data to the Monark Software 2.5.

1. The test was performed following these steps:
2. The participant was informed about the test process.
3. The seat height was adjusted.
4. The pedaling speed was set to 60 RPM, and the participant was instructed to maintain this speed.
5. The test began with a 5-minute warm-up, during which the participant adjusted to pedaling.
6. Finally, the data transmitted from the HR belt to the Monark software was checked.

The test consisted of three 4-minute exercise periods, with stepwise increases in load. Based on the entered data, the Monark software determined the appropriate test load and predicted the heart rate range for the test. The software displayed each load in watts (W) and the recommended HR range. The next load was automatically applied by the software, with increments of about 25-50 W between each test, such that the final HR load reached about 80% of the maximum HR. Maximum HR was calculated using the formula: $220 - \text{participant's age}$. If the participant's HR exceeded the predicted value during the test, the load was reduced to bring the HR back within the recommended range. If the HR was too low, the load was increased.

The criteria for discontinuing the test were as follows:

1. An incomplete test;
2. A participant expressed desire to stop participating in the study;
3. Technical problems occurred during the test.

The Monark software calculated the maximum load the participant manage with their maximum HR considering all three loads and the HR at the end of each load, and calculated the respective maximum oxygen consumption using the following formula:

$$W_{\max} (W) = 3 \cdot \text{load} (W) + \left[(\max HR^* - HR \text{ 3. load}) * \frac{3 \cdot \text{load} (W) - \frac{1 \cdot \text{load} (W) + 2 \cdot \text{load} (W)}{2}}{HR \text{ 3. load} - \frac{HR \text{ 1. load} + HR \text{ 2. load}}{2}} \right]$$

$$\text{VO}_2 \max = \frac{W_{\max} (W) * 12.48 + 217}{\text{weight (kg)}}$$

VO_2 max was expressed as body weight in kilograms and was evaluated according to Shvartz and Reibold's normative data (Shvartz & Reibold, 1990).

Following the cycle ergometry test, the data from participants who did not complete the test or experienced technical problems during the test were excluded from the analysis. The test procedure is shown in the flow chart below (Fig. 1).

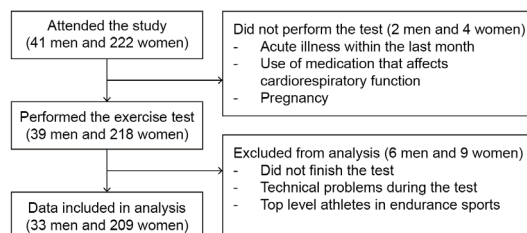


Fig. 1. Flow chart of the test procedure

Statistical Analyses

Statistical data analysis was performed using SPSS Statistics v. 29.0 (IBM Corporation, USA) with the significance level set at $p < 0.05$. The analysis included descriptive statistics for the whole sample and was stratified by gender in all cases. The results are presented as the mean value with standard deviation. The Kolmogorov-Smirnov test was performed to assess the normality of the distribution of continuous variables. The significance level for the Kolmogorov-Smirnov test was set at $p < 0.05$. Due to the Gaussian distribution, ANOVA tests were used to assess differences in height and weight at three-year intervals, as well as differences in the VO_2 max of the female students in the three BMI groups. The Levene's test for equality of variances was used to test homogeneity of age, weight, height, BMI and the VO_2 max. An independent samples t-test assuming the equal variances was used to assess differences in age, height, weight, BMI, and VO_2 max between the male and female participants, as well as inequalities in the VO_2 max values between males in the normal and elevated BMI groups. As the distribution of VO_2 max in the groups stratified by year of testing was not Gaussian, inequalities in VO_2 max within these groups were assessed using the Kruskal-Wallis test. Associations between the VO_2 max and age, height, weight and BMI values were assessed using the Pearson correlation test for parameters with Gaussian distribution or the Spearman correlation test for those with non-Gaussian distribution.

Results

A total of 242 students met the inclusion criteria for the study, and their data were considered valid for the analysis. The majority of the study population (89%) were female. The physical characteristics, as well as the predicted VO_2 max, of the males and females participants included in the study, are presented in Table 1. The Levene's test for equality of variances was not significant ($p > 0.05$), indicating that the assumption of equal variances was met. Consequently, a t-test assuming equal variances was used to compare the variables between males and females.

Table 1. The physical characteristics and calculated VO₂ max of the male and female participants.

	Males (n = 33)		Females (n = 209)		Levene's Test (F, p-value)	t-test of sex group differences (Equal Variances Assumed)
	M	SD	M	SD		
Age (years)	21.1	1.7	21.0	1.4	F = 1.538, p = 0.216	t = 0.295, p = 0.768
Height (cm)	181.4	6.3	168.8	5.7	F = 1.344, p = 0.248	t = 11.517, p < 0.001
Weight (kg)	75.7	9.4	62.2	9.3	F = 0.152, p = 0.697	t = 7.803, p < 0.001
BMI (kg/m ²)	23.0	2.4	21.8	3.0	F = 1.917, p = 0.167	t = 2.154, p = 0.032
VO ₂ max(ml/min/kg)	44.0	6.3	35.2	5.0	F = 1.740, p = 0.188	t = 9.069, p < 0.001

* p of group differences due to independent-samples t-test

There was no difference in age between the two sex groups, while the heights, weights and BMIs of the female participants were lower than the males'. The female participants had a 20% lower VO₂ max than the males (35.2 ± 5.0 ml/min./kg vs. 44.0 ± 6.3 ml/min./kg).

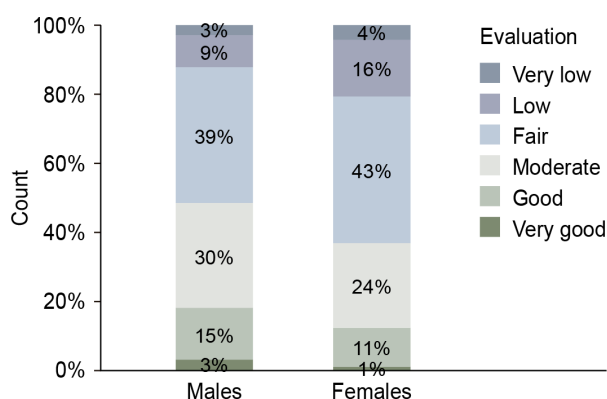
The distribution of VO₂ max for males had a skewness of -0.080 (standard error = 0.49) and a kurtosis of 0.098 (standard error = 0.80), and female data had a skewness of 0.114 (standard error = 0.168) and a kurtosis of -0.126 (standard error = 0.335), indicating a nearly symmetrical and slight mesokurtic distribution consistent with normality.

The most recent normative data on the VO₂ max of the European population, measured using the cycle ergometry test, have been derived from the results of exercise testing in the USA, Canada, and seven European countries (Shvartz & Reibold, 1990). The VO₂ max values obtained for the physiotherapy students were classified according to evaluation classes for their respective age groups (Fig. 2).

In this study, 30% of the male participants and 24% of the female participants had moderate VO₂ max values. Only 18% of the males and 12% of the females had good and very good VO₂ max values, while 52% of males and 63% of females had a lower than average VO₂ max, with 3% and 4% of the males and females, respectively, being in the very poor range (Fig 2 and 3).

To evaluate the differences in the VO₂ max values of students who entered the university program directly after secondary school and those who delayed their entry by a year or more, all of the students were divided into two age groups—18-20 and 21-25 years of age. The differences in the VO₂ max value were not statistically significant for both male and female students in these age groups.

To investigate whether there was a change in VO₂ max during the study period, the data were divided into 3-year

**Fig. 2.** Distribution of study population according to the evaluation of VO₂ max

time intervals corresponding to when the cycle ergometry tests were carried out. The characteristics of the participants in these ranges and the differences between them are detailed in Table 2.

The VO₂ max values for three periods were compared (Fig. 3 and 4). Over the entire testing period from 2007 to 2023, a decline in the VO₂ max values was observed for both sexes, but a statistical significance was found only for the female participants between years 2007-2009 and 2022-2023 (Fig 4 and 5). The proportion of women that had a below-moderate VO₂ max in 2007-2009 was 54 %, but in 2022-2023, this rose to 71 %.

The effect of BMI on the VO₂ max was determined by dividing all the students into groups with low (< 18.5 kg/m²), normal (18.5-24.9 kg/m²), and increased (>24.9 kg/m²) BMIs (Fig 5 and 6).

Table 2. Characteristics of participants in three testing periods.

	2007-2009		2010-2012		2022-2023		p*
	M	SD	M	SD	M	SD	
Males	n = 9		n = 12		n = 12		
Height (cm)	181.2	5.56	180.1	7.6	182.9	5.7	0.562
Weight (kg)	77.3	8.4	74.8	11.4	75.5	8.4	0.827
Females	n = 76		n = 63		n = 70		
Height (cm)	169.3	6.2	168.9	4.7	168.3	6.1	0.590
Weight (kg)	61.5	7.9	62.1	9.1	62.9	10.8	0.646

* p of differences in measured parameters obtained using One-Way ANOVA test

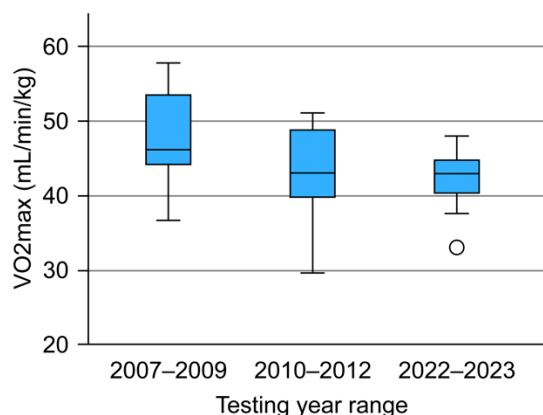


Fig. 3. Boxplot of the VO_2 max of male participants according to the testing year.

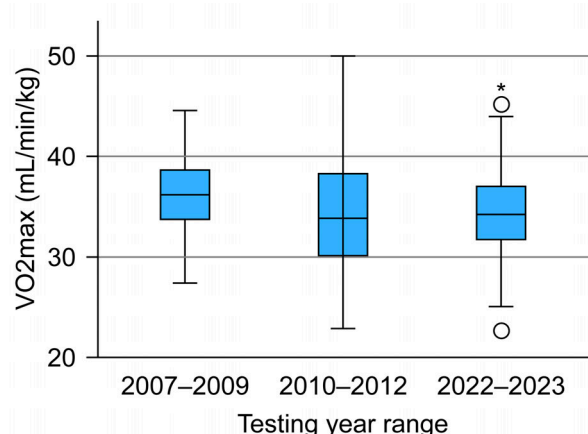


Fig. 4. Boxplot of the VO_2 max of female participants according to the testing year (* $p < 0.05$ vs year 2007–2009 according to the independent samples Kruskal–Wallis test)

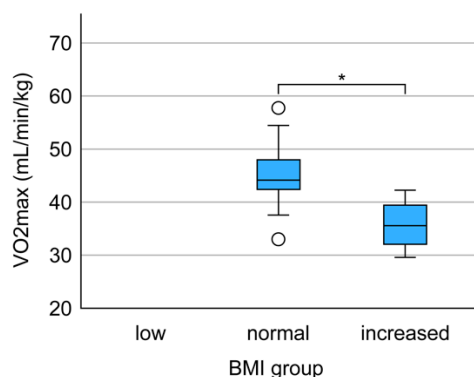


Fig. 5. Boxplot of the VO_2 max of male students in the three BMI groups (* $p < 0.05$ of difference between groups according to the independent samples t-test)

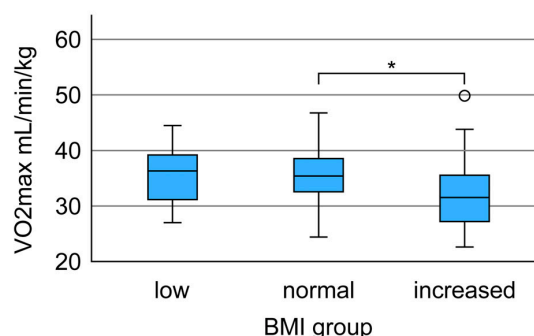


Fig. 6. Boxplot of the VO_2 max of female students in the three BMI groups (* $p < 0.05$ of difference between groups according to the one-way ANOVA with the Tukey post hoc test)

No correlations were observed between the VO_2 max calculated for the different age and height groups for both sexes, but there was a correlation between VO_2 max and BMI ($r = -0.362$ and $r = -0.319$ for males and females, respectively, $p < 0.05$). Students with an increased BMI in both sex groups presented lower VO_2 max than those with a normal BMI. There were no male participants with a low BMI, and male students with a BMI greater than 25 kg/m^2 had a 9.4 mL/min/kg lower VO_2 max on average than males with a normal BMI ($t_{(31)} = 3.162$; $p = 0.03$). Female students with an increased BMI had lower VO_2 max than those with a normal BMI, as demonstrated by the ANOVA test ($F_{(2,206)} = 5.019$; $p = 0.007$). The post hoc comparisons using the Tukey HSD test indicated that the mean VO_2 max for females with an increased BMI ($M = 32.1$, $SD = 6.6$) was significantly different from that of those with a normal BMI ($M = 35.6$, $SD = 4.6$).

Discussion

The aim of this study was to investigate trends in CRF among physiotherapy students across three cohorts (2007–2009, 2010–2012, and 2022–2023) and assess differences in VO_2 max based on gender and BMI categories. The

findings provide important insights into the fitness levels of physiotherapy students, particularly in light of their future roles in healthcare. Given that physiotherapists are expected to be role models for healthy living, understanding their CRF levels is essential not only for their personal health but also for their professional credibility in promoting healthy lifestyles. Moreover, the results shed light on potential impacts of the COVID-19 pandemic on students' fitness, with implications for long-term public health outcomes.

The results of this study show that the mean VO_2 max of the male participants in this study is similar to the Latvian data recorded for individuals who are engaged in high-intensity dynamic and medium-high-intensity static exercise for 300 minutes a week or more and participate in competitions, but is higher than that for those who train for less than 300 minutes a week (Rozenštoka & Ērglis, 2020). The mean VO_2 max of the females participants in this study was between that of both groups in the Latvian study. This study included participants who do not compete in sports competitions; thus, the summary data may be lower than those for the athletes participating in the Latvian study.

The VO_2 max of students of both sexes was similar to the data published for Lithuania (Grigaliūnienė et al., 2013), Germany (Rapp et al., 2018), and the USA (Kaminsky et al.,

Table 3. Comparison of VO₂ max levels between physiotherapy data and other values from Latvia and other countries.

	VO ₂ max (ml/min./kg)			
	Man		Woman	
	M	SD	M	SD
Physiotherapy students in the current study	44.0	6.3	35.2	5.0
Latvia (Rozenštoka & Ērglis, 2020)				
training < 300 min. per week	37.6	7.1	31.4	5.0
training ≥ 300 min. per week	44.4	7.0	37.6	6.0
Lithuania (Grigaliūnienė et al., 2013)	40.4	5.77	34.7	6.8
Norway (Loe et al., 2013)	54.4	8.4	43.0	7.7
Germany (Rapp et al., 2018)	(35-45) ^a		(29-38) ^a	
Switzerland (Wagner et al., 2021)	46.6	7.9	39.3	6.5
Greece (Triantafyllidi et al., 2021)	37 (34-40) ^a		30	5
The Netherlands and Belgium (van der Steeg & Takken, 2021)	47.7	6.5	39.5	8.8
USA – FRIEND update (Kaminsky et al., 2022)	45.1	13.3	32.0	10.6

^a Median (25-75% CI)

2022). The data for the USA (Kaminsky et al., 2022) are an update to normative values recommended by the American College of Sports Medicine for the cycle ergometer CRF test (Kaminsky et al., 2017). In this study, the VO₂ max for both sexes was higher than that in a study performed in Greece (Triantafyllidi et al., 2021), but lower than what was found in the populations of the Netherlands and Belgium (van der Steeg & Takken, 2021) and that of Norway in the Nord-Trøndelag study (Loe et al., 2013). The data for the male participants in this study were similar to those recorded for Switzerland, but the females in this study had a lower VO₂ max (Table 3). Based on the other countries' data, it seems that the students tested in this study fit into the young adult population results of Europe and North America, but there is still work to be carried out to reach more advanced countries' data.

Compared with the normative data of Shvartz and Reibold (Shvartz & Reibold, 1990), which is derived from the directly measured VO₂ max in the USA, Canada and 7 European countries, the relative VO₂ max estimate in this study was lower, especially in females, where 63% of the tested participants had lower than average VO₂ max. According to the data, increased PA levels in students should be promoted to raise CRF for future specialists, who should be able to recommend PA for their clients.

VO₂ max is highest at a young age and decreases with age. In a longitudinal study carried out in Germany, VO₂ max was found to decrease by about 5 ml/min/kg each decade (Bahls et al., 2021). In a cross-sectional study in Switzerland, VO₂ max was highest in 20–29 year-olds and reduced by 10% for each subsequent decade (Wagner et al., 2021). Similar data can be found in the other studies which involve participants of different ages (Kaminsky et al., 2022; van der Steeg & Takken, 2021; Wagner et al., 2021). Thus, young adults who have a current VO₂ max below the average level are at a greater risk of an increased risk of morbidity and mortality from cardiovascular and other causes (Isath et al., 2023; Taylor et al., 2021). Despite genetics significantly contributing to VO₂ max (Schutte et al., 2016) and its

trainability (Williams et al., 2017), those who are more active have higher values for both relative and absolute VO₂ max (Tangen et al., 2022). The frequency of exercise per week has an impact on mean VO₂ max – it is significantly higher when exercising two or more times per week regardless of the exercise being carried out (Sovová et al., 2020). High-intensity interval running (HIIT-R) and high-intensity functional training (HIFT) lead to similar improvements in VO₂ max (17.1 % ± 5.6 % and 12.7 % ± 6.7 %, respectively, $p > 0.05$) (Lu et al., 2021). Further recommendations after the determination of aerobic capacity could help in guiding students towards PA and exercise at university and sports clubs in their city.

The relative VO₂ max did not differ for the students who entered university immediately after secondary school compared to those who took one or two years off. This indicates that the school physical education program has a small or no impact on the VO₂ max of future students, and the results most likely depend on extracurricular activities which do not change following secondary school. The review of studies showed that the level of PA in university students in general is satisfactory, but this depends on the cultural differences and educational program in a particular country (Kljajević et al., 2021). However, in a longitudinal study on teenagers who were followed until 24-27 years of age, a decrease in PA level was found in the period of transition from young adults into early adulthood. The greatest decline was found in men who entered college or university (Kwan et al., 2012). This study involved predominantly female students in which the decline is not as significant, and at the beginning of the study program, the effect of decreased PA on VO₂ max was likely not yet visible.

The VO₂ max and the proportion of students placing in below-moderate fitness groups in the years 2022-2023 increased compared to 2007-2009. This might be related to the COVID-19 pandemic, which influenced people's ability to exercise due to the decreased availability of sports facilities and the increased risk of infection. In multiple studies in Europe, America, and Australia, a decrease in

cardiorespiratory endurance until 2010–2012 was found in children and adolescents, which then stabilized or even improved (Fühner et al., 2021). In 2019, the COVID-19 pandemic began, leading to a worldwide decrease in PA (Ng et al., 2022; Park et al., 2022; Wunsch et al., 2022).

The CRF of students with an increased BMI was lower than that of students with a normal BMI. Obesity might lead to decreased respiratory and cardiovascular function, which decreases oxygen uptake and delivery to the muscles (Sood, 2009). Negative associations between BMI and VO_2 max were also found in Pakistani physiotherapy students (Ali et al., 2020). However, the results of other studies, depending on the expression of VO_2 max values, did not prove that people with moderate-to-mild obesity have reduced CRF compared to normal-weight people (O'Donnell et al., 2012). In this study, only one male participant and two female participants had a BMI above 30 kg/m². Both BMI and aerobic capacity can be improved by increasing PA. In a study comparing the effects of regular and irregular training on the aerobic fitness, blood markers, and anthropometric characteristics of obese adolescent males, health benefits were found regardless of training regularity. Body mass, BMI, and waist circumference decreased, and the peak VO_2 increased in both groups, with no significant differences between the groups (Karami et al., 2021). Thus, the negative associations between the BMI and VO_2 max found in this study could be due to low PA together with a higher than necessary caloric intake that causes both an increase in BMI and a decrease in VO_2 max. Further studies might be necessary to clarify this correlation.

This study has several strengths and limitations. **Strengths:** The study features a long-term measurement period, with exercise test results collected over 15 years to observe changes in the VO_2 max of physiotherapy students. The post-pandemic timing of the exercise stress tests, conducted after the return to full-time university studies, offers valuable insights into how the pandemic may have influenced VO_2 max levels. A uniform protocol was applied across all exercise tests, ensuring data comparability throughout the measurement period. Additionally, the inclusion of physiotherapy students is significant, as their lifestyle choices—such as PA levels—can influence their professional credibility and effectiveness as role models for promoting healthy behaviors. Studying this group provides insights into whether those expected to inspire healthy living practices also embody such behaviors themselves, with implications for their future professional roles and their potential impact on public health.

Limitations

A key limitation is the indirect determination of VO_2 max using heart rate (HR) data during submaximal exercise. However, indirect VO_2 max tests are increasingly favored for fitness assessments due to their practicality—they do not require participants to exercise to exhaustion (minimizing health risks), nor do they demand costly equipment or highly specialized personnel (ACSM, 2021). Additionally, this was a cross-sectional study, which limits the ability to establish cause–effect relationships between parameters. Future studies should adopt a longitudinal design to better explore causality. Furthermore, assessing PA levels during

the pandemic would have provided more precise insights into changes in PA before and during COVID-19, helping to correlate these changes with VO_2 max variations. The gender imbalance limits the ability to draw direct comparisons between sexes.

Despite the limitations, the data obtained highlight a significant trend that could continue to develop if PA is not given special attention. It is necessary to comprehensively plan PA and help students/young specialists not to forget about their own health during their studies, which will be essential throughout their professional and personal lives. This study provides crucial foundational data for future research investigating the relationship between cardiorespiratory fitness, clinical skills, and patient satisfaction among physiotherapy students.

Conclusion

This study provides valuable insights into the trends of VO_2 max among physiotherapy students, highlighting the importance of CRF as a key health indicator. It emphasizes the need for healthcare students, particularly younger individuals, to prioritize their own health, not only for personal well-being but also as role models for society. Given the association between CRF and combating sedentary lifestyles, the study underscores the importance of strategic planning to maintain fitness levels. To improve CRF among future physiotherapists, it is recommended that universities implement targeted interventions to boost PA and overall fitness levels. Further research should focus on longitudinal studies and comparisons with other student populations to deepen understanding of the factors affecting student fitness. Additionally, the findings suggest the need for exploring physiotherapy students' awareness of CRF and how they apply this knowledge in maintaining their health. By addressing the limitations of this research and building on its strengths, more effective strategies can be developed to promote healthier lifestyles among future healthcare professionals.

Supporting Information

S1 Table. The physical characteristics and calculated VO_2 max of the male and female participants. <https://dataverse.rsu.lv/dataset.xhtml?persistentId=doi:10.48510/FK2/7AQABY>.

S2 Table 2. Characteristics of participants in three testing periods. <https://dataverse.rsu.lv/dataset.xhtml?persistentId=doi:10.48510/FK2/7AQABY>.

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References

Alparslan, Z., Özer, Ö., Arslan, E.N., Aktaş, İ.I., Susuz, İ.E., & Özeydin, A.N. (2024). *Relationship between Physical*

- Activity and Self-esteem of High School Students: Cross-sectional Study*. medRxiv, 2024.2001.2003.23300489.
- Klussman, K., Langer, J., & Nichols, A.L. (2021). The relationship between physical activity, health, and well-being: Type of exercise and self-connection as moderators. *European Journal of Health Psychology*, 28(2), 59-70.
- Wong, M.Y. C., Chung, P.-K., & Leung, K.-M. (2021). The Relationship Between Physical Activity and Self-Compassion: a Systematic Review and Meta-analysis. *Mindfulness*, 12(3), 547-563.
- Raghuveer, G., Hartz, J., Lubans, D.R., Takken, T., Wiltz, J.L., Mietus-Snyder, M., Perak, A.M., Baker-Smith, C., Pietris, N., & Edwards, N.M. (2020). Cardiorespiratory Fitness in Youth: An Important Marker of Health: A Scientific Statement From the American Heart Association. *Circulation*, 142(7), e101-e118.
- Harber, M.P., Kaminsky, L.A., Arena, R., Blair, S.N., Franklin, B.A., Myers, J., & Ross, R. (2017). Impact of Cardiorespiratory Fitness on All-Cause and Disease-Specific Mortality: Advances Since 2009 [Review]. *Progress in Cardiovascular Diseases*, 60(1), 11-20. <https://doi.org/10.1016/j.mayocp.2016.10.003>
- Lang, J.J., Prince, S.A., Merucci, K., Cadenas-Sanchez, C., Chaput, J.P., Fraser, B.J., Manyanga, T., McGrath, R., Ortega, F.B., Singh, B., & Tomkinson, G.R. (2024). Cardiorespiratory fitness is a strong and consistent predictor of morbidity and mortality among adults: an overview of meta-analyses representing over 20.9 million observations from 199 unique cohort studies. *Br J Sports Med*, 58(10), 556-566. <https://doi.org/10.1136/bjsports-2023-107849>
- Fernström, M., Fernberg, U., Eliason, G., & Hurtig-Wennlöf, A. (2017). Aerobic fitness is associated with low cardiovascular disease risk: the impact of lifestyle on early risk factors for atherosclerosis in young healthy Swedish individuals - the Lifestyle, Biomarker, and Atherosclerosis study. *Vasc Health Risk Manag*, 13, 91-99.
- Isath, A., Koziol, K.J., Martinez, M.W., Garber, C.E., Martinez, M.N., Emery, M.S., Baggish, A.L., Naidu, S.S., Lavie, C.J., Arena, R., & Krittanawong, C. (2023). Exercise and cardiovascular health: A state-of-the-art review. *Prog Cardiovasc Dis*, 79, 44-52.
- Chaabna, K., Mamtani, R., Abraham, A., Maisonneuve, P., Lowenfels, A.B., & Cheema, S. (2022). Physical Activity and Its Barriers and Facilitators among University Students in Qatar: A Cross-Sectional Study. *Int J Environ Res Public Health*, 19(12).
- Ali, B., Ansari, M.A., Qambrani, M.R., Memon, A.R., Ahmed, I., & Rehman Memon, A.U. (2020). Association of body mass index, cardiorespiratory fitness, and their correlates among female physiotherapy students in Nawabshah. *J Pak Med Assoc*, 70(1), 80-85.
- Sovová, M., Sovová, E., Asswad, A.G., & Sova, M. (2020). Is population's cardiorespiratory fitness really declining? *Cent Eur J Public Health*, 28(2), 120-123.
- Mandsager, K., Harb, S., Cremer, P., Phelan, D., Nissen, S.E., & Jaber, W. (2018). Association of Cardiorespiratory Fitness With Long-term Mortality Among Adults Undergoing Exercise Treadmill Testing. *JAMA Netw Open*, 1(6), e183605. <https://doi.org/10.1001/jamanetworkopen.2018.3605>
- Ali, H.I., Attlee, A., Alhebshi, S., Elmi, F., Al Dhaheri, A.S., Stojanovska, L., El Mesmoudi, N., & Platat, C. (2021). Feasibility Study of a Newly Developed Technology-Mediated Lifestyle Intervention for Overweight and Obese Young Adults. *Nutrients*, 13(8).
- García-Suárez, P.C., Canton-Martínez, E., Rentería, I., Moura Antunes, B., Machado-Parra, J.P., Aburto-Corona, J.A., Gómez-Miranda, L.M., & Jiménez-Maldonado, A. (2022). Remote, Whole-Body Interval Training Improves Muscular Endurance and Cardiac Autonomic Control in Young Adults. *International Journal of Environmental Research and Public Health*, 19(21).
- Al-Khlaifat, L., Al-Yahya, E., Qutishat, D., Okasheh, R., Mohammad, M.T., & Muhaidat, J. (2024). Health and skill-related physical fitness of physiotherapy students: An observational study [Article]. *Journal of Human Sport and Exercise*, 19(2), 461-472.
- Tišlar, M.H., Starc, G., & Kukec, A. (2022). Work-related musculoskeletal disorders among physiotherapists and physiotherapy students in Croatia and their association with physical fitness [Article]. *Zdravstveno Varstvo*, 61(3), 171-180.
- Maldonado-Alicea, O.R., Arbelo-Figueroa, E.G., Vélez-Jiménez, L.M., & Miranda-Belandria, M.A. (2024). Experience of Physiotherapy students in a project to promote Physical Activity during their academic training: a phenomenological study [Article]. *Cuestiones de Fisioterapia*, 53(1).
- Lewandowski, A., Sarwińska, J., Siedlaczek, M., & Piekorz, Z. (2020). 10-Year Longitudinal Changes in Fitness Parameters in Physiotherapy Students. *Biomed Res Int*, 2020, 7154797.
- Veseta, U., Rumaka, M., Arnis, V., Vinberga, I., Abele, A., Spundina, L., & Zvejniece, S. (2023). *Aerobic capacity of students of RSU Physiotherapy study programme (2007-2023) (Version V1) [experimental data]*. Rīga Stradiņš University Institutional Repository Dataverse.
- Liepiņa L., Arnis V., Vinberga I., & M., K. (2013). Precision of Test of Indirect Aerobic Working Capacity in People of Different Ages, Sexes and Physical Fitness. *Rīgas Stradiņa universitātes 2013. gada Medicīnas nozares zinātniskie raksti*, 363-373. https://rsu-staging.elsevierpure.com/ws/files/34585301/2013_medicinas_nozares_raksti_rev.pdf
- Shvartz, E., & Reibold, R.C. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: a review. *Aviat Space Environ Med*, 61(1), 3-11.
- Rozenštoka, S., & Ērglis, A. (2020). Exercise, Chronotropic and Inotropic Capacity in Athletes with Different Training Programmes. Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences., 74(1), 18-24.
- Grigaliūnienė, A., Ramonas, A., Celutkienė, J., Sileikienė, V., Rudys, A., Juocevičius, A., & Laucevičius, A. (2013). Cardiorespiratory parameters of exercise capacity in a healthy Lithuanian population: the pilot study. *Hellenic J Cardiol*, 54(2), 107-118.
- Rapp, D., Scharhag, J., Wagenpfeil, S., & Scholl, J. (2018). Reference values for peak oxygen uptake: cross-sectional analysis of cycle ergometry-based cardiopulmonary exercise tests of 10 090 adult German volunteers from the Prevention First Registry. *BMJ Open*, 8(3), e018697. <https://doi.org/10.1136/bmjopen-2018-023866>
- Kaminsky, L.A., Arena, R., Myers, J., Peterman, J.E., Bonikowske, A.R., Harber, M.P., Medina Inojosa, J.R.,

- Lavie, C.J., & Squires, R.W. (2022). Updated Reference Standards for Cardiorespiratory Fitness Measured with Cardiopulmonary Exercise Testing: Data from the Fitness Registry and the Importance of Exercise National Database (FRIEND). *Mayo Clinic Proceedings*, 97(2), 285-293. <https://doi.org/10.1016/j.mayocp.2021.08.020>
- Kaminsky, L.A., Imboden, M.T., Arena, R., & Myers, J. (2017). Reference Standards for Cardiorespiratory Fitness Measured With Cardiopulmonary Exercise Testing Using Cycle Ergometry: Data From the Fitness Registry and the Importance of Exercise National Database (FRIEND) Registry. *Mayo Clinic Proceedings*, 92(2), 228-233. <https://doi.org/10.1016/j.mayocp.2016.10.003>
- Triantafyllidi, H., Benas, D., Birba, D., Triviliou, P., & Iliodromitis, E. (2021). Reference values for aerobic capacity estimated by cardiopulmonary exercise test on a cycle ergometer in a healthy Greek population. *Hellenic J Cardiol*, 62(2), 121-126.
- van der Steeg, G.E., & Takken, T. (2021). Reference values for maximum oxygen uptake relative to body mass in Dutch/Flemish subjects aged 6-65 years: the LowLands Fitness Registry. *Eur J Appl Physiol*, 121(4), 1189-1196. <https://doi.org/10.1007/s00421-021-04596-6>
- Loe, H., Rognmo, Ø., Saltin, B., & Wisløff, U. (2013). Aerobic capacity reference data in 3816 healthy men and women 20-90 years. *PLoS One*, 8(5), e64319. <https://doi.org/10.1371/journal.pone.0064319>
- Bahls, M., Ittermann, T., Ewert, R., Stubbe, B., Völzke, H., Friedrich, N., Felix, S.B., & Dörr, M. (2021). Physical activity and cardiorespiratory fitness-A ten-year follow-up. *Scand J Med Sci Sports*, 31(3), 742-751. <https://doi.org/10.1111/sms.13882>
- Wagner, J., Knaier, R., Infanger, D., Königstein, K., Klenk, C., Carrard, J., Hanssen, H., Hinrichs, T., Seals, D., & Schmidt-Trucksäss, A. (2021). Novel CPET Reference Values in Healthy Adults: Associations with Physical Activity. *Med Sci Sports Exerc*, 53(1), 26-37. <https://doi.org/10.1249/MSS.0000000000002454>
- Taylor, J.L., Bonikowske, A.R., & Olson, T.P. (2021). Optimizing Outcomes in Cardiac Rehabilitation: The Importance of Exercise Intensity. *Front Cardiovasc Med*, 8, 734278. <https://doi.org/10.3389/fcvm.2021.734278>
- Schutte, N.M., Nederend, I., Hudziak, J.J., Bartels, M., & de Geus, E.J. (2016). Twin-sibling study and meta-analysis on the heritability of maximal oxygen consumption. *Physiol Genomics*, 48(3), 210-219. <https://doi.org/10.1152/physiolgenomics.00117.2015>
- Williams, C.J., Williams, M.G., Eynon, N., Ashton, K.J., Little, J.P., Wisloff, U., & Coombes, J.S. (2017). Genes to predict VO(2max) trainability: a systematic review. *BMC Genomics*, 18(Suppl 8), 831. <https://doi.org/10.1186/s12864-017-4192-6>
- Tangen, E.M., Gjestvang, C., Stensrud, T., & Haakstad, L.A. H. (2022). Is there an association between total physical activity level and VO(2max) among fitness club members? A cross-sectional study. *BMC Sports Sci Med Rehabil*, 14(1), 109.
- Lu, Y., Wiltshire, H.D., Baker, J.S., & Wang, Q. (2021). The Effects of Running Compared with Functional High-Intensity Interval Training on Body Composition and Aerobic Fitness in Female University Students. *Int J Environ Res Public Health*, 18(21).
- Kljajević, V., Stanković, M., Đorđević, D., Trkulja-Petković, D., Jovanović, R., Plazibat, K., Oršolić, M., Čurić, M., & Sporiš, G. (2021). Physical Activity and Physical Fitness among University Students-A Systematic Review. *Int J Environ Res Public Health*, 19(1).
- Kwan, M.Y., Cairney, J., Faulkner, G.E., & Pullenayegum, E.E. (2012). Physical activity and other health-risk behaviors during the transition into early adulthood: a longitudinal cohort study. *Am J Prev Med*, 42(1), 14-20. <https://doi.org/10.1016/j.amepre.2011.08.026>
- Fühner, T., Kliegl, R., Arntz, F., Kriemler, S., & Granacher, U. (2021). An Update on Secular Trends in Physical Fitness of Children and Adolescents from 1972 to 2015: A Systematic Review. *Sports Med*, 51(2), 303-320. <https://doi.org/10.1007/s40279-020-01373-x>
- Ng, T.K. Y., Kwok, C.K. C., Ngan, G.Y. K., Wong, H.K. H., Zoubi, F.A., Tomkins-Lane, C.C., Yau, S.K., Samartzis, D., Pinto, S.M., Fu, S.N., Li, H., & Wong, A.Y. L. (2022). Differential Effects of the COVID-19 Pandemic on Physical Activity Involvements and Exercise Habits in People With and Without Chronic Diseases: A Systematic Review and Meta-analysis. *Arch Phys Med Rehabil*, 103(7), 1448-1465.e1446.
- Park, A.H., Zhong, S., Yang, H., Jeong, J., & Lee, C. (2022). Impact of COVID-19 on physical activity: A rapid review. *J Glob Health*, 12, 05003. <https://doi.org/10.7189/jogh.12.05003>
- Wunsch, K., Kienberger, K., & Niessner, C. (2022). Changes in Physical Activity Patterns Due to the Covid-19 Pandemic: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*, 19(4). <https://doi.org/10.3390/ijerph19042250>
- Sood, A. (2009). Altered resting and exercise respiratory physiology in obesity. *Clin Chest Med*, 30(3), 445-454, VII. <https://doi.org/10.1016/j.ccm.2009.05.003>
- O'Donnell, D.E., O'Donnell, C.D., Webb, K.A., & Guenette, J.A. (2012). Respiratory Consequences of Mild-to-Moderate Obesity: Impact on Exercise Performance in Health and in Chronic Obstructive Pulmonary Disease. *Pulm Med*, 2012, 818925. <https://doi.org/10.1155/2012/818925>
- Karami, H., Dehnou, V.V., Nazari, A., & Gahreman, D. (2021). Regular training has a greater effect on aerobic capacity, fasting blood glucose and blood lipids in obese adolescent males compared to irregular training. *J Exerc Sci Fit*, 19(2), 98-103.
- ACSM, A.C. o.S. M. (2021). *ACSM's Guidelines for Exercise Testing and Prescription 11th edition*. Wolters Kluwer Health.

Оцінка тенденцій кардіореспіраторної підготовленості серед студентів-фізіотерапевтів: Поперечне дослідження тривалістю 15 років (2007–2023)

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 10 с., 3 табл., 6 рис., 46 джерел.

Історія питання. Кардіореспіраторна підготовленість (КРП) є ключовим показником здоров'я, зокрема для студентів-фізіотерапевтів, які повинні дотримуватися моделі здорового способу життя.

Мета дослідження. Метою дослідження було проаналізувати тенденції розвитку КРП серед студентів-фізіотерапевтів у період з 2007 по 2023 рік та оцінити відмінності в показниках максимального споживання кисню ($\text{VO}_2 \text{ max}$) залежно від статі та індексу маси тіла (ІМТ).

Матеріали та методи. Проведено порівняльний аналіз вторинних даних за 2007–2009 та 2010–2012 роки з первинними даними, зібраними у 2022–2023 роках. Вимірювання КРП проведено за допомогою субмаксимального тесту на велоергометрі Monark Ergonomic 839E у 242 студентів (віком 18–25 років). Статистичні методи аналізу включали t-критерій, дисперсійний аналіз, непараметричні критерії ($p < 0.05$). З метою проведення міжгрупових порівнянь застосовано критерій Краскала-Волліса, а для оцінки тенденцій протягом певного періоду часу — кореляцію Спірмена.

Результати. У понад половини учасників чоловічої статі (52%) та жіночої статі (63%) рівні КРП були нижчими за референтні значення. У студенток спостерігалось значне зниження показника $\text{VO}_2 \text{ max}$ у 2022–2023 роках порівняно з 2007–2009 роками (середня різниця = 1.78 мл/хв/кг, $p < 0.05$), тоді як у представників чоловічої статі такої тенденції не виявлено. Студенти з $\text{IMT} > 25 \text{ kg/m}^2$ мали значно нижчий показник $\text{VO}_2 \text{ max}$, ніж особи з $\text{IMT} \leq 25 \text{ kg/m}^2$ ($p < 0.05$).

Висновки. Отримані результати підкреслюють необхідність впровадження цільових програм з фізичної підготовки для студенток та осіб з підвищеним ІМТ. Подальші дослідження повинні бути спрямовані на вивчення факторів способу життя та інтервенційних стратегій з метою поліпшення КРП у студентів. Представлене дослідження надає фундаментальні дані для проведення подальших досліджень щодо взаємозв'язку між КРП, клінічними навичками та задоволеністю пацієнтів серед студентів-фізіотерапевтів.

Ключові слова: кардіореспіраторна підготовленість, максимальне споживання кисню, студенти-фізіотерапевти, субмаксимальний велоергометричний тест.

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Yogic Practices and Their Influence on Hematological Responses: A Physiological Perspective

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Abstract

Background. Yoga, an ancient discipline integrating physical postures, breath control, and meditation, has been linked to various physiological benefits. Investigating its influence on hematological parameters is essential, as these are key indicators of health and performance.

Objectives. This study aimed to assess the effects of yogic practices on hematological parameters —specifically hemoglobin (Hb), red blood cell (RBC) count, packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) — among college students.

Materials and Methods. A total of 20 male college students aged 17 to 22 years participated in the study. They were randomly assigned to either an experimental group (n = 10), which underwent the yogic intervention, or a control group (n = 10), which did not participate in any structured physical activity. The experimental group (EG) engaged in daily 60-minute sessions, six days per week, comprising Surya Namaskar, asanas, pranayama, and relaxation techniques. Hematological parameters were measured at baseline and after 12 weeks using the Tulip Coralyzer Smart 200, an automated hematology analyser. Statistical analysis was performed using paired and independent t-tests, with significance set at $p < 0.05$.

Results. Post-intervention analysis revealed a statistically significant increase in Hb levels within the EG ($p = .015$), indicating enhanced oxygen-carrying capacity. No significant changes were observed in RBC count, PCV, MCV, MCH, and MCHC in either group.

Conclusions. Significantly improved hemoglobin levels were determined in the EG, indicating potential benefits for oxygen transport and aerobic capacity. The findings demonstrate that enhancing other hematological parameters suggests selective hematological adaptations to yogic practices.

Keywords: hematologic tests, hemoglobins, erythrocyte count, yoga, intervention studies.

Introduction

The role of yogic practices in enhancing human health and well-being has been extensively documented across traditional and contemporary scientific literature (Woodyard,

2011; Chen, 2024). Yoga, a discipline that integrates physical postures (asanas), breath regulation (pranayama), and relaxation techniques, has been recognized for its capacity to improve autonomic function (Shobana et al., 2022), reduce oxidative stress (Patil et al., 2014), and enhance systemic homeostasis (Pratiti, 2022). While a substantial body of research has explored the physiological benefits of yogic practices, its specific influence on hematological parameters remains insufficiently examined. The Complete Blood Count (CBC) is a vital hematological test used to assess overall

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health, detect deficiencies like anemia, and monitor recovery (Chanda et al., 2025). Hematological variables, including Hb, RBC, PCV, MCV, MCH, and MCHC, are critical indicators of oxygen transport efficiency (Witeska et al., 2022), erythropoiesis (Valent et al., 2018), and overall hematopoietic function (Witeska et al., 2023). These variables are integral to sustaining optimal physiological performance (Brocherie et al., 2015), particularly among populations exposed to stress and sedentary lifestyles, such as students (Alhmoud et al., 2021). Imbalances in hematological parameters, including hemoglobin (Hb), red blood cell (RBC) count, packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), may signify underlying physiological or pathological conditions. A reduction in these indices is often associated with anemia (Johnson-Wimbley & Graham, 2011), leading to impaired oxygen transport and diminished physiological efficiency (Haas & Brownlie, 2001), whereas elevated levels may indicate polycythemia (Lupak et al., 2020), dehydration (Chidozie et al., 2020). Alterations in MCV, MCH, and MCHC reflect morphological variations in erythrocytes (Caimi et al. 2024), commonly linked to nutritional deficiencies or hematological disorders (Deepthi et al., 2018; Zhang et al., 2022). Given their critical role in oxygen delivery and metabolic function, maintaining hematological equilibrium is essential for overall health and optimal physiological performance.

Hematopoiesis, the process of blood cell formation (Jagannathan-Bogdan & Zon, 2013), is intricately regulated by neuroendocrine mechanisms (Maestroni, 1998), physical activity (Vanhie & De Lisio, 2022), and overall systemic health (Carpenter & Maryanovich, 2024). Hemoglobin, a crucial oxygen-carrying protein within erythrocytes (Longeville & Stingaciu, 2017; Mairbäurl & Weber, 2012), plays a fundamental role in sustaining aerobic metabolism (Storz, 2016), and cellular respiration (Sera, 2023). Maintaining adequate hemoglobin levels is crucial for ensuring optimal oxygen transport to tissues and organs, which is fundamental for cellular energy production and overall physiological homeostasis (Billett, 1990; Pittman, 2011). Red blood cells (RBCs) are integral to oxygen transport and the preservation of physiological homeostasis (Kuhn et al., 2017). An adequate RBC count is essential for optimizing oxygen delivery to tissues and muscles, which is crucial for sustaining overall physiological function (Mairbäurl, 2013). RBC count and PCV serve as indicators of blood viscosity and oxygen-carrying capacity (Nader et al., 2019; Roberson & Bennett-Guerrero, 2012), while MCV, MCH, and MCHC provide insights into erythrocyte morphology and functional integrity (Erhabor et al., 2021). Disruptions in these parameters can have profound implications for health, predisposing individuals to fatigue, impaired cognitive function, and diminished immune competence. Given the increasing prevalence of lifestyle-induced hematological imbalances (Agarwal, 2022), identifying holistic, non-invasive interventions such as yogic practice is of paramount scientific and public health significance.

The yogic practice has been postulated to induce favorable hematological adaptations through multiple physiological pathways. The practice of pranayama enhances pulmonary efficiency (Mooventhan & Khode, 2014), optimizes oxygenation (Pandey et al., 2019), and regulates autonomic

function (Bhimani et al., 2011), all of which contribute to the improved erythropoietic activity. Additionally, yoga-mediated modulation of endocrine function, particularly in relation to cortisol and erythropoietin levels, plays a pivotal role in maintaining hematological stability (Arora & Bhattacharjee, 2008; Kelly et al., 2000). The cumulative effects of these mechanisms suggest that yogic practices serve as a viable intervention for improving hematological health, yet empirical validation remains limited.

The scientific rationale for exploring yoga's effects on hematological parameters is grounded in its demonstrated impact on physiological homeostasis, autonomic balance, and metabolic efficiency. Prior studies indicate that yogic practices positively influence cardiovascular and pulmonary function, leading to improved tissue oxygenation and metabolic efficiency (Loganathan et al., 2019; Panjeta et al., 2019; Chaya & Nagendra, 2008). These benefits are closely linked to hematopoietic activity, given that enhanced oxygen transport mechanisms stimulate erythropoiesis and improve overall hematological stability.

Furthermore, stress-related hormonal imbalances are known to affect hematological variables (Mischler et al., 2005). Chronic stress, which is prevalent among college students, elevates cortisol levels (Cay et al., 2018), leading to hematopoietic suppression (Gilboa-Geffen et al., 2012), and dysregulated erythrocyte production (Obeagu et al., 2024). Yogic practices reduce cortisol levels (Thirthalli et al., 2013), thereby mitigating stress-induced hematological imbalances. Additionally, yogic practice's impact on nitric oxide bioavailability and endothelial function contributes to improved microcirculation (Singh & Shah, 2024), facilitating more efficient oxygen transport and erythropoiesis.

Existing literature on the relationship between exercise and hematological variables has primarily focused on endurance training (Prommer et al., 2018), resistance exercises (Skouras et al., 2023), and high-intensity interval training (HIIT) (Belviranli et al., 2017). While these modalities demonstrate significant hematopoietic adaptations, they may not be suitable for all populations due to their intensity and potential physical constraints. Yogic practices, as a low-impact, accessible, and holistic practice, offer a viable alternative that warrants systematic exploration in the context of hematological health.

The need for this study is further reinforced by the gap in the literature regarding the direct impact of yogic practices on specific hematological markers. Most studies investigating yogic practice's health benefits focus on its effects on stress reduction, cardiovascular health, and metabolic regulation, while hematological responses remain an under-researched domain. Given that Hb, RBC, PCV, MCV, MCH, and MCHC are crucial indicators of overall physiological resilience, a deeper understanding of yogic practice's influence on these parameters contributes to more comprehensive health recommendations.

This study is designed to generate robust scientific insights into the impact of yogic practices on key hematological parameters, thereby elucidating the physiological underpinnings of yogic practice's influence on hematopoiesis. By addressing the existing research void, it aims to provide a foundation for the integration of yogic practices into evidence-based health interventions. Given the accessibility, cost-effectiveness, and holistic

benefits of yogic practices, its potential role in optimizing hematological health warrants further scholarly inquiry and clinical validation. The findings of this study hold substantial implications for educational institutions, healthcare practitioners, and policymakers aiming to enhance holistic well-being among young adults and the broader population. Furthermore, this research contributes meaningfully to public health and preventive healthcare by addressing anemia and hematological deficiencies, which remain prevalent global health concerns (Chaparro & Suchdev, 2019). The identification of non-invasive, lifestyle-based interventions, such as yogic practices, offers a viable alternative or complementary approach to conventional therapeutic strategies, thereby expanding the scope of evidence-based wellness initiatives.

Materials and Methods

A comprehensive literature search was systematically conducted across multiple reputable databases, including MEDLINE, EMBASE, Scopus, Science Direct, the Directory of Open Access Journals (DOAJ), PubMed, and Google Scholar. The search utilized a well-defined set of keywords, including “Yogic practices,” “Hemoglobin,” “Red Blood Cells,” “PCV,” “MCV,” “MCH,” and “MCHC,” combined with Boolean operators “AND” and “OR” to optimize both the scope and relevance of the results. The search was confined to studies published in English, with a focused intent to identify research exploring the impact of yogic practices on various hematological parameters. To ensure methodological rigor and the inclusion of high-quality evidence, the search criteria specifically prioritized peer-reviewed articles, clinical trials, and observational studies. This approach was designed to provide a robust and comprehensive evidence base for the ensuing literature review, contributing to a thorough understanding of the potential effects of yogic practices on hematological outcomes.

Study Participants

The present study was conducted at Shyampahari Government Primary Teacher Training Institute, Birbhum, West Bengal, India, and included 20 male participants aged 17 to 22 years. All participants had normal vision and were randomly assigned to either the experimental group (EG) or control group (CG), with each group comprising 10 individuals. The inclusion criteria required participants to be free from smoking and alcohol consumption, have no history of acute or chronic medical conditions, and not be under any form of medication. Furthermore, individuals with any known hematological disorders or conditions that could potentially affect hematological variables were excluded to ensure the validity of the findings. A detailed summary of the participants’ demographic and health characteristics is presented in Table 1. Before enrolment, each participant underwent a comprehensive medical evaluation conducted by a qualified physician to confirm eligibility and overall health status. Written informed consent was obtained from all participants following a thorough explanation of the study’s objectives, methodology, and potential risks. The study was conducted in strict accordance with established guidelines, prioritizing the safety, well-being, and rights of

all participants. This study was approved by the Department of Physical Education and Sports Sciences, University of Delhi, India following clearance from the Department Research Committee and the Board of Research Studies (Ref. no. SF-1/Ph.D/2023/1481, dated 01/02/2023) Informed consent was obtained from all participants after a detailed briefing on the study’s objectives, procedures, and their rights, including voluntary participation and the option to withdraw at any stage.”

Table 1. Baseline profile of participants (Mean $\pm$ SD)

Parameters	Overall Group (N=20)	EG (n=10)	CG (n=10)
Age (years)	20.00 $\pm$ 0.97	19.70 $\pm$ 0.67	20.30 $\pm$ 1.16
Height (cm)	169.95 $\pm$ 6.82	170.10 $\pm$ 5.24	169.80 $\pm$ 8.40
Weight (kg)	63.85 $\pm$ 10.94	58.30 $\pm$ 5.85	69.40 $\pm$ 12.24
BMI (kg/m ²)	22.11 $\pm$ 3.42	20.21 $\pm$ 2.45	24.00 $\pm$ 3.26
WHR	0.86 $\pm$.11	0.87 $\pm$ 0.14	0.85 $\pm$ 0.06
Systolic Blood Pressure (mmHg)	122.85 $\pm$ 3.48	122.00 $\pm$ 2.67	123.70 $\pm$ 4.11
Diastolic Blood Pressure (mmHg)	80.50 $\pm$ 2.93	81.70 $\pm$ 2.63	79.30 $\pm$ 2.83
Pulse Rate	74.95 $\pm$ 3.97	74.60 $\pm$ 4.00	75.30 $\pm$ 4.10

Randomisation

A computerised randomisation procedure was implemented using Random Allocation Software (version 1.0.0; M. Saghaei, MD, Department of Anesthesia, Isfahan University of Medical Sciences, Isfahan, Iran) to assign 20 eligible participants to either the experimental group (n = 10) or the control group (n = 10). Allocation concealment was ensured through the use of sequentially numbered, opaque, sealed envelopes (SNOSE), thereby minimising selection bias.

Blinding/Masking

Owing to the nature of the yogic intervention, blinding of participants was not practicable. Nevertheless, to uphold methodological rigor and reduce the risk of bias, a single-blind design was employed. The principal investigator remained blinded to group assignments throughout the duration of the study. An independent researcher, not involved in the randomisation procedure or data analysis, was responsible for delivering the intervention and performing all outcome evaluations.

Study Organization

This study adopted a rigorous experimental research design employing a two-group pre-test and post-test framework to examine the effects of a twelve-week yogic intervention on selected hematological parameters. Participants were systematically chosen through probability sampling from the student population to enhance methodological rigor and representativeness. The intervention protocol adhered to standardized yogic practices, ensuring consistency, reliability, and reproducibility. The primary objective was to

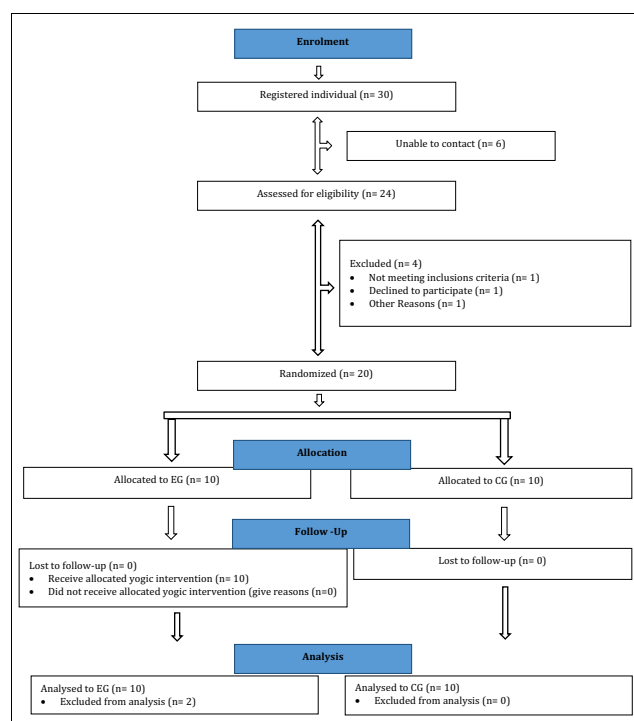


Fig. 1. Participations selection consort flow chart

generate robust empirical evidence on the impact of yogic practices on hematological variables, thereby contributing to the advancement of scholarly research on their potential therapeutic efficacy.

Experimental Protocol

The EG was subjected to a meticulously structured yogic intervention that encompassed suryanamaskar, a systematically sequenced regimen of asanas, pranayama techniques, and relaxation practices. These sessions were conducted six days a week, from Monday to Saturday, between 8:00 and 9:00 AM at the Shyampahari Government Primary Teacher Training Institute ground in Birbhum, West Bengal, India. To ensure methodological rigor and strict adherence to the established protocol, the investigator provided continuous supervision throughout the intervention period. In contrast, the CG maintained their habitual daily activities without any external modifications or structured interventions. To systematically assess the efficacy of the intervention, comprehensive pre- and post-assessments were conducted for all participants. These evaluations, administered at both the commencement and conclusion of the twelve weeks, were designed to objectively quantify changes in the selected hematological variables. A detailed schematic representation of the intervention protocol was provided in Figure 2, illustrating the precise sequencing, duration, and constituent components of the yogic practices integrated into the study.

Outcome Measures.

This study aimed to evaluate the effects of a 12-week yogic intervention on hematological parameters, including Hb, RBC, PCV, MCV, MCH, and MCHC. A pre-test and

post-test research design was employed to systematically assess changes in these parameters. Blood samples were collected from the antecubital vein using sterile techniques, ensuring strict adherence to aseptic protocols. Following collection, the samples were promptly transported under controlled conditions to a certified pathology laboratory for analysis. Hematological assessments were performed using the Tulip Coralyzer Smart 200, a high-precision automated analyser recognized for its reliability in clinical diagnostics. To enhance the validity and reproducibility of the findings, the study adhered to rigorous laboratory protocols and implemented comprehensive quality control measures. Regular calibration of equipment, strict compliance with standardized procedural guidelines, and the incorporation of both internal and external quality assurance mechanisms minimized measurement errors. Additionally, all assessments were conducted under continuous supervision by qualified laboratory personnel to ensure methodological rigor, maintain participant safety, and uphold ethical and procedural standards. These methodological safeguards collectively strengthened the accuracy, consistency, and scientific credibility of the results.

Statistical Analysis

The normality of the data distribution was assessed using the Shapiro-Wilk test (Shapiro & Wilk, 1965), while Levene's test was employed to evaluate the homogeneity of variances. Descriptive statistics were utilized to summarize the data. Inferential analysis was conducted using paired t-tests to examine within-group differences and independent t-tests to compare differences between groups. All statistical analyses were performed using IBM SPSS Statistics (version 25), with the significance level set at 0.05. Assumptions underlying the statistical tests were verified to ensure the robustness of the analysis.

Results

Table 2 presented the Shapiro-Wilk test results for hematological parameters in the EG and the CG. The test was conducted to evaluate the normality of data distribution for each parameter within both groups. A p-value greater than 0.05 indicated that the data were normally distributed, whereas a p-value less than 0.05 signified a significant deviation from normality, suggesting the need for non-parametric statistical approaches.

Table 3 presented the results of Levene's test for hematological parameters in the EG and the CG. The test was conducted to assess the homogeneity of variance for each parameter between the groups. All results were statistically significant ($p > 0.05$), confirming that the assumption of equal variances was met across all parameters. Therefore, parametric statistical analyses were deemed appropriate for further comparisons.

The findings of the present study, as detailed in Table 4, indicated differences in hematological parameters between the EG and CG following the intervention. Among the hematological variables, hemoglobin (Hb) levels in the EG increased by 4.28%, from a mean of 14.97 mg/dL (SD = 1.03) in the pre-test to 15.61 mg/dL (SD = 0.99) in the post-test. In contrast, the CG exhibited a reduction of 2.76%, with Hb decreasing from a mean of 15.24 mg/dL (SD = 0.77) to 14.82 mg/dL

Weeks	Surya Namaskar (Dynamic Warm-up)	Asanas Practiced (In Sequential Order)	Asana Parameters (Holding Time × Repetitions × Rest)	Total Asana Duration	Pranayama (Anulom Vilom and Bhastrika)			Relaxation (Integrative Recovery)
1–3	1 Round (5 min)	Ardha-Halasana, Sarvangasana, Matsyasana, Halasana, Chakrasana, Naukasana, Bhujangasana, Shalabhasana, Naukasana, Dhanurasana, Ardha Matsyendrasana, Paschimottanasana, Vajrasana, Yogamudra, Ushtrasana, Padmasana, Utkatasana, Trikonasana, Vrikshasana, Tadasana, Shavasana	15 sec × 2 × 5 sec (60 sec rest between sets)	30 (min)	Breathing Ratio (1:1)			Shavasana (5 min)
					I	E	Cycle × Repetition × Rest between Repetitions	
4–6	2 Rounds (5 min)	Same as above	20 sec × 2 × 5 sec (50 sec rest between sets)	30 (min)	Breathing Ratio (1:1:1)			Shavasana (5 min)
					I	H	E	
7–9	3 Rounds (5 min)	Same as above	25 sec × 2 × 3 sec (40 sec rest between sets)	30 (min)	Breathing Ratio (1:2:2)			Shavasana (5 min)
					I	H	E	
10–12	4 Rounds (5 min)	Same as above	30 sec × 2 × 3 sec (30 sec rest between sets)	30 (min)	Breathing Ratio (1:4:2)			Shavasana (5 min)
					I	H	E	

Note: Inhale (I), Hold (H), Exhale (E)

Fig. 2. Yogic intervention module

dL (SD = 0.90). Similarly, red blood cell (RBC) count in the EG increased by 1.08%, from a pre-test mean of 5.57 million/cumm (SD = 0.57) to 5.63 million/cumm (SD = 0.33), while the CG showed a decline of 2.31%, from a mean of 5.20 million/cumm (SD = 0.52) to 5.08 million/cumm (SD = 0.42). Packed cell volume (PCV) in the EG increased by 2.10% from a mean of 45.63% (SD = 3.02) to 46.59% (SD = 5.61). Conversely, the CG experienced a reduction of 4.56%, with PCV decreasing from a mean of 46.05% (SD = 2.09) to 43.95% (SD = 3.73). Mean corpuscular volume (MCV) showed an increase of 5.38% in the EG, from 82.51 fl (SD = 10.15) to 86.95 fl (SD = 9.17), whereas the CG exhibited a decline of 2.60%, from a mean of 88.91 fl (SD = 5.49) to 86.60 fl (SD = 4.10). Further, mean corpuscular hemoglobin (MCH) in the EG increased by 2.51%, from 27.13 pg (SD = 3.22) to 27.81 pg (SD = 2.19), while the CG showed a negligible decline of

0.61%, from 29.42 pg (SD = 1.90) to 29.24 pg (SD = 1.19). The mean corpuscular hemoglobin concentration (MCHC) in the EG, however, exhibited a slight decrease of 2.40%, from 32.90 gm/dL (SD = 0.43) to 32.11 gm/dL (SD = 1.84), whereas the CG showed an increase of 2.21%, from 33.09 gm/dL (SD = 0.61) to 33.82 gm/dL (SD = 1.83).

The observed changes in hematological parameters within the EG suggested that the intervention enhanced oxygen-carrying capacity, hematopoiesis, and overall circulatory efficiency. The decline in hematological values within the CG may have been attributed to the absence of an intervention, emphasizing the impact of the experimental regimen. These findings aligned with previous studies highlighting the role of structured physical activity, particularly yogic practices, in optimizing hematological variables and overall physiological health.

Table 2. Shapiro-Wilk Test Results for Hematological Parameters

Variables	Group	Test	df	Shapiro-wilk (p-value)	Normality assumption
Hb	EG	Pre-test	10	.299	Normal
		Post-test	10	.827	Normal
	CG	Pre-test	10	.537	Normal
		Post-test	10	.982	Normal
RBC	EG	Pre-test	10	.861	Normal
		Post-test	10	.694	Normal
	CG	Pre-test	10	.057	Normal
		Post-test	10	.824	Normal
PCV	EG	Pre-test	10	.862	Normal
		Post-test	10	.494	Normal
	CG	Pre-test	10	.463	Normal
		Post-test	10	.748	Normal
MCV	EG	Pre-test	10	.903	Normal
		Post-test	10	.195	Normal
	CG	Pre-test	10	.692	Normal
		Post-test	10	.330	Normal
MCH	EG	Pre-test	10	.777	Normal
		Post-test	10	.058	Normal
	CG	Pre-test	10	.706	Normal
		Post-test	10	.318	Normal
MCHC	EG	Pre-test	10	.876	Normal
		Post-test	10	.068	Normal
	CG	Pre-test	10	.939	Normal
		Post-test	10	.059	Normal

Table 3. Levene's Test Results for Hematological Parameters

Variables	Test	Group	df	Levene's Test (p-value)	Equality of Variances
Hb	Pre-test	EG	18	.385	Equal
		CG	18	.656	Equal
	Post-test	EG	18	.656	Equal
		CG	18	.656	Equal
RBC	Pre-test	EG	18	.483	Equal
		CG	18	.488	Equal
	Post-test	EG	18	.488	Equal
		CG	18	.488	Equal
PCV	Pre-test	EG	18	.355	Equal
		CG	18	.171	Equal
	Post-test	EG	18	.171	Equal
		CG	18	.171	Equal
MCV	Pre-test	EG	18	.089	Equal
		CG	18	.069	Equal
	Post-test	EG	18	.069	Equal
		CG	18	.069	Equal
MCH	Pre-test	EG	18	.124	Equal
		CG	18	.074	Equal
	Post-test	EG	18	.074	Equal
		CG	18	.074	Equal
MCHC	Pre-test	EG	18	.359	Equal
		CG	18	.701	Equal
	Post-test	EG	18	.701	Equal
		CG	18	.701	Equal

Table 5 presented the paired t-test results, highlighting improvements in hematological variables within the EG following the intervention. The EG demonstrated a statistically significant enhancement in Hb levels, $t_{(9)} = 3.02$, $p = .015$, indicating a substantial increase in oxygen-carrying capacity, which may have contributed to improved aerobic performance and overall physiological function. Conversely, the CG did not exhibit significant changes in Hb levels, $t_{(9)} = 1.99$, $p = .078$, suggesting that the intervention played a crucial role in the observed improvement in the EG. Other hematological variables, including RBC count, PCV, MCV, MCH, and MCHC, did not show statistically significant changes in either the EG or CG. Specifically, the RBC count in the EG, $t_{(9)} = 0.35$, $p = .740$, and CG, $t_{(9)} = 0.98$, $p = .353$, remained relatively stable. Similarly, PCV levels in the EG, $t_{(9)} = 0.54$, $p = .600$, and CG, $t_{(9)} = 1.71$, $p = .121$, did not exhibit significant variation. Furthermore, MCV, $t_{(9)} = 1.16$, $p = .280$; MCH, $t_{(9)} = 0.68$, $p = .513$; and MCHC, $t_{(9)} = 1.32$, $p = .220$, did not demonstrate significant differences post-intervention. The CG also showed no significant changes in MCV, $t_{(9)} = 1.49$, $p = .169$; MCH, $t_{(9)} = 0.35$, $p = .733$; and MCHC, $t_{(9)} = 1.16$, $p = .275$.

The lack of significant changes in these additional hematological parameters suggested that while the

intervention effectively improved Hb levels, it did not induce substantial alterations in other erythrocyte-related indices. This may have indicated that the intervention primarily influenced oxygen transport efficiency rather than overall erythropoiesis or red blood cell morphology. Conversely, the CG did not exhibit statistically significant changes in any of the measured hematological parameters, reinforcing the specificity and efficacy of the intervention implemented in the EG. The observed improvements in Hb levels within the EG underscored the potential benefits of structured training programs in optimizing hematological function, which was crucial for endurance and overall athletic performance. These findings provided valuable insights into the impact of targeted interventions on hematological adaptations. Future research may explore the long-term effects of such interventions, particularly in diverse populations, to further elucidate their role in enhancing physiological function and athletic performance. The independent t-test analysis presented in Table 6 revealed notable changes in hematological variables between the EG and CG. The pre-test Hb levels were comparable between the groups ($p = 0.512$), while post-test values showed an increase in the EG, though the difference was not statistically significant ($p = 0.079$). A

Table 4. Descriptive Statistics

Variables	Group	Test	N	Mean	Std. Deviation	% Change	Reference Range
Hb	EG	Pre-test	10	14.97	1.03	4.28	12-18 mg/dl
		Post-test	10	15.61	0.99		
	CG	Pre-test	10	15.24	.77	-2.76	
		Post-test	10	14.82	.90		
RBC	EG	Pre-test	10	5.57	.57	1.08	4.5-6.5 millions/cumm
		Post-test	10	5.63	.33		
	CG	Pre-test	10	5.20	.52	-2.31	
		Post-test	10	5.08	.42		
PCV	EG	Pre-test	10	45.63	3.02	2.10	36-46 %
		Post-test	10	46.59	5.61		
	CG	Pre-test	10	46.05	2.09	-4.56	
		Post-test	10	43.95	3.73		
MCV	EG	Pre-test	10	82.51	10.15	5.38	77-93 fl
		Post-test	10	86.95	9.17		
	CG	Pre-test	10	88.91	5.49	-2.60	
		Post-test	10	86.60	4.10		
MCH	EG	Pre-test	10	27.13	3.22	2.51	27-32 pg
		Post-test	10	27.81	2.19		
	CG	Pre-test	10	29.42	1.90	-.61	
		Post-test	10	29.24	1.19		
MCHC	EG	Pre-test	10	32.90	.43	-2.40	31-35 gm/dl
		Post-test	10	32.11	1.84		
	CG	Pre-test	10	33.09	.61	2.21	
		Post-test	10	33.82	1.83		

significant improvement was observed in the RBC count, as the EG had a higher post-test mean compared to the CG ($p = 0.004$), suggesting a positive effect of the intervention. However, PCV did not differ significantly between groups in both pre-test and post-test assessments ($p = 0.722$ and $p = 0.230$, respectively). MCV values remained statistically unchanged after the intervention ($p = 0.913$), indicating minimal impact. Similarly, MCH did not show significant differences in either the pre-test or post-test values ($p = 0.068$ and $p = 0.087$, respectively). MCHC were also comparable between the groups in the pre-test phase ($p = 0.427$), but the post-test values indicated a near-significant difference favoring the CG ($p = 0.051$). These findings, as shown in Table 6, suggested that the intervention was particularly effective in improving RBC count, while other hematological variables exhibited changes that were not statistically significant. The increase in Hb levels in the EG approached significance, highlighting the potential benefits of the intervention, which warranted further research with a larger sample size to establish definitive conclusions.

Discussions

This study examines the effects of yogic practices on select hematological parameters, revealing distinct trends

that underscore the potential physiological benefits of yogic practices. The findings suggest that regular engagement in yogic practices contributes to hematological stability and enhancement, particularly in parameters associated with oxygen transport and erythropoiesis. These results align with previous research indicating that mind-body interventions, including yogic practices, play a crucial role in improving hematological health and overall physiological well-being (Banerjee et al., 2019).

The increase in Hb levels in the EG suggests that yogic practices positively influence erythropoiesis and oxygen-carrying capacity. Prior studies report similar findings (Ramanath et al., 2013; Longeville & Stingaciu, 2017), highlighting that pranayama and controlled breathing techniques enhance pulmonary function (Kakkar et al., 2024), leading to increased oxygen diffusion and improved hemoglobin synthesis (Soni et al., 2012). Additionally, yoga's role in reducing physiological stress mitigates cortisol-induced suppression of erythropoietin production, thereby supporting red blood cell proliferation (Arora & Bhattacharjee, 2008; Kelly et al., 2000; Naragatti, 2025). In contrast, the decline in hemoglobin levels in the CG reinforces research indicating that a sedentary lifestyle negatively impacts erythropoiesis and overall hematological stability (Koivula et al., 2022).

Table 5. Paired t-test comparison of pre-test and post-test in EG and CG

Variables	Group	Test	Mean Difference	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Hb	EG	Pre-test	.64	.67	.21	3.02	9	.015
		Post-test						
	CG	Pre-test	.42	.67	.21	1.99	9	.078
		Post-test						
RBC	EG	Pre-test	.06	.54	.17	.35	9	.74
		Post-test						
	CG	Pre-test	.13	.41	.13	.98	9	.353
		Post-test						
PCV	EG	Pre-test	.96	5.58	1.77	.54	9	.60
		Post-test						
	CG	Pre-test	2.10	3.89	1.23	1.71	9	.121
		Post-test						
MCV	EG	Pre-test	4.44	12.11	3.83	1.16	9	.28
		Post-test						
	CG	Pre-test	2.32	4.91	1.55	1.49	9	.169
		Post-test						
MCH	EG	Pre-test	.68	3.15	.99	.68	9	.513
		Post-test						
	CG	Pre-test	.18	1.64	.52	.35	9	.733
		Post-test						
MCHC	EG	Pre-test	.80	1.91	.60	1.32	9	.220
		Post-test						
	CG	Pre-test	.73	1.99	.63	1.16	9	.275
		Post-test						

*Significant at 0.05 level

Although the RBC count in the EG exhibits a minor increase, it does not reach statistical significance. Prior studies report similar findings (Chandrashekhar, 2012; Purohit et al., 2013). However, existing literature supports the notion that regular engagement in yogic practice optimizes autonomic function (Jain et al., 2017), and circulation efficiency (Chen, 2024), which contributes to the long-term maintenance of RBC homeostasis. The reduction in RBC count in the CG further corroborates findings from studies emphasizing the detrimental effects of physical inactivity on erythropoiesis (Daniele et al., 2022).

The increase in PCV in the EG highlights the potential benefits of yogic practices in improving blood viscosity and oxygen transport efficiency (Brown & Chevalier, 2015; Puli & Reddy, 2016). Prior studies report similar findings (Sivananda & Srinivasan, 2017). This adaptation likely results from enhanced cardiovascular function and improved metabolic efficiency associated with regular yogic practice (Sharma et al., 2024; Tyagi & Cohen, 2013). Prior research shows that physical activity, including yogic practice, enhances hematological parameters by promoting optimal blood circulation and reducing oxidative stress (Sharma et al., 2024; Patil et al., 2014). The CG decline in

packed cell volume further reinforces the importance of physical activity in maintaining optimal blood composition.

The increased MCV observed in the EG suggests improvements in erythrocyte morphology and oxygen-carrying potential (Gowtham et al., 2018). This finding aligns with earlier studies (Bara et al., 2024), indicating that yogic practices improve cellular integrity and hematopoietic efficiency (Chen, 2024; Bhargav et al., 2010). In contrast, the reduction in mean corpuscular volume in the CG supports research showing that sedentary behavior impairs erythrocyte stability and function.

A modest increase in MCH in the EG. This finding aligns with earlier studies (Purohit et al., 2013), and suggests that yogic practice optimizes hemoglobin synthesis within erythrocytes (Ramanath et al., 2013), potentially enhancing oxygen delivery at the cellular level. This improvement likely relates to yogic practice's stress-modulating effects, which mitigate hormonal imbalances that negatively affect erythropoiesis (Arora & Bhattacharjee, 2008; Kelly et al., 2000; Naragatti, 2025). Research suggests that regular yogic practice enhances metabolic efficiency and nutrient absorption (Tyagi & Cohen, 2013; Verma et al., 2017), which contributes to improved hemoglobin synthesis.

Table 6. Independent t-test comparison of pre-test and post-test between EG and CG

Variables	Tests	EG		CG		t	P-value
		Mean	SD	Mean	SD		
Hb	Pre-test	14.97	1.03	15.24	.77	.67	.512
	Post-test	15.61	0.99	14.82	.90	1.86	.079
RBC	Pre-test	5.57	.57	5.20	.52	1.48	.157
	Post-test	5.63	.33	5.08	.42	3.25	.004
PCV	Pre-test	45.63	3.02	46.05	2.09	.36	.722
	Post-test	46.59	5.61	43.95	3.73	1.24	.230
MCV	Pre-test	82.51	10.15	88.91	5.49	1.76	.096
	Post-test	86.95	9.17	86.60	4.10	.11	.913
MCH	Pre-test	27.13	3.22	29.42	1.90	1.94	.068
	Post-test	27.81	2.19	29.24	1.19	1.81	.087
MCHC	Pre-test	32.90	.43	33.09	.61	.81	.427
	Post-test	32.11	1.84	33.82	1.83	2.09	.051

*Significant at 0.05 level

A minor decline in MCHC in the yogic practices group. This finding aligns with earlier studies (Subramanian et al., 2012). Given the role of hydration status and erythrocyte stability in determining mean corpuscular hemoglobin concentration (Palka et al., 2023), further research is needed to explore the underlying mechanisms influencing this parameter. Studies on yoga's effects on hemodynamics and fluid balance provide additional insights into these findings.

The observed improvements in hematological parameters likely result from multiple physiological adaptations facilitated by yogic practices. Physiological mechanisms underlying these changes may include enhanced oxygenation (Roberson & Bennett-Guerrero, 2012), improved circulation (Chen, 2024), autonomic nervous system modulation (Shobana et al., 2022; Nontakhod et al., 2024), reduced oxidative stress (Patil et al., 2014), and hormonal regulation (Naragatti, 2025), all contributing to hematological balance and efficiency.

The findings of this study provide valuable insights into the role of yogic practices in promoting hematological health. The positive trends observed in hemoglobin and related parameters highlight the potential benefits of yogic practices as a non-invasive and holistic intervention for improving blood composition and oxygen transport capacity. These findings emphasize the significance of integrating yogic practices into lifestyle interventions aimed at enhancing physiological resilience and circulatory efficiency.

Limitations and Future of the Study

Despite yielding promising insights into the influence of yogic practices on hematological responses, this study is not without limitations. The small sample size ($n = 20$) constrains the statistical power and may limit the generalizability of the findings. The exclusive focus on male college students from a single institution further restricts the applicability of results across different genders, age brackets, and sociocultural contexts. Additionally, extrinsic variables such as nutritional intake, hydration status, sleep quality, and psychosocial stress—which can significantly impact

hematological outcomes—were not controlled during the intervention period. The study also lacks follow-up data to determine the long-term sustainability of the observed hematological changes post-intervention.

Future research should consider employing a larger, more heterogeneous sample encompassing diverse demographic profiles. Longitudinal study designs with extended follow-up periods are recommended to assess the durability of hematological adaptations. Integrating biochemical, cardiorespiratory, and psychophysiological markers alongside hematological indices could offer a more comprehensive understanding of the systemic effects of yogic interventions. Inclusion of female participants and assessment of lifestyle variables would further enhance the robustness and translational value of subsequent findings.

Strengths and Implications

The primary strength of this study lies in its well-structured and time-bound yogic intervention, implemented over a twelve-week period with consistent supervision. The use of a randomized controlled design, combined with standardized hematological assessments via a fully automated analyzer, enhances the internal validity and ensures precision in the measurement of key hematological markers. The application of both paired and independent t-tests allowed for rigorous intra- and inter-group comparisons, lending statistical credibility to the observed outcomes.

Another noteworthy strength is the selection of specific hematological parameters—Hb, RBC, PCV, MCV, MCH, and MCHC—which are critical indicators of oxygen transport and erythropoietic activity. By focusing on these indices, the study provides targeted insights into how yogic practices may influence hematopoietic function, particularly among healthy young adults.

From an applied physiological standpoint, the findings underscore the potential role of structured yogic practices—especially combinations of suryanamaskar, asanas, pranayama, and relaxation techniques—in enhancing hemoglobin concentration, a key factor in aerobic

performance and oxygen delivery. This suggests that regular yogic practices can contribute to improved cardiovascular efficiency and overall vitality in young populations.

In terms of practical implications, the study supports the integration of yoga into college wellness programs as a cost-effective, non-invasive, and accessible strategy for optimizing hematological health. Although significant changes were observed only in hemoglobin levels, the trend toward improvement in other parameters suggests a broader, gradual hematological adaptation that may become more evident with longer or more intensive interventions. These outcomes provide a compelling rationale for policymakers and educators to promote yoga-based health modules in academic settings as a sustainable method for enhancing physical and mental health without reliance on pharmacological approaches.

Conclusions

This study found that a twelve-week yogic intervention led to notable improvements in hematological parameters within the EG, with Hb levels showing a statistically significant increase, indicating enhanced oxygen-carrying capacity and overall physiological function. Although other hematological variables—RBC count, PCV, MCV, MCH, and MCHC—did not reach statistical significance, the observed trends suggest positive physiological adaptations in response to the yogic intervention. In contrast, the CG exhibited declines or negligible changes across all measured parameters, reinforcing the effectiveness of the intervention.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

- Woodyard C. (2011). Exploring the therapeutic effects of yoga and its ability to increase quality of life. *International journal of yoga*, 4(2), 49-54. <https://doi.org/10.4103/0973-6131.85485>
- Chen, Q. (2024). Neurobiological and anti-aging benefits of yoga: A comprehensive review of recent advances in non-pharmacological therapy. *Experimental Gerontology*, 196, 112550. <https://doi.org/10.1016/j.exger.2024.112550>
- Shobana, R., Maheshkumar, K., Venkateswaran, S.T., Geetha, M.B., & Padmavathi, R. (2022). Effect of long-term yoga training on autonomic function among the healthy adults. *Journal of family medicine and primary care*, 11(7), 3471-3475. https://doi.org/10.4103/jfmpc.jfmpc_199_21
- Patil, S.G., Dhanakshirur, G.B., Aithala, M.R., Naregal, G., & Das, K.K. (2014). Effect of yoga on oxidative stress in elderly with grade-I hypertension: a randomized controlled study. *Journal of clinical and diagnostic research: JCDR*, 8(7), BC04-BC7. <https://doi.org/10.7860/JCDR/2014/9498.4586>
- Pratiti, G. (2022). Wellness - Homeostasis through yoga. *Journal of Yoga & Physiotherapy*, 9(5), 555774. <https://doi.org/10.19080/JYP.2021.09.555774>
- Chanda, S., Sujon, H.A., Boby, F.A., Camenidis, C.M., & Geantă, V.A. (2025). Blood blueprint of cricket players: Exploring variations in hematological parameters based on playing roles. *Retos*, 66, 240-250. <https://doi.org/10.47197/retos.v66.110093>
- Witeska, M., Kondera, E., Ługowska, K., & Bojarski, B. (2022). Hematological methods in fish - Not only for beginners. *Aquaculture*, 547, 737498. <https://doi.org/10.1016/j.aquaculture.2021.737498>
- Valent, P., Büsche, G., Theurl, I., Uras, I.Z., Germing, U., Stauder, R., Sotlar, K., Füreder, W., Bettelheim, P., Pfeilstöcker, M., Oberbauer, R., Sperr, W.R., Geissler, K., Schwaller, J., Moriggl, R., Béné, M.C., Jäger, U., Horny, H.P., & Hermine, O. (2018). Normal and pathological erythropoiesis in adults: from gene regulation to targeted treatment concepts. *Haematologica*, 103(10), 1593-1603. <https://doi.org/10.3324/haematol.2018.192518>
- Witeska, M., Kondera, E., & Bojarski, B. (2023). Hematological and Hematopoietic Analysis in Fish Toxicology-A Review. *Animals : an open access journal from MDPI*, 13(16), 2625. <https://doi.org/10.3390/ani13162625>
- Brocherie, F., Millet, G.P., Hauser, A., Steiner, T., Wehrin, J.P., Rysman, J., & Girard, O. (2015). Association of Hematological Variables with Team-Sport Specific Fitness Performance. *PloS one*, 10(12), e0144446. <https://doi.org/10.1371/journal.pone.0144446>
- Alhmoud, J.F., Farah, H.S., Al-Qaisi, T., Hamdan, W.A., Oriquat, G.A., Atoom, A., & Al-Qaisi, K.M. (2021). The changes in some hematological parameters among university students due to stressful conditions during and after examinations period. *Indian Journal of Forensic Medicine & Toxicology*, 15(1), 1181-1186. <https://doi.org/10.37506/ijfmt.v15i1.13578>
- Johnson-Wimbley, T.D., & Graham, D.Y. (2011). Diagnosis and management of iron deficiency anemia in the 21st century. *Therapeutic advances in gastroenterology*, 4(3), 177-184. <https://doi.org/10.1177/1756283X11398736>
- Haas, J.D., & Brownlie, T. IV. (2001). Iron deficiency and reduced work capacity: A critical review of the research to determine a causal relationship. *The Journal of Nutrition*, 131(2), 676S-690S. <https://doi.org/10.1093/jn/131.2.676S>
- Lupak, O., Han, X., Xie, P., Mahmood, S., Mohammed, H., & Donthireddy, V. (2020). The role of a low erythropoietin level for the polycythemia vera diagnosis. *Blood Cells, Molecules, and Diseases*, 80, 102355. <https://doi.org/10.1016/j.bcmd.2019.102355>
- Chidozie, V.N., Okwori, A.E. J., Oluwatayo, B.O., Adekeye, A.M., Kinjir, H., Okeke, C., Abah, I.M., & Salako, Y. (2020). Assessment of packed cell volume among students of Federal College of Veterinary and Medical Laboratory Technology, Vom, Plateau State. *International Journal of Advanced Research*, 8(5), 457-460. <https://doi.org/10.21474/IJAR01/10947>
- Caimi, G., Carlisi, M., & Presti, R.L. (2024). Red blood cell distribution width, erythrocyte indices, and elongation index at baseline in a group of trained subjects. *Journal of Clinical Medicine*, 13(1), 151. <https://doi.org/10.3390/jcm13010151>
- Deepthi, A., Prasad, C.S. B.R., & Prasad, R.B. N. (2018). Study of dimorphic anemia in adults with reference to basic

- etiology. *Indian Journal of Pathology and Oncology*, 5(1), 61-66. <https://doi.org/10.18231/2394-6792.2018.0012>
- Zhang, Z., Gao, S., Dong, M., Luo, J., Xu, C., Wen, W., Huang, Y., Wu, Y., Zhou, J., & Yuan, Z. (2022). Relationship between Red Blood Cell Indices (MCV, MCH, and MCHC) and Major Adverse Cardiovascular Events in Anemic and Nonanemic Patients with Acute Coronary Syndrome. *Disease markers*, 2022, 2193343.
- Jagannathan-Bogdan, M., & Zon, L.I. (2013). Hematopoiesis. *Development (Cambridge, England)*, 140(12), 2463-2467. <https://doi.org/10.1242/dev.083147>
- Vanhie, J.J., & De Lisio, M. (2022). How Does Lifestyle Affect Hematopoiesis and the Bone Marrow Microenvironment?. *Toxicologic pathology*, 50(7), 858-866. <https://doi.org/10.1177/01926233221123523>
- Carpenter, R.S., & Maryanovich, M. (2024). Systemic and local regulation of hematopoietic homeostasis in health and disease. *Nature cardiovascular research*, 3(6), 651-665. <https://doi.org/10.1038/s44161-024-00482-4>
- Longeville, S., & Stingaciu, L.R. (2017). Hemoglobin diffusion and the dynamics of oxygen capture by red blood cells. *Scientific Reports*, 7, 10448. <https://doi.org/10.1038/s41598-017-09146-9>
- Mairbäurl, H., & Weber, R.E. (2012). Oxygen transport by hemoglobin. *Comprehensive Physiology*, 2(2), 1463-1489. <https://doi.org/10.1002/cphy.c080113>
- Storz, J.F. (2016). Gene duplication and evolutionary innovations in hemoglobin-oxygen transport. *American Physiological Society*, 31(3), 223-232. <https://doi.org/10.1152/physiol.00060.2015>
- Sera, R. (2023). Hemoglobin: The oxygen-carrying molecule that keeps us alive. *Journal of Evolutionary Medicine*, 11(5), 110915. <https://doi.org/10.4303/jem/110915>
- Billett, H.H. (1990). Hemoglobin and hematocrit. In H.K. Walker, W.D. Hall, & J.W. Hurst (Eds.), *Clinical methods: The history, physical, and laboratory examinations* (3rd ed., p. 151). Butterworths. <https://www.ncbi.nlm.nih.gov/books/NBK259/>
- Pittman, R.N. (2011). *Regulation of tissue oxygenation*. Morgan & Claypool Life Sciences. <https://www.ncbi.nlm.nih.gov/books/NBK54104/>
- Kuhn, V., Diederich, L., Keller, T.C. S., Kramer, C.M., Lückstädt, W., Panknin, C., Suvorava, T., Isakson, B.E., Kelm, M., & Cortese-Krott, M.M. (2017). Red Blood Cell Function and Dysfunction: Redox Regulation, Nitric Oxide Metabolism, Anemia. *Antioxidants & redox signaling*, 26(13), 718-742. <https://doi.org/10.1089/ars.2016.6954>
- Mairbäurl H. (2013). Red blood cells in sports: effects of exercise and training on oxygen supply by red blood cells. *Frontiers in physiology*, 4, 332. <https://doi.org/10.3389/fphys.2013.00332>
- Nader, E., Skinner, S., Romana, M., Fort, R., Lemonne, N., Guillot, N., Gauthier, A., Antoine-Jonville, S., Renoux, C., Hardy-Dessources, M.D., Stauffer, E., Joly, P., Bertrand, Y., & Connes, P. (2019). Blood Rheology: Key Parameters, Impact on Blood Flow, Role in Sickle Cell Disease and Effects of Exercise. *Frontiers in physiology*, 10, 1329. <https://doi.org/10.3389/fphys.2019.01329>
- Roberson, R.S., & Bennett-Guerrero, E. (2012). Impact of red blood cell transfusion on global and regional measures of oxygenation. *The Mount Sinai journal of medicine, New York*, 79(1), 66-74. <https://doi.org/10.1002/msj.21284>
- Erhabor, O., Muhammad, H.A., Muhammad, K., Onwuchekwa, C., & Egenti, N.B. (2021). Interpretation of full blood count parameters in health and disease. *Haematology International Journal*, 5(1), 00180. <https://doi.org/10.23880/hij-16000180>
- Agarwal, S.K. (2022). Lifestyles and their association with hematological diseases. *Asian Hematology Research Journal*, 5(1), 21-33. <https://journalahjr.com/index.php/AHRJ/article/view/107>
- Mooventhana, A., & Khode, V. (2014). Effect of Bhramari pranayama and OM chanting on pulmonary function in healthy individuals: A prospective randomized control trial. *International journal of yoga*, 7(2), 104-110. <https://doi.org/10.4103/0973-6131.133875>
- Pandey, P., Pandey, S., & Kumar, A. (2019). Effect of pranayam on vital and lung parameters. *World Journal of Pharmaceutical Research*, 8(7), 1892-1901. <https://doi.org/10.20959/wjpr20197-15168>
- Bhimani, N.T., Kulkarni, N.B., Kowale, A., & Salvi, S. (2011). Effect of Pranayama on stress and cardiovascular autonomic function. *Indian journal of physiology and pharmacology*, 55(4), 370-377.
- Arora, S., & Bhattacharjee, J. (2008). Modulation of immune responses in stress by Yoga. *International journal of yoga*, 1(2), 45-55. <https://doi.org/10.4103/0973-6131.43541>
- Kelly, J.J., Martin, A., & Whitworth, J.A. (2000). Role of erythropoietin in cortisol-induced hypertension. *Journal of human hypertension*, 14(3), 195-198. <https://doi.org/10.1038/sj.jhh.1000959>
- Loganathan, N., Aruchunan, M., & Manjunath, N.K. (2019). Effects of yoga for cardiovascular and respiratory functions: a pilot study. *Integrative medicine research*, 8(3), 180. <https://doi.org/10.1016/j.imr.2019.05.004>
- Panjeta, E., Panjeta, M., Dervišević, A., & Ćorić, J. (2019). Effect of yoga exercise on circulatory system. *Journal of Yoga & Physio*, 8(1), 555726. <https://doi.org/10.19080/JYP.2019.08.555726>
- Chaya, M.S., & Nagendra, H.R. (2008). Long-term effect of yogic practices on diurnal metabolic rates of healthy subjects. *International journal of yoga*, 1(1), 27-32. <https://doi.org/10.4103/0973-6131.36761>
- Mischler, K., Fischer, J.E., Zraggen, L., Kudielka, B.M., Preckel, D., & von Känel, R. (2005). The effect of repeated acute mental stress on habituation and recovery responses in hemoconcentration and blood cells in healthy men. *Life Sciences*, 77(10), 1166-1179. <https://doi.org/10.1016/j.lfs.2005.03.006>
- Cay, M., Ucar, C., Senol, D., Cevirgen, F., Ozbag, D., Altay, Z., & Yildiz, S. (2018). Effect of increase in cortisol level due to stress in healthy young individuals on dynamic and static balance scores. *Northern clinics of Istanbul*, 5(4), 295-301. <https://doi.org/10.14744/nci.2017.42103>
- Gilboa-Geffen, A., Hartmann, G., & Soreq, H. (2012). Stressing hematopoiesis and immunity: an acetylcholinesterase window into nervous and immune system interactions. *Frontiers in molecular neuroscience*, 5, 30. <https://doi.org/10.3389/fnmol.2012.00030>
- Obeagu, E.I., Igwe, M.C., & Obeagu, G.U. (2024). Oxidative stress's impact on red blood cells: Unveiling implications for health and disease. *Medicine*, 103(9), e37360. <https://doi.org/10.1097/MD.00000000000037360>

- Thirithalli, J., Naveen, G.H., Rao, M.G., Varambally, S., Christopher, R., & Gangadhar, B.N. (2013). Cortisol and antidepressant effects of yoga. *Indian journal of psychiatry*, 55(Suppl 3), S405-S408. <https://doi.org/10.4103/0019-5545.116315>
- Singh, V., & Shah, S.R. (2024). Enhancing cardiovascular health: The positive impact of yoga on blood flow and circulation. *Indian Journal of Yoga Exercise & Sport Science and Physical Education*, 9(2), 23-34. <https://doi.org/10.58914/ijyesspe.2024-9.2.4>
- Prommer, N., Wachsmuth, N., Thieme, I., Wachsmuth, C., Mancera-Soto, E.M., Hohmann, A., & Schmidt, W.F. J. (2018). Influence of endurance training during childhood on total hemoglobin mass. *Frontiers in Physiology*, 9, 251. <https://doi.org/10.3389/fphys.2018.00251>
- Skouras, A.Z., Antonakis-Karamintzas, D., Tsantes, A.G., Triantafyllou, A., Papagiannis, G., Tsolakis, C., & Koulouvaris, P. (2023). The acute and chronic effects of resistance and aerobic exercise in hemostatic balance: A brief review. *Sports*, 11(4), 74. <https://doi.org/10.3390/sports11040074>
- Belviranlı, M., Okudan, N., & Kabak, B. (2017). The Effects of Acute High-Intensity Interval Training on Hematological Parameters in Sedentary Subjects. *Medical sciences (Basel, Switzerland)*, 5(3), 15. <https://doi.org/10.3390/medsci5030015>
- Chaparro, C.M., & Suchdev, P.S. (2019). Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. *Annals of the New York Academy of Sciences*, 1450(1), 15-31. <https://doi.org/10.1111/nyas.14092>
- Shapiro, S.S., & Wilk, M.B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, 52(3-4), 591-611. <https://doi.org/10.1093/biomet/52.3-4.591>
- Banerjee, A.B., Banerjee, A.A., Sharma, L.K., & Kumar, S. (2019). Effect of yoga on physical and various hematological parameters. *International Journal of Community Medicine and Public Health*, 6(12), 5186-5190. <https://doi.org/10.18203/2394-6040.ijcmph20195467>
- Ramanath, B., Shaik, T., & Reddy, M.S. (2013). A randomized control study of yoga on anemic patients. *International Journal of Research in Medical Sciences*, 1(3), 240-242. <https://doi.org/10.5455/2320-6012.ijrms20130815>
- Kakkar, S., Sharma, V., & Jaiswal, G. (2024). The impact of yoga practice on pulmonary function: A comprehensive review. *International Journal of Ayurvedic Medicine*, 15(S1), 193-197. <https://doi.org/10.47552/ijam.v15iS1>
- Soni, R., Munish, K., Singh, K., & Singh, S. (2012). Study of the effect of yoga training on diffusion capacity in chronic obstructive pulmonary disease patients: A controlled trial. *International journal of yoga*, 5(2), 123-127. <https://doi.org/10.4103/0973-6131.98230>
- Naragatti, S. (2025). The role of yoga in balancing hormones: A comprehensive research review. *International Journal for Multidisciplinary Research*, 7(1), 1-12.
- Koivula, T., Lempiäinen, S., Laine, S., Sjöros, T., Vähä-Ypyä, H., Garthwaite, T., Löyttyneimi, E., Sievänen, H., Vasankari, T., Knuuti, J., & Heinonen, I.H. A. (2022). Cross-Sectional Associations of Body Adiposity, Sedentary Behavior, and Physical Activity with Hemoglobin and White Blood Cell Count. *International journal of environmental research and public health*, 19(21), 14347. <https://doi.org/10.3390/ijerph192114347>
- Chandrashekhar, K. (2012). Effect of six weeks yogasana training on hematological parameters and lipid profile. *National Journal of Basic Medical Sciences*, 3(2), 119-122.
- Purohit, G., Mendpara, S., Chawla, V.K., & Harsoda, J.M. (2013). Cardioprotectant and antistress effect of yoga training and its correlation with hematological parameters: A prospective study of 47 young healthy individuals. *Scholars Journal of Applied Medical Sciences*, 1(6), 852-856. <https://doi.org/10.36347/sjams.2013.v01i06.0045>
- Jain, A., Agarwal, S.K., Maurya, A., & Bhatia, M. (2017). Impact of integrative yoga exercise on autonomic function and health-related quality of life in COPD. *European Respiratory Journal*, 50(Suppl 61), PA3678. <https://doi.org/10.1183/13930003.congress-2017.PA3678>
- Daniele, A., Lucas, S.J., & Rendeiro, C. (2022). Detrimental effects of physical inactivity on peripheral and brain vasculature in humans: Insights into mechanisms, long-term health consequences, and protective strategies. *Frontiers in Physiology*, 13, 998380. <https://doi.org/10.3389/fphys.2022.998380>
- Brown, R., & Chevalier, G. (2015). Grounding the human body during yoga exercise with a grounded yoga mat reduces blood viscosity. *Open Journal of Preventive Medicine*, 5(4), 159-168. <https://doi.org/10.4236/ojpm.2015.54019>
- Puli, S.H., & Reddy, L.R. (2016). Estimation of VO₂ max before and after yoga training in healthy female medical students. *Scholars Journal of Applied Medical Sciences*, 4(10B), 3665-3668. <https://doi.org/10.36347/sjams.2016.v04i10.023>
- Sivananda, K., & Srinivasan, M.V. (2017). Impact of yogic practices and aerobic training on packed cell volume among middle-aged women. *International Journal of Multidisciplinary Research Review*, 1(33), 194-197.
- Sharma, H., Swetanshu, S., & Singh, P. (2024). Role of yoga in cardiovascular diseases. *Current Problems in Cardiology*, 49(1, Part A), 102032. <https://doi.org/10.1016/j.cpcardiol.2023.102032>
- Tyagi, A., & Cohen, M. (2013). Oxygen consumption changes with yoga practices: A systematic review. *Journal of Evidence-Based Complementary & Alternative Medicine*, 18(4), 290-308. <https://doi.org/10.1177/2156587213492770>
- Gowtham, L., Vasanthi, B., Jayshree, N., Ambika, & Jacob, S.M. (2018). Effects of yoga in type 2 diabetes mellitus with hypertension: Alteration in RBC morphology as a marker for oxidative stress. *Indian Journal of Physiology and Pharmacology*, 62(1), 51-58.
- Bara, F.T., S.K., Oka, I., Bagenda, E.F., & S.H. (2024). Prenatal yoga practice increases ferritin and MCV levels in pregnant women. *Indonesian Journal of Global Health Research*, 6(6), 4335-4342. <https://doi.org/10.37287/ijghr.v6i6.5508>
- Bhargav, H., Raghuram, N., Rao, N.H., Tekur, P., & Koka, P.S. (2010). Potential yoga modules for treatment of hematopoietic inhibition in HIV-1 infection. *Journal of stem cells*, 5(3), 129-148.
- Verma, A., Shete, S., Kulkarni, D., & Bhogal, R.S. (2017). Effect of yoga practices on micronutrient absorption in urban residential school children. *Journal of physical therapy*

science, 29(7), 1254-1258.

<https://doi.org/10.1589/jpts.29.1254>

Subramanian, S., Elango, T., Malligarjuna, H., Kochupillai, V., & Dayalan, H. (2012). Role of sudarshan kriya and pranayam on lipid profile and blood cell parameters during exam stress: A randomized controlled trial.

International journal of yoga, 5(1), 21-27.

<https://doi.org/10.4103/0973-6131.91702>

Pałka, T., Koteja, P.M., Tota, Ł., Rydzik, Ł., Kopańska, M., Kaczorowska, I., Javdaneh, N., Mikulakova, W., Wolski,

H., & Ambroży, T. (2023). The Influence of Various Hydration Strategies (Isotonic, Water, and No Hydration) on Hematological Indices, Plasma Volume, and Lactate Concentration in Young Men during Prolonged Cycling in Elevated Ambient Temperatures. *Biology*, 12(5), 687. <https://doi.org/10.3390/biology12050687>

Nontakhod, K., Wandee, A., Sremsiri, C., Chansingha, P., Chaweeram, N., & Kamnanat, A. (2024). Effects of yoga exercise on heart rate in post-COVID-19 patients. *Retos*, 61, 861-867. <https://doi.org/10.47197/retos.v61.108844>

Йогічні практики та їхній вплив на гематологічні реакції: Фізіологічна перспектива

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 10 с., 6 табл., 1 рис., 75 джерел.

Історія питання. Йога — стародавня дисципліна, яка поєднує фізичні пози, контроль дихання та медитацію, пов'язана з низкою фізіологічних переваг. Дослідження її впливу на гематологічні показники є надзвичайно важливим, оскільки вони є ключовими індикаторами здоров'я та працездатності.

Мета дослідження. Мета цього дослідження полягала в оцінці впливу йогічних практик на гематологічні показники, а саме: гемоглобін (Hb), кількість еритроцитів (RBC), об'єм осаджених клітин (PCV), середній корпускулярний об'єм (MCV), середній корпускулярний гемоглобін (MCH) та середню корпускулярну концентрацію гемоглобіну (MCHC) серед студентів коледжу.

Матеріали та методи. У дослідженні взяли участь 20 студентів чоловічої статі віком від 17 до 22 років. Вони були розподілені за методом рандомізації на експериментальну групу (n=10), яка проходила інтервенцію із занять йогою, та контрольну групу (n=10), яка не брала участі в жодній структурованій фізичній активності. Експериментальна група (ЕГ) щоденно, шість днів на тиждень, займалася 60-хвилинними сесіями, що включали комплекс вправ Сур'я-намаскара, асани, пранаяму та техніки релаксації. Вимірювання гематологічних показників здійснювалося на початку дослідження та через 12 тижнів за допомогою автоматичного гематологічного аналізатора Tulip Coralyzer Smart 200. Статистичний аналіз проводився із застосуванням t-критеріїв для парних та незалежних вибірок, при цьому рівень значущості встановлено на рівні $p < 0.05$.

Результати. Постінтервенційний аналіз виявив статистично значуще підвищення рівнів гемоглобіну в експериментальній групі ($p = 0.015$), що свідчить про підвищену здатність до перенесення кисню. У жодній з груп не спостерігалось суттєвих змін у показниках кількості еритроцитів, об'єму осаджених клітин, середнього корпускулярного об'єму, середнього корпускулярного гемоглобіну та середньої корпускулярної концентрації гемоглобіну.

Висновки. В експериментальній групі встановлено значне поліпшення рівнів гемоглобіну, що вказує на потенційні переваги для транспорту кисню та аеробної здатності. Результати дослідження показують, що покращення інших гематологічних показників свідчить про наявність селективних гематологічних адаптацій до йогічних практик.

Ключові слова: гематологічні тести, гемоглобіни, кількість еритроцитів, йога, інтервенційні дослідження.

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The Effect of a Six-Week Intervention Using Small-Sided Games (SSG), Ladder Drill, and Dynamic Balance on Agility of Young Futsal Players

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Abstract

Objectives. This study aimed to compare the effects of small-sided games (SSG) and ladder drills (LD) on agility performance in futsal players with different levels of dynamic balance (DB), which was examined as a moderating variable.

Materials and Methods. Twenty-four male futsal athletes (mean age: 17.1 ± 0.8 years) were randomly assigned to either SSG or LD training groups and further classified into high or low DB levels, forming four experimental subgroups. Over a 6-week intervention (3 sessions/week), participants underwent agility-specific training, and agility was assessed using the Illinois Agility Test. Dynamic balance was measured via the Y Balance Test. A two-way ANOVA with Tukey's post hoc test ($p < 0.05$) was used to assess main and interaction effects.

Results. Both training interventions produced significant improvements in agility ($p < 0.05$). Players with high DB showed the most substantial gains following SSG (21.5% improvement), whereas those with low DB benefited more from LD training (11.0% improvement). A significant interaction was observed between training type and DB level, suggesting that agility adaptations depend on athletes' balance proficiency.

Conclusions. The effectiveness of agility training in futsal players is moderated by individual dynamic balance capacity. SSG is particularly beneficial for players with high DB due to its game-representative movement demands, while LD training provides structured improvements for players with low DB. These findings support the implementation of personalised training strategies based on neuromuscular profiles to optimise agility development in futsal.

Keywords: small-sided games, ladder drill, dynamic balance, agility, futsal.

Introduction

Futsal is a small-sided variant of football that requires a deep understanding of tactical elements, including attack, defence, and transition play (Fahrudin et al., 2024). Played on a reduced field, typically ranging from 25 to 42 meters in

length and 15 to 25 meters in width, the game is fast-paced and high-intensity (Guerra Echevarria & Valencia Sánchez, 2022; Taufik et al., 2021). The compact playing area creates constant pressure from opponents, demanding explosive actions like sprints, accelerations, decelerations, and sharp directional changes (Borges et al., 2021; Tanyeri & Öncen, 2020). Most actions last under 20 seconds, requiring quick decisions, rapid execution, and efficient recovery between efforts (Caetano et al., 2015; Oliveira et al., 2013).

Futsal players must be technically skilled and physically fit to move swiftly and adapt (Pauli et al., 2024; Selin et

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al., 2024). Fitness helps execute technical and tactical plans, improving competitiveness (Bompa & Buzzichelli, 2015; Fitriani et al., 2023; Naser et al., 2017). Players must be agile enough to change direction fast in high-pressure futsal games with little space (Ilham et al., 2024; Rozi et al., 2023). Agility is the ability to change direction quickly while maintaining equilibrium (Pereira et al., 2018; X. Wang et al., 2024). Agility involves rapid directional and speed changes, physical ability, technical execution, and cognitive processing (Ilham et al., 2024; Nygaard Falch et al., 2019). Teaching players' agility is crucial to sports performance (Afonso et al., 2020; Sattler et al., 2015). Athletic development requires a holistic approach that accommodates varied training loads that impact performance and team success (Guntoro et al., 2023; Serrano et al., 2020). Thus, agility training should be routinely included to improve performance (Rozi et al., 2023; Setiawan et al., 2017). Agility is improved through small-sided games and ladder drills by enhancing motor function, neuromuscular control, coordination, and reducing the risk of injury (Afonso et al., 2020; Suryadi et al., 2023; Young & Rogers, 2014).

Small-sided games simulate actual practice situations by changing field size, number of players, goals, ball-touch constraints, and vocal instructions, making them more intense and challenging (Arslan et al., 2022; Theocharis et al., 2023). In real play, players must make quick decisions, adapt to changing situations, and communicate directly with colleagues and opponents (Arslan et al., 2021). Specific, game-like movements in small-sided games improve general motor skills. They also cause neuromuscular and metabolic stress, elevating heart rate to above 80% of maximum (Arslan et al., 2020; Clemente, Ramirez-Campillo, et al., 2021). Ladder drills teach athletes to synchronise quick steps, manage body motions, and maintain balance during rapid directional adjustments (Koestanto et al., 2017; Padrón-Cabo et al., 2020). Ladder drills are used to train speed, coordination, balance, and agility in individuals of all ages, genders, and sports (Sari et al., 2024; Selviani et al., 2025; Wahyono et al., 2024). This training emphasises rhythm, timing, and fine motor control to optimise reactive and anticipatory movement techniques in competitive contexts (Bassa et al., 2024).

Agility requires balance, quickness, and explosive force; agility performance encompasses acceleration and deceleration, and balance is crucial during quick directional shifts following a sequence of actions (Gidu et al., 2022; Sun et al., 2025). Balance is essential in athletics, allowing directional shifts, quick accelerations and decelerations, object manipulation, and body positions (Ahmed et al., 2022; Szabo et al., 2020). Balance is the ability to maintain the centre of gravity within the base of support during both static and dynamic activities (Lesinski et al., 2015; Sari et al., 2025). Dynamic balance involves complex proprioception and range of motion to maintain a steady posture during movement (Hammami et al., 2022; Ozmen, 2016; Sari et al., 2023).

Balance is known to affect agility, but few studies have examined its impact on specific types of training, such as ladder skills and small-sided games. It's still unclear whether these methods work differently for athletes with varying degrees of dynamic balance. Tailoring training to an athlete's physical profile can improve agility, enhance performance,

and reduce the risk of injury. This study aims to examine the effects of ladder and small-sided game training on the agility of futsal players, considering dynamic balance as a moderating factor—this forms the core of the research aim.

Materials and Methods

Research Design

This study utilised a 2×2 factorial design to examine the effects of small-sided games and ladder drills on agility in futsal players, with dynamic balance considered as a moderating variable. This experimental approach allowed for the analysis of both the main effects and interaction effects between training type and dynamic balance on agility outcomes. Participants were randomly assigned to one of four groups to ensure balanced conditions across the intervention.

The training program lasted six weeks, during which standardised exercise protocols were implemented under the supervision of certified trainers. To control for confounding variables, all participants were instructed to maintain their usual dietary habits and refrain from additional high-intensity physical activity throughout the study period.

Table 1. The number of participants in each treatment group.

Dynamic Balance (B)	Agility Training (A)				Total (n)
	SSG (A1)	n	LD (A2)	n	
High (B1)	A1B1	6	A2B1	6	12
Low (B2)	A1B2	6	A2B2	6	12
Total	A1	12	A2	12	24

Notes: SSG = Small Side Games, LD = ladder drill

Participants

The study involved 46 futsal players from Vamos Academy in Padang. Based on body mass index (BMI) percentiles, the top and bottom 27% were selected to represent contrasting levels of dynamic balance, resulting in the inclusion of 12 participants with high dynamic balance and 12 with low dynamic balance. Thus, a total of 24 male futsal players (mean age: 17.2 ± 0.76 years; height: 166.8 ± 5.4 cm; weight: 59.8 ± 7.4 kg; BMI: 20.5 ± 2.3 kg/m²), all with provincial-level competitive experience, voluntarily participated in the study. Participants engaged in three training sessions per week (Ilham et al., 2024).

Following dynamic balance assessment, participants were stratified into high and low dynamic balance groups using a percentile-based classification. To ensure balanced group allocation, an A-B-B-A pairing method was employed, alternating assignments to maintain group equivalence. Randomisation was executed using IBM SPSS Version 25 to reduce selection bias. The Y Balance Test (YBT) served as the basis for dynamic balance classification, with groupings derived from the highest and lowest performance scores (Garima et al., 2024; Olszewski et al., 2024) which measures dynamic postural control, has been reported to be predictive of lower limb injuries in athletes. It requires subjects to control their body while maintaining a single-leg stance,

which necessitates sufficient strength of the hip muscles to maintain stability. The purpose of the study was to investigate the correlation between the performance of the YBT-LQ and the hip abductor or extensor muscle strength in athletes following anterior cruciate ligament reconstruction surgery (ACLR).

All participants were fully informed of the research procedures and provided written informed consent prior to participation. For those under 18 years of age, additional written consent was obtained from a parent or legal guardian, along with participant assent, by ethical and legal standards. The study was conducted in line with the Declaration of Helsinki and received ethical approval from the Ethics Committee of Universitas Negeri Padang (Approval No: 13.02/KEP-UNP/5/2024).

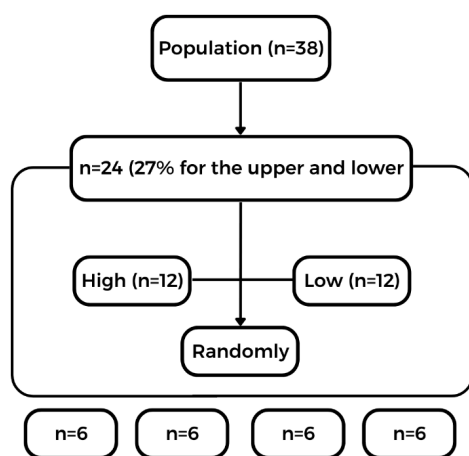


Fig. 1. The research's treatment group assignment process

Training Protocol

The program ran for six weeks, with training sessions conducted three times per week. Each session began with a 10-minute warm-up that included both static and dynamic stretching. The 30-minute agility training included ladder drills that focused on rapid footwork, coordination, direction changes, and explosive power through hurdle jumps. Participants performed three sets of two ladder drill variations—snake jumps and icky shuttle sequences—with 30 seconds of rest between sets. Each session concluded with a 5-minute cool-down that included recovery and active stretching.

Small-sided games (SSG) training utilised a 3v3 format on a 10×10 meter field, with a 2:1 work-to-rest ratio (2 minutes of activity, 1 minute of rest) repeated for 8 sets. Each session began with Team A playing against Team B, and Team C playing against Team D. A 2-minute work interval and a 1-minute rest interval followed each repetition. The cumulative activity duration per repetition is 3 minutes, yielding a total training period of 24 minutes for all 8 repetitions, encompassing both work and rest intervals. This style offers many roles for players, sustains game tension, and improves tactical abilities and physical fitness. The training protocol was designed by the first author, who is a certified fitness trainer.

Training intensity was progressively increased each week, in line with the principles of overload and individualization. During the first two weeks, the emphasis was placed on movement recognition and technical refinement at a moderate intensity level. In the third and fourth weeks, both the complexity and intensity of exercises were elevated, incorporating multi-directional movements and varied speed drills. The final two weeks (weeks five and six) focused on maximal effort, emphasising high-speed execution and rapid transitions. A tapering phase was introduced in week four to allow for recovery and optimal performance in the concluding stage of the intervention.

Measurements and Data Collection

Participants completed the Y-Balance Test – Lower Quarter (YBT-LQ) in the anterior, posterolateral, and postero-medial directions (Bodden et al., 2024; Garima et al., 2024; Olszewski et al., 2024)posterior medial (PM. Prior to testing, the trainer provided standardised verbal instructions and visual demonstrations. During the test, participants placed both hands on the iliac crest, and the foot most frequently used for kicking served as the support foot. The big toe of the support foot was positioned at the intersection of three measuring tapes fixed on the floor. While maintaining balance on the support foot, participants extended the opposite foot to reach as far as possible in the designated direction, touched the ground lightly with the big toe, and then returned to the starting position. To avoid the influence of footwear, all tests were performed barefoot. Following three familiarization trials, participants rested for two minutes before performing three test trials per direction. The order of reaching directions was randomised. Any trial in which balance was lost or the starting position was not properly regained was discarded and repeated. The longest reach distance in each direction was recorded for analysis. Reach distances were normalised to leg length to account for individual differences (Bodden et al., 2024)posterior medial (PM with leg length measured from the anterior superior iliac spine to the centre of the ipsilateral medial malleolus (Amani-Shalamzari et al., 2019; Souilah & Kessouri, 2024)anaerobic power and agility of young futsal players. It was also aim of this study to compare the variations on the internal load markers (heart rate and perceived exertion. A composite score was calculated using the formula: (sum of three directions / [leg length × 3]) × 100 (Ozmen & Aydogmus, 2016).

Agility performance was assessed using the Illinois Agility Test under standardised conditions. Participants began the test lying on their backs with their head aligned to the start line and both hands placed on their shoulders. Upon the command “Go,” the stopwatch was started. The participant quickly rose, sprinted 10 meters forward around a set of cones, ran 10 meters backward, and completed a slalom run through four cones. This was followed by another 10-meter sprint forward and backwards, finishing past the last cone, at which point the timing stopped. Each participant performed three trials with a two-minute rest between trials. The fastest recorded time was used for statistical analysis. All assessments were conducted on a futsal court, with cones positioned at standard intervals, and a trained coach supervised the tests to ensure accuracy and minimise variability.

Statistical Analysis

Descriptive statistics were employed to summarise participant characteristics and evaluate the effects of the training intervention. The Shapiro–Wilk test was used to assess the normality of data distribution, while Levene's test evaluated the homogeneity of variances. A two-way analysis of variance (ANOVA) was conducted to examine the main effects and interaction effects of training modality and dynamic balance on agility performance. Where significant differences were detected, Tukey's post-hoc test was applied to determine specific group differences ($p < 0.05$). Effect sizes were calculated using partial eta squared (η^2) to quantify the magnitude of observed effects. Additionally, 95% confidence intervals were reported to enhance the interpretability and reliability of the findings. All statistical analyses were performed using IBM SPSS Statistics Version 25, with the significance threshold set at $p < 0.05$.

Results

The results showed improvements in agility from pre- to post-test in all groups: A1B1 (18.56 ± 0.18 to 14.57 ± 0.47), A1B2 (18.62 ± 0.12 to 17.08 ± 0.46), A2B1 (18.45 ± 0.09 to 15.99 ± 0.51), and A2B2 (18.63 ± 0.10 to 16.58 ± 0.40). The highest improvement was recorded in group A1B1, with a 21.53% increase ($\Delta = 3.99$ seconds). The A2B1 group showed a 13.33% improvement ($\Delta = 2.46$), ranking second among the groups. Subsequently, the A2B2 group exhibited the third-highest proportion at 11.03% (2.06). The A1B2 group demonstrated an 8.26% improvement ($\Delta = 1.54$), the lowest among the four groups. Further details are presented in Table 2.

Table 2. The mean differences, standard deviations, and percentage improvements in pre-test and post-test agility scores for each treatment group

Agility Method	Agility DB level of each group (n = 5)	Pre Test	Post Test	Δ	%
		$\bar{x} \pm SD$	$\bar{x} \pm SD$		
SSG	High (A1B1)	$18,56 \pm 0,179$	$14,57 \pm 0,470$	3,99	21,53
	Low (A1B2)	$18,62 \pm 0,120$	$17,08 \pm 0,460$	1,54	8,26
LD	High (A2B1)	$18,45 \pm 0,091$	$15,99 \pm 0,510$	2,46	13,33
	Low (A2B2)	$18,63 \pm 0,102$	$16,58 \pm 0,400$	2,06	11,03

Note : Notes: DB = dynamic balance, SSG = small side games, LD = ladder drill, Δ = delta

The study's findings indicated that the average agility scores for groups A1 and A2 were 15.71 ± 1.336 and 16.28 ± 0.464 , respectively. For groups B1 and B2, the means were 15.28 ± 0.876 and 16.83 ± 0.276 , respectively. The mean agility scores for groups A1B1 and A2B1 were 14.57 ± 0.47 and 15.99 ± 0.51 , respectively. Similarly, A1B2 and A2B2 recorded values of 17.08 ± 0.46 and 16.58 ± 0.40 , respectively. Table 2 confirms that the A1B1 group showed the most substantial improvement compared to the other treatment groups. The information is displayed in Table 3 and Figure 2. Table 4 shows that the data met assumptions of normality and homogeneity ($p > 0.05$). Figure 3 presents the Q–Q plot and the detrended Q–Q plot.

Table 3. The outcomes of the agility for each treatment group

Group	n	Min	Max	M $\pm$ SD
A1	12	14,21	17,13	$15,71 \pm 1,336$
A2	12	15,28	16,83	$16,28 \pm 0,464$
B1	12	14,21	16,83	$15,28 \pm 0,876$
B2	12	16,52	17,13	$16,83 \pm 0,276$
A1B1	6	14,21	15,43	$14,57 \pm 0,470$
A2B1	6	15,24	16,83	$15,99 \pm 0,510$
A1B2	6	17,01	17,13	$17,08 \pm 0,460$
A2B2	6	16,52	16,78	$16,58 \pm 0,400$

Note: The dependent variable was agility, measured in seconds. "A1" refers to Small Side Games training, "A2" indicates ladder drill training, "B1" indicates high dynamic balance, "B2" signifies low dynamic balance, "A1B1" describes Small Side Games training with high dynamic balance, "A2B1" relates to ladder drill training with high dynamic balance, "A1B2" describes Small Side Games training with low dynamic balance, and "A2B2" relates to ladder drill with low dynamic balance.

Table 4. Testing for normality and homogeneity

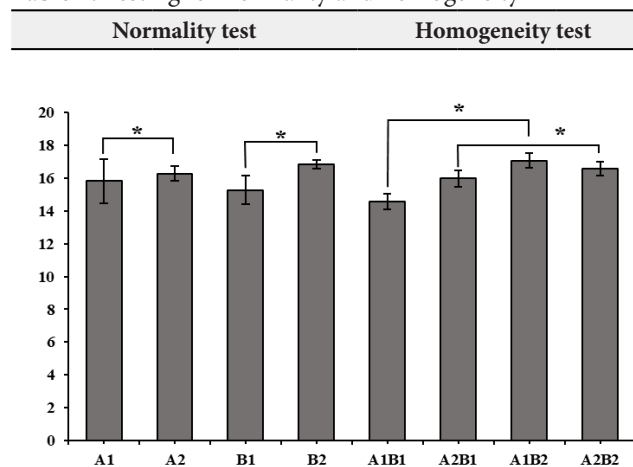


Fig. 2. The mean agility of each treatment group (* $p < 0.05$) in comparison to each group. The statistics are shown with mean and standard deviation values for agility

Shapiro-Wilk			Levene's		
Statistic	df	p	df1	df2	P
0.142	24	0.107	3	20	0.387

Note: The data are normally distributed and homogeneous ($P > 0.05$).

Table 5 presents the results of the two-way ANOVA. The table shows significant differences in agility scores between groups A1 and A2 ($p < 0.05$) and between B1 and B2 ($p < 0.05$). Figure 4 shows a significant interaction between groups A and B ($P < 0.05$). A Tukey post hoc test was conducted to identify which specific group differences in agility were statistically significant.

Table 6 demonstrates that Tukey's post hoc analysis indicated that group A1 outperformed group A2 ($P < 0.05$) in enhancing agility. This was evidenced by the lower mean score of group A1 (15.71) compared to A2 (16.28). Likewise,

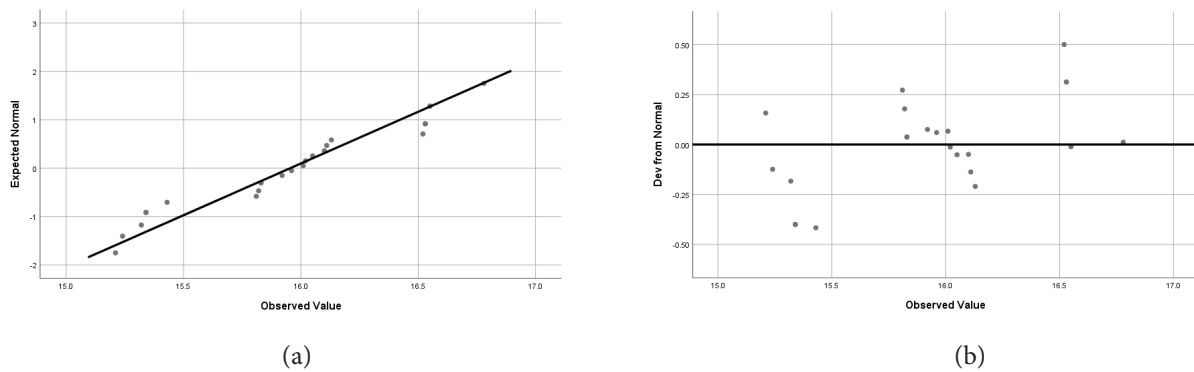


Fig. 3. (a) Normality Q-Q Plot and Detrended Normality Q-Q Plot Graphs

group B1 outperformed group B2 ($p < 0.05$), with mean agility scores of 15.28 and 16.83, respectively. Group A1B1 had significantly better agility than A2B1 ($p < 0.05$), with average times of 14.57 and 15.99 seconds, respectively. Additionally, A2B2 outperformed A1B2 ($p < 0.05$), with mean scores of 16.58 and 17.08, respectively.

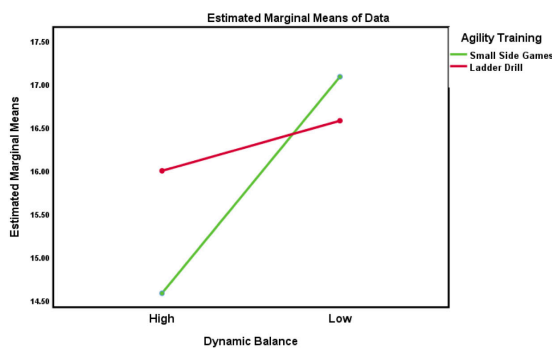


Fig. 4. The relationship between agility training and dynamic balance (DB)

Table 5. Two-way factorial ANOVA

Origin	Type III Sum of Squares	df	Mean Square	F	P
Agility Training (A)	1.238	1	1.238	9.985	.005
Dynami Balance (B)	14.307	1	14.307	115.429	.000
Agility Training (A) * Dynamic Balance (B)	5.578	1	5.578	45.002	.000

Note: Agility served as the dependent variable in this study. A statistically significant difference was found between the SSG (A1) and LD (A2) training groups ($p < 0.05$), indicating that the type of agility training had a measurable impact on agility performance. Additionally, a significant difference was observed between participants with high (B1) and low (B2) dynamic balance levels ($p < 0.05$). Notably, a significant interaction effect between training modality and dynamic balance level ($A \times B$) was identified ($p < 0.05$), demonstrating that the athletes' dynamic balance capacity influenced the effectiveness of agility training.

Discussion

The purpose of this study was to examine the impact of small-sided games and ladder drills on agility, with dynamic

Table 6. Tukey's test

Compare Groups	P	Conclusion
A1 and A2	0.006	Significant
B1 and B2	0.000	Significant
A1B1 and A2B1	0.000	Significant
A1B2 and A2B2	0.001	Significant

Note: The variable that depends on others is agility. The difference is statistically significant ($P < 0.05$).

balance as a moderating factor. The findings revealed that both training methods significantly improved agility, with small-sided games yielding greater improvements, particularly among participants with higher dynamic balance. Additionally, it was found that dynamic balance influenced the level of agility improvement, with players exhibiting higher dynamic balance showing more significant performance improvements.

The higher effectiveness of small-sided games training can be attributed to the specific nature of the training. In small-sided games training, the rules of the game are modified, such as the size of the field, number of players, duration, and verbal encouragement from technical staff (Kunz et al., 2019; Yenes et al., 2025). During training, small-sided games can increase the frequency of movement, acceleration/deceleration density, and optimal changes in direction (Young & Rogers, 2014). Small-sided games require players to make rapid decisions, adapt to dynamic situations, and engage in realistic gameplay, which enhances oxygen uptake, agility, and repeated sprint ability (Chaouachi et al., 2014; Ouertatani et al., 2022). Meanwhile, ladder drill emphasizes quick footwork, proper body control, rhythm, balance, and regular changes of direction (Padrón-Cabo et al., 2021; Prakash et al., 2021). While ladder drills rely on planned and repetitive movements (Bassa et al., 2024), small-sided games demand reactive, unpredictable actions that mirror real match situations (Karahan, 2020).

Small-sided games more effectively replicate match-specific conditions in futsal, thereby enhancing player engagement, motivation, decision-making, and creativity (Amani-Shalamzari et al., 2019; Sekulic et al., 2019). Training that resembles actual game situations can be an effective multi-component training strategy (Mota et al., 2022). Investigating the offensive sequences that lead to goals in elite futsal matches reveals that game situation training is

crucial in the development of physical fitness and technique (Sari et al., 2025; Sarmiento et al., 2016). The results of the current meta-analysis reveal moderate beneficial effects of small games on 10- and 20-meter sprint performance and jump height, as well as significant beneficial effects on agility (Bujalance-Moreno et al., 2019; Clemente, Afonso, et al., 2021). Thus, small-sided games contribute to moderate to significant improvements in physical fitness variables relevant to team sports.

Another important finding was the moderating effect of dynamic balance on agility development. Dynamic balance refers to the ability to maintain balance while moving, such as when changing direction or making sudden movements (Bashir et al., 2019; Neptune & Vistamehr, 2019). In other words, body segments seem to maintain their direction of movement due to inertia, while balance capacity ensures positional stability and subsequent changes in direction (J. Wang et al., 2025). Well-developed dynamic balance enables runners to maintain proper running form and technique, which is crucial for maximizing their speed and power (Dominguez-Navarro et al., 2023; Jouira et al., 2024). Meanwhile, athletes with poor dynamic balance development experience a loss of control, which can lead to inefficient movements, slower times, and increased risk of injury (Wilczyński et al., 2021).

Balance involves performing movements in harmony with the central nervous system and musculoskeletal system (Gouveia et al., 2019; Lesinski et al., 2015). Having good dynamic balance skills indicates that athletes have fewer postural oscillations and greater stabilization (Domínguez-Navarro et al., 2022; Zech et al., 2018). Previous studies have demonstrated a relationship between dynamic balance and reactive agility, with improvements in dynamic balance skills leading to enhanced reactive agility performance (Kocahan et al., 2022; Stirling et al., 2018). However, interestingly, individuals with low dynamic balance benefit from small games and ladder drills. This suggests that structured agility programs are beneficial for all types of balance. Maximizing an athlete's agility potential may require a customized training regimen that considers balance and other physical characteristics.

Coaches, instructors, and sports scientists involved in futsal and related sports will find the findings of this study beneficial. Agility training programs must include workouts that closely replicate the specialized movement patterns of the sport, such as small-sided games, to attain significant enhancements in player performance. Athlete evaluations should encompass supplementary examinations, including balance evaluations, to tailor training loads, progressive programs, and other therapies to individual requirements. This study highlights the potential for further research to determine the optimal combination of training regimens tailored to customized athletes with varying physical attributes. Prolonging intervention durations and integrating diverse training intensities can yield significant insights into the long-term development and preservation of agility during an athlete's career.

Conclusions

This study illustrates that both SSG and LD are efficacious in improving the agility of futsal players. Nonetheless, SSG

demonstrated superior efficacy compared to LD, irrespective of the athletes' dynamic balance proficiency. Athletes with superior dynamic balance demonstrated considerably enhanced agility, highlighting the essential importance of neuromuscular coordination and postural control in agility training adaptations.

These findings underscore the need to develop training programmes tailored to individual neuromuscular profiles. Customising agility interventions according to an athlete's dynamic balance ability may promote more equal and effective performance improvements among various sports groups. Subsequent research ought to investigate supplementary physical and physiological variables, including muscular strength, power output, flexibility, and cardiovascular endurance, and their interactions with agility-centric training. Furthermore, longitudinal studies are essential to evaluate the enduring durability of training-induced enhancements and to determine the most effective combinations of training modalities for various age demographics, competitive tiers, and physical characteristics. These investigations will enhance the formulation of tailored and evidence-based training methods designed to optimise performance in futsal and associated sports.

Acknowledgment

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Conflict of interest

All authors assert the absence of any conflict of interest.

References

- Fahrudin, M. F., Siantoro, G., Kusuma, I. D. M. A. W., Syafii, I., Prianto, D. A., Pramono, B. A., & Fajar, M. K. (2024). Enhancing Anaerobic Endurance in Student Futsal Players through Small-Sided Games Combined with High-Intensity Interval Training. *Physical Education Theory and Methodology*, 24(2), 232-236. <https://doi.org/10.17309/tmfv.2024.2.06>
- Guerra Echevarria, A. D., & Valencia Sánchez, W. G. (2022). Análisis de las acciones ofensivas que resultaron en goles en la copa Conmebol Libertadores de Fútbol Sala Uruguay 2021. *Retos*, 46, 501-510. <https://doi.org/10.47197/retos.v46.93543>
- Taufik, M. S., Solahuddin, S., Pratama, R. R., Iskandar, T., & Ridlo, A. F. (2021). The Effect of Virtual Media-Based Obstacle Run Training on Woman Futsal Player's Dribbling Ability During Covid-19 Pandemic. *Physical Education Theory and Methodology*, 21(4), 299-303. <https://doi.org/10.17309/tmfv.2021.4.02>
- Borges, L., Dermargos, A., Gorjão, R., Cury-Boaventura, M. F., Hirabara, S. M., Abad, C. C., Pithon-Curi, T. C., Curi, R., Barros, M. P., & Hatanaka, E. (2022). Updating futsal physiology, immune system, and performance. *Research in Sports Medicine*, 30(6), 659-676. <https://doi.org/10.1080/15438627.2021.1929221>
- Tanyeri, L., & Öncen, S. (2020). The Effect of Agility and Speed Training of Futsal Players Attending School of Physical

- Education and Sports on Aerobic Endurance. *Asian Journal of Education and Training*, 6(2), 219-225. <https://doi.org/10.20448/journal.522.2020.62.219.225>
- Caetano, F. G., Oliveira, M. J. De, Marche, A. L., Nakamura, F. Y., Cunha, A., & Moura, F. A. (2015). Characterization of the Sprint and Repeated-Sprint Sequences Performed by Professional Futsal Players, According to Playing Position, During Official Matches. *Journal of Applied Biomechanics*, 31(6), 423-429. <https://doi.org/10.1123/jab.2014-0159>
- Oliveira, R. S., Leicht, A. S., Bishop, D., Barbero-Álvarez, J. C., & Nakamura, F. Y. (2013). Seasonal changes in physical performance and heart rate variability in high level futsal players. *International Journal of Sports Medicine*, 34(5), 424-430. <https://doi.org/10.1055/s-0032-1323720>
- Pauli, P. H., de Borba, E. F., da Silva, M. P., Martins, M. V. S., Batista, M. M., & Tartaruga, M. P. (2024). Effects of Complex and Contrast Training on Strength, Power, and Agility in Professional Futsal Players: A Preliminary Study. *Journal of Science in Sport and Exercise*, 6(4), 378-385. <https://doi.org/10.1007/s42978-023-00238-9>
- Selin, K. A., Antari, N. K. A. J., Sugiritama, I. W., & Widnyana, M. (2024). The relationship between agility and dribbling skills among futsal players. *Physical Therapy Journal of Indonesia*, 5(1), 77-80. <https://doi.org/10.51559/ptji.v5i1.195>
- Bompa, T., & Buzzichelli, C. (2015). *Periodization training for sports*, 3e. Human kinetics.
- Fitrian, Z. A., Graha, A. S., Nasrulloh, A., Munir, A., Asmara, M., & Irsyad, N. Y. (2023). The effect of circuit training, fartlek, and small-sided games on maximum oxygen consumption capacity building in futsal players. *Health, Sport, Rehabilitation*, 9(2 SE-Original articles. Sport), 48-60. <https://doi.org/10.34142/HSR.2023.09.02.04>
- Naser, N., Ali, A., & Macadam, P. (2017). Physical and physiological demands of futsal. *Journal of Exercise Science and Fitness*, 15(2), 76-80. <https://doi.org/10.1016/j.jesf.2017.09.001>
- Ilham, I., Agus, A., Tomoliyus, T., Sugiyanto, F. X., Tirtawirya, D., Lumintuarso, R., Berhimpong Willner, M., Putra Alsyaifa, R., Kurniawan, R., Septri, S., Effendi, R., Ayubi, N., Alben Suud Cahyo, A., Perdana Sukma, G., Rifki Sazeli, M., Ndayisenga, J., Sibomana, A., & Jean-Berchmans, B. (2024). Comparative Analysis of Adaptations Progress in VO2max, Leg Power, and Agility among Male and Female Sports Science Students. *Análisis Comparativo del Progreso de las Adaptaciones en VO2max, Potencia de Piernas y Agilidad entre Estudiantes Masculinos y Retos*, 57, 245-257. <https://doi.org/10.47197/retos.v57.107053>
- Rozi, M. F., Resmana, R., Selviani, I., Okilanda, A., Sumantri, R. J., Suganda, M. A., & Suryadi, D. (2023). Imagery and Agility Training: How do They Affect the Reaction Ability of Futsal Goalkeepers? *Physical Education Theory and Methodology*, 23(3), 325-332. <https://doi.org/10.17309/tmfv.2023.3.02>
- Pereira, L. A., Nimphius, S., Kobal, R., Kitamura, K., Turisco, L. A. L., Orsi, R. C., & Oturco, I. R. L. (2018). Relationship Between Change of Direction, Speed, and Power in Male and Female National Olympic Team Handball Athletes. *Journal of Strength and Conditioning Research*, 32(10), 2987-2994. <https://doi.org/10.1519/JSC.0000000000002494>
- Wang, X., Zhang, K., Samsudin, S., Hassan, M. Z., Yaakob, S. N., & Dong, D. (2024). Effects of plyometric training on measures of physical fitness in racket sport athletes: a systematic review and meta-analysis. *Journal of Sports Science and Medicine*, 23(1), 177-195. <https://doi.org/10.7717/peerj.16638>
- Nygaard Falch, H., Guldteig Rædergård, H., & van den Tillaar, R. (2019). Effect of Different Physical Training Forms on Change of Direction Ability: a Systematic Review and Meta-analysis. *Sports Medicine - Open*, 5(1). <https://doi.org/10.1186/s40798-019-0223-y>
- Afonso, J., Da Costa, I. T., Camões, M., Silva, A., Lima, R. F., Milheiro, A., Martins, A., Laporta, L., Nakamura, F. Y., & Clemente, F. M. (2020). The Effects of Agility Ladders on Performance: A Systematic Review. *International Journal of Sports Medicine*, 41(11), 720-728. <https://doi.org/10.1055/a-1157-9078>
- Sattler, T., Sekulić, D., Spasić, M., Perić, M., Krolo, A., Uljević, O., & Kondrić, M. (2015). Analysis of the Association between Motor and Anthropometric Variables with Change of Direction Speed and Reactive Agility Performance. *Journal of Human Kinetics*, 47(1), 137-145. <https://doi.org/10.1515/hukin-2015-0069>
- Guntoro, T. S., Sutoro, Putra, M. F. P., Kurdi, Németh, Z., & Setiawan, E. (2023). The role of anthropometry, physical, psychological and personality for elite athletes in competitive sports. *Pedagogy of Physical Culture and Sports*, 27(4), 331-339. <https://doi.org/10.15561/26649837.2023.0409>
- Serrano, C., Sánchez-Sánchez, J., López-Fernández, J., Hernando, E., & Gallardo, L. (2020). Influence of the playing surface on changes of direction and plantar pressures during an agility test in youth futsal players. *European Journal of Sport Science*, 20(7), 906-914. <https://doi.org/10.1080/17461391.2019.1677780>
- Setiawan, H., Tangkudung, J. W., & Syarif, A. (2017). The Impact Agility Training Toward Dribbling Ability of Futsal Beginners Player. *Journal of Physical Education, Sport, Health and Recreations*, 6(2), 133-139. <https://doi.org/10.15294/active.v9i1.37058>
- Suryadi, D., Okilanda, A., Yanti, N., Suganda, M. A., Mashud, Santika, I. G. P. N. A., Vanagosi, K. D., & Hardinata, R. (2023). Combination of varied agility training with small sided games: How it influences football dribbling skills? *Pedagogy of Physical Culture and Sports*, 27(3), 190-197. <https://doi.org/10.15561/26649837.2023.0302>
- Young, W., & Rogers, N. (2014). Effects of small-sided game and change-of-direction training on reactive agility and change-of-direction speed. *Journal of Sports Sciences*, 32(4), 307-314. <https://doi.org/10.1080/02640414.2013.823230>
- Arslan, E., Kilit, B., Clemente, F. M., Murawska-Ciałowicz, E., Soyulu, Y., Sogut, M., Akca, F., Gokkaya, M., & Silva, A. F. (2022). Effects of Small-Sided Games Training versus High-Intensity Interval Training Approaches in Young Basketball Players. *International Journal of Environmental Research and Public Health*, 19(5). <https://doi.org/10.3390/ijerph19052931>
- Theocharis, K., Stergios, K., George, K., & Zacharoula, P. (2023). The effect of a four-week mesocycle with small side games on the agility and sprinting ability of professional soccer players during in-season. *Journal of Physical Education and Sport*, 23(6), 1449-1455. <https://doi.org/10.7752/jpes.2023.06177>

- Arslan, E., Soyly, Y., Clemente, F., Hazir, T., Kin Isler, A., & Kilit, B. (2021). Short-term effects of on-field combined core strength and small-sided games training on physical performance in young soccer players. *Biology of Sport*, 38(4), 609-616. <https://doi.org/10.5114/biolsport.2021.102865>
- Arslan, E., Orer, G., & Clemente, F. (2020). Running-based high-intensity interval training vs. small-sided game training programs: effects on the physical performance, psychophysiological responses and technical skills in young soccer players. *Biology of Sport*, 37(2), 165-173. <https://doi.org/10.5114/biolsport.2020.94237>
- Clemente, F. M., Ramirez-Campillo, R., Sarmiento, H., Praça, G. M., Afonso, J., Silva, A. F., Rosemann, T., & Knechtle, B. (2021). Effects of Small-Sided Game Interventions on the Technical Execution and Tactical Behaviors of Young and Youth Team Sports Players: A Systematic Review and Meta-Analysis. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.667041>
- Clemente, F. M., Afonso, J., & Sarmiento, H. (2021). Small-sided games: An umbrella review of systematic reviews and meta-analyses. *PLOS ONE*, 16(2), e0247067.
- Koestanto, H. S., Setijino, H., & Mintarto, E. (2017). Model Comparison Exercise Circuit Training Game and Circuit Ladder Drills to Improve Agility and Speed History Article. *Health and Sport Journal of Physical Education, Health and Sport*, 4(2), 78-83. <https://doi.org/10.15294/jpehs.v4i2.6852>
- Padrón-Cabo, A., Rey, E., Kalén, A., & Costa, P. B. (2020). Effects of Training with an Agility Ladder on Sprint, Agility, and Dribbling Performance in Youth Soccer Players. *Journal of Human Kinetics*, 73(1), 219-228. <https://doi.org/10.2478/hukin-2019-0146>
- Sari, A. P., Kurniawan, R., Selviani, I., Okilanda, A., Rifki, M. S., Setiawan, E., Effendi, R., Putra, R. A., Pavlovic, R., Vicente, J., & Jimenez, G. (2024). Maumere exercise therapy and low salt diet in hypertension sufferers: an effort to lower blood pressure. *Retos*, 56, 1016-1025. <https://doi.org/10.47197/retos.v56.106718>
- Selviani, I., Sari, A. P., Gustina, T., Maliza, R. P., Yusriana, A., Qori, A. M., Car, B., Pavlović, R., Jimenez, J. V. G., & Kurniawan, R. (2025). Effectiveness of Kegel Exercise as an Intervention to Reduce Pain in Parturients. *Annals of Applied Sport Science*, 13(Special-Issue), 83-86.
- Wahyono, M., Setijono, H., Wiriawan, O., Akbar Harmono, B., Nuryadi, A., Pranoto, A., Purwoto, S. P., Kholis, M. N., Zawawi, M. A., & Puspodari, P. (2024). The effect of ladder drill exercises on some physical abilities in male junior high school students. *SPORT TK-EuroAmerican Journal of Sport Sciences*, 13(SE), 20. <https://doi.org/10.6018/sportk.554801>
- Bassa, E., Lola, A. C., Melliou, A., Prassa, M., Stavropoulou, G., & Ziogas, N. (2024). Agility Ladder Training Combined With Plyometric or Multi-directional Speed Drills: Short-Term Adaptations on Jump, Speed, and Change of Direction Performance in Young Female Volleyball Players. *Pediatric Exercise Science*, 36(4), 248-257. <https://doi.org/10.1123/pes.2024-0024>
- Gidu, D. V., Badau, D., Stoica, M., Aron, A., Focan, G., Monea, D., Stoica, A. M., & Calota, N. D. (2022). The Effects of Proprioceptive Training on Balance, Strength, Agility and Dribbling in Adolescent Male Soccer Players. *International Journal of Environmental Research and Public Health*, 19(4). <https://doi.org/10.3390/ijerph19042028>
- Sun, M., Soh, K. G., Ma, S., Wang, X., Zhang, J., & Yaacob, A. Bin. (2025). Effects of speed, agility, and quickness (SAQ) training on soccer player performance—a systematic review and meta-analysis. *PLOS ONE*, 20(2), e0316846.
- Ahmed, S., Saraswat, A., & Esht, V. (2022). Correlation of core stability with balance, agility and upper limb power in badminton players: a cross-sectional study. *Sport Sciences for Health*, 18(1), 165-169. <https://doi.org/10.1007/s11332-021-00789-w>
- Szabo, D. A., Neagu, N., & Sopa, I. S. (2020). Research regarding the development and evaluation of agility (balance, coordination and speed) in children aged 9-10 years. *Health, Sports & Rehabilitation Medicine*, 21(2). <https://doi.org/10.26659/pm3.2020.21.1.33>
- Lesinski, M., Hortobágyi, T., Muehlbauer, T., Gollhofer, A., & Granacher, U. (2015). Effects of Balance Training on Balance Performance in Healthy Older Adults: A Systematic Review and Meta-analysis. *Sports Medicine*, 45(12), 1721-1738. <https://doi.org/10.1007/s40279-015-0375-y>
- Sari, A. P., Indika, P. M., Arnando, M., Welis, W., Umar, Bahtra, R., Car, B., Pavlović, R., Jimenez, J. V. G., & Kurniawan, R. (2025). Creative Gymnastics: An Innovative Approach to Blood Pressure Management in Hypertensive Patients. *Annals of Applied Sport Science*, 13(Special-Issue), 57-62.
- Hammami, R., Duncan, M. J., Nebigh, A., Werfelli, H., & Rebai, H. (2022). The Effects of 6 Weeks Eccentric Training on Speed, Dynamic Balance, Muscle Strength, Power, and Lower Limb Asymmetry in Prepubescent Weightlifters. *The Journal of Strength & Conditioning Research*, 36(4). <https://doi.org/10.1519/JSC.0000000000003598>
- Ozmen, T. (2016). Relationship between core stability, dynamic balance and jumping performance in soccer players. *Turkish Journal of Sport and Exercise*, 18(1), 110-113. <https://doi.org/10.15314/tjse.93545>
- Sari, A. P., Kurniawan, R., Indika, P. M., Wulan, T. S., Syafrianto, D., & Sari, D. N. (2023). Exploring the impact of aerobic gymnastics on reducing blood: with hypertension medications vs without hypertension medications. *Journal of Physical Education and Sport*, 23(12), 3253-3263. <https://doi.org/10.7752/jpes.2023.12372>
- Garima, Malhotra, D., Kapoor, G., & Nuhmani, S. (2024). Correlation between hip muscle strength and the lower quarter Y-balance test in athletes following anterior cruciate ligament reconstruction. *Journal of Bodywork and Movement Therapies*, 37, 188-193. <https://doi.org/10.1016/j.jbmt.2023.11.010>
- Olszewski, M., Zajac, B., Mika, A., & Golec, J. (2024). Ankle dorsiflexion range of motion and hip abductor strength can predict Lower Quarter Y-Balance Test performance in healthy males. *Journal of Bodywork and Movement Therapies*, 38, 567-573. <https://doi.org/10.1016/j.jbmt.2024.03.053>
- Bodden, J. G., Needham, R. A., & Chockalingam, N. (2024). Comparing reach distance between the Y-Balance Test-Lower Quarter and Star Excursion Balance Test: Are practitioners using the correct protocol? *Physical Therapy in Sport*, 69, 84-90. <https://doi.org/10.1016/j.ptsp.2024.07.007>
- Amani-Shalamzari, S., Khoshghadam, E., Doniaee, A., Parnow, A., Bayati, M., & Clemente, F. M. (2019). Generic vs. small-sided game training in futsal: Effects on aerobic

- capacity, anaerobic power and agility. *Physiology and Behavior*, 204(February), 347-354. <https://doi.org/10.1016/j.physbeh.2019.03.017>
- Souilah, A., & Kessouri, O. (2024). Comparing Speed-Agility-Quickness and Small-Sided Games Training Effects on Speed and Power Performance in Young Soccer Players. *Polish Journal of Sport and Tourism*, 31(3), 9-17. <https://doi.org/10.2478/pjst-2024-0016>
- Ozmen, T., & Aydogmus, M. (2016). Effect of core strength training on dynamic balance and agility in adolescent badminton players. *Journal of Bodywork and Movement Therapies*, 20(3), 565-570. <https://doi.org/10.1016/j.jbmt.2015.12.006>
- Kunz, P., Engel, F. A., Holmberg, H.-C., & Sperlich, B. (2019). A Meta-Comparison of the Effects of High-Intensity Interval Training to Those of Small-Sided Games and Other Training Protocols on Parameters Related to the Physiology and Performance of Youth Soccer Players. *Sports Medicine - Open*, 5(1), 7. <https://doi.org/10.1186/s40798-019-0180-5>
- Yenes, R., Pratama, A. O., Astuti, Y., Orhan, B. E., Kaur, D., Beulah, S., & Valappil, I. N. K. (2025). Small-Side Games (SSG) and Conventional Training : How It Affects the Improvement of Shooting Ability of Young Basketball Athletes ? *International Journal of Human Movement and Sports Sciences*, 13(2), 274-279. <https://doi.org/10.13189/saj.2025.130203>
- Chaouachi, A., Chtara, M., Hammami, R., Chtara, H., Turki, O., & Castagna, C. (2014). Multi-directional Sprints and Small-Sided Games Training Effect on Agility and Change of Direction Abilities in Youth Soccer. *The Journal of Strength & Conditioning Research*, 28(11). <https://doi.org/10.1519/JSC.0000000000000505>
- Ouertatani, Z., Selmi, O., Marsigliante, S., Aydi, B., Hammami, N., & Muscella, A. (2022). Comparison of the Physical, Physiological, and Psychological Responses of the High-Intensity Interval (HIIT) and Small-Sided Games (SSG) Training Programs in Young Elite Soccer Players. *International Journal of Environmental Research and Public Health*, 19(21). <https://doi.org/10.3390/ijerph192113807>
- Padrón-Cabo, A., Lorenzo-Martínez, M., Pérez-Ferreirós, A., Costa, P. B., & Rey, E. (2021). Effects of Plyometric Training with Agility Ladder on Physical Fitness in Youth Soccer Players. *International Journal of Sports Medicine*, 42(10), 896-904. <https://doi.org/10.1055/a-1308-3316>
- Prakash, K. V. S., Sadvika, P. D., & Chakravarthi, C. A. (2021). Effectiveness of Ladder Training Versus Plyometric Training Program on Agility in Kabaddi Players. *International Journal of Health Sciences and Research*, 11(11), 320-334. <https://doi.org/10.52403/ijhsr.20211138>
- Karahan, M. (2020). Effect of skill-based training vs. small-sided games on physical performance improvement in young soccer players. *Biology of Sport*, 37(3), 305-312. <https://doi.org/10.5114/biolSport.2020.96319>
- Sekulic, D., Foretic, N., Gilic, B., Esco, M. R., Hammami, R., Uljevic, O., Versic, S., & Spasic, M. (2019). Importance of agility performance in professional futsal players; reliability and applicability of newly developed testing protocols. *International Journal of Environmental Research and Public Health*, 16(18). <https://doi.org/10.3390/ijerph16183246>
- Mota, T., Afonso, J., Sá, M., & Clemente, F. M. (2022). An Agility Training Continuum for Team Sports: From Cones and Ladders to Small-Sided Games. *Strength & Conditioning Journal*, 44(1). <https://doi.org/10.1519/SSC.0000000000000653>
- Sarmiento, H., Paul, B., M. Teresa, A., Tiago, P., Rui, R., & and Campaniço, J. (2016). Quantifying the offensive sequences that result in goals in elite futsal matches. *Journal of Sports Sciences*, 34(7), 621-629. <https://doi.org/10.1080/02640414.2015.1066024>
- Bujalance-Moreno, P., Pedro Ángel, L.-R., & and García-Pinillos, F. (2019). A systematic review on small-sided games in football players: Acute and chronic adaptations. *Journal of Sports Sciences*, 37(8), 921-949. <https://doi.org/10.1080/02640414.2018.1535821>
- Bashir, S. F., Nuhmani, S., Dhall, R., & Muaidi, Q. I. (2019). Effect of core training on dynamic balance and agility among Indian junior tennis players. *Journal of Back and Musculoskeletal Rehabilitation*, 32(2), 245-252. <https://doi.org/10.3233/BMR-170853>
- Neptune, R. R., & Vistamehr, A. (2019). Dynamic Balance During Human Movement: Measurement and Control Mechanisms. *Journal of Biomechanical Engineering*, 141(7). <https://doi.org/10.1115/1.4042170>
- Wang, J., Qin, Z., Zhang, Q., & Wang, J. (2025). Lower limb dynamic balance, strength, explosive power, agility, and injuries in volleyball players. *Journal of Orthopaedic Surgery and Research*, 20(1), 211. <https://doi.org/10.1186/s13018-025-05566-w>
- Dominguez-Navarro, F., Casaña, J., Perez-Dominguez, B., Ricart-Luna, B., Cotolí-Suárez, P., & Calatayud, J. (2023). Dynamic balance and explosive strength appears to better explain single leg hop test results among young elite female basketball athletes. *Scientific Reports*, 13(1), 5476. <https://doi.org/10.1038/s41598-023-31178-7>
- Jouira, G., Alexe, D. I., Tohänean, D. I., Alexe, C. I., Tomozei, R. A., & Sahli, S. (2024). The Relationship between Dynamic Balance, Jumping Ability, and Agility with 100 m Sprinting Performance in Athletes with Intellectual Disabilities. *Sports*, 12(2). <https://doi.org/10.3390/sports12020058>
- Wilczyński, B., Hincă, J., Ślęzak, D., & Zorena, K. (2021). The Relationship between Dynamic Balance and Jumping Tests among Adolescent Amateur Rugby Players. A Preliminary Study. *International Journal of Environmental Research and Public Health*, 18(1). <https://doi.org/10.3390/ijerph18010312>
- Gouveia, É. R., Gouveia, B. R., Ihle, A., Kliegel, M., Marques, A., & Freitas, D. L. (2019). Balance and mobility relationships in older adults: A representative population-based cross-sectional study in Madeira, Portugal. *Archives of Gerontology and Geriatrics*, 80, 65-69. <https://doi.org/10.1016/j.archger.2018.10.009>
- Domínguez-Navarro, F., Benitez-Martínez, J. C., Ricart-Luna, B., Cotolí-Suárez, P., Blasco-Igual, J. M., & Casaña-Granell, J. (2022). Impact of hip abductor and adductor strength on dynamic balance and ankle biomechanics in young elite female basketball players. *Scientific Reports*, 12(1), 3491. <https://doi.org/10.1038/s41598-022-07454-3>
- Zech, A., Meining, S., Hötting, K., Liebl, D., Mattes, K., & Hollander, K. (2018). Effects of barefoot and footwear conditions on learning of a dynamic balance task: a

randomized controlled study. *European Journal of Applied Physiology*, 118(12), 2699-2706.
<https://doi.org/10.1007/s00421-018-3997-6>

Kocahan, T., Güraslan, H., Kabak, B., Hasanoğlu, A., & Akinoğlu, B. (2022). Examining the Relationship Between Dynamic Balance Skill and Reactive Agility Performance

in Karate Athletes. *Turkish Journal of Sport and Exercise*, 24(2), 187-192.

Stirling, L., Eke, C., & Cain, S. M. (2018). Examination of the perceived agility and balance during a reactive agility task. *PLOS ONE*, 13(6), e0198875.

Вплив шеститижневої інтервенції з використанням ігор неповними складами (ІНС), тренувань з координаційною драбиною та динамічної рівноваги на спритність юних футзалістів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 6 табл., 4 рис., 73 джерел.

Мета дослідження. Мета цього дослідження полягала в порівнянні впливу ігор неповними складами (ІНС) та тренувань з координаційною драбиною (ТКД) на спритність футзалістів з різним рівнем динамічної рівноваги (ДР), яка розглядалася як модеруюча змінна.

Матеріали та методи. Двадцять чотири футзалісти чоловічої статі (середній вік: 17.1 ± 0.8 років) розподілено за методом рандомізації на групи ІНС або ТКД із подальшою класифікацією за високим або низьким рівнем ДР, що дозволило сформувати чотири експериментальні підгрупи. Протягом 6-тижневої інтервенції (3 сесії на тиждень) учасники проходили специфічні тренування, спрямовані на розвиток спритності, яка оцінювалася за допомогою Іллінойського тесту на спритність. Для вимірювання динамічної рівноваги використовувався Y баланс-тест. З метою оцінки основних і взаємодійних ефектів застосовано двофакторний дисперсійний аналіз з використанням post hoc тесту Тьюкі ($p < 0.05$).

Результати. Обидві тренувальні інтервенції призвели до значного поліпшення показників спритності ($p < 0.05$). Гравці з високим рівнем ДР продемонстрували найсуттєвіші результати після проведення ІНС (покращення на 21.5 %), тоді як гравці з низьким рівнем ДР досягли більших успіхів після виконання ТКД (покращення на 11.0 %). Між типом тренування та рівнем ДР спостерігалася значна взаємодія, що свідчить про залежність адаптаційних процесів спритності від рівня майстерності спортсменів у підтримці рівноваги.

Висновки. Ефективність тренування спритності у футзалістів модується індивідуальною здатністю до динамічної рівноваги. ІНС є особливо ефективним методом для гравців з високим рівнем ДР через репрезентативні для гри вимоги до рухів, тоді як ТКД забезпечує структуроване поліпшення для гравців з низьким рівнем ДР. Зазначені результати підтверджують доцільність впровадження індивідуальних стратегій тренування на основі нервово-м'язових профілів задля оптимізації розвитку спритності у футзалі.

Ключові слова: ігри неповними складами, тренування з координаційною драбиною, динамічна рівновага, спритність, футзал.

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Review Article

The Effectiveness of Martial Arts Interventions in Autism Spectrum Disorder: A Scoping Review

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Abstract

Background. Autism Spectrum Disorder (ASD) is a neurodevelopmental condition marked by social-communication difficulties, restricted interests, and motor coordination challenges. In recent years, structured physical activity programs — particularly martial arts — have gained attention as promising complementary interventions for youth with ASD.

Objectives. This scoping review aimed to map and synthesize empirical evidence on martial arts interventions for individuals aged 6–18 years with ASD.

Materials and Methods. A systematic search of PubMed, Scopus, and Web of Science databases was conducted between January and March 2025.

Results. After screening 89 records and applying rigorous eligibility filters (regarding study design, diagnosis, age range, and sample size ≥ 10), only two studies were included. Both studies reported statistically significant improvements in motor coordination and balance following structured martial arts programs, specifically karate kata ($n = 30$) and Tai Chi Chuan ($n = 18$). However, methodological limitations such as a lack of blinding and small sample sizes were noted. Broader literature supports additional benefits of martial arts on social engagement, executive function, emotional regulation, and parental outcomes, although the two included trials did not capture these effects.

Conclusions. Despite the limited number of eligible RCTs, current evidence suggests that martial arts interventions may offer meaningful benefits across multiple developmental domains in children and adolescents with ASD. Further well-designed and rigorous trials are needed to confirm and expand these findings.

Keywords: Autism Spectrum Disorder (ASD), martial arts, karate, Tai Chi, motor coordination, neurodevelopmental disorders (NDDs).

Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by deficits in social interaction, communication, and repetitive behaviors (American Psychiatric Association, 2022).

In recent years, there has been growing interest in the use of structured physical activity interventions, particularly martial arts, as complementary therapeutic approaches for individuals with ASD.

Among various physical modalities, martial arts have emerged as a promising approach to enhance social and behavioral outcomes in this population. Recent research suggests that martial arts-based interventions not only support motor skill development but also promote improvements in behavioral self-regulation, communication abilities, and social participation (Bahrami et al., 2016; Rivera et al., 2020a). Additionally, empirical work by Pusponero et al. (2016) confirmed that children with ASD who exhibited lower gross motor skills also scored significantly lower in measures of socialization, reinforcing the rationale for motor-based interventions aimed at supporting broader developmental outcomes.

Children and adolescents with ASD engage in significantly less physical activity than their neurotypical peers, underscoring the need for structured and engaging interventions such as martial arts (Gehricke et al., 2020).

Martial arts programs offer an organized, repetitive, and highly structured environment, which may align with the sensory and behavioral needs of children and adolescents on the spectrum with documented benefits in reducing stereotyped behaviors (Bahrami et al., 2012).

Furthermore, the discipline and concentration required in martial arts may boost executive functions such as attention, inhibitory control, and cognitive flexibility (Amonkar et al., 2021).

A recent network meta-analysis verified the specific advantages of martial arts in enhancing inhibitory control among children with ASD (Hou et al., 2024).

These findings are especially important given the high rate of executive dysfunction in youth with ASD. Wang et al. (2025) analysed 23 randomised controlled trials to assess how physical exercise, including martial arts, affects social, motor, and behavioural outcomes in children with ASD. Their analysis showed notable improvements in motor coordination- particularly in younger children- behavioral regulation across different ages, and mixed but encouraging effects on social skills, emphasising the importance of tailored program design and implementation. Similarly, a recent systematic review and meta-analysis by Costanza et al. (2025) further supports the efficacy of structured physical activity programs in enhancing social communication, emotional regulation, and adaptive functioning in children with ADHD (Attention-Deficit/Hyperactivity Disorder), highlighting martial arts as a particularly promising modality within this broader category.

Given this background, the present review aims to synthesize recent empirical evidence on the impact of martial arts programs on motor, social, cognitive, and behavioral domains in children and adolescents with ASD. It also considers secondary outcomes, such as sleep quality and caregiver well-being, providing a comprehensive view of the therapeutic potential of martial arts in neurodevelopmental contexts.

Materials and Methods

This scoping review aimed to map the existing evidence on martial arts interventions for children and adolescents with Autism Spectrum Disorder (ASD). We conducted searches across three electronic databases—PubMed, Scopus, and Web of Science Core Collection—between January and March 2025. In each database, we employed parallel search strategies focusing on ASD and martial arts terms in titles, abstracts, and keywords. In PubMed, we specifically searched titles and abstracts using the string “autism spectrum disorder” OR “ASD” AND “martial arts” OR “karate” OR “taekwondo” OR “judo” OR “kung fu,” with filters for human studies and articles in English. In Scopus, we employed an analogous advanced search query—TITLE-ABS-KEY (“autism spectrum disorder” OR ASD) AND TITLE-ABS-KEY (“martial arts” OR karate OR taekwondo OR judo OR “kung fu”)—with additional filters for articles (DOCTYPE = “ar”), English language, and publication year after 2004. For the Web of Science Core Collection, we applied TS= (“autism spectrum disorder” OR ASD) AND TS= (“martial arts” OR karate OR taekwondo OR judo OR “kung fu”), limiting the results to articles published in English from 2005 to 2025.

All retrieved records were exported into a reference-management software, where duplicates were automatically identified and removed. Two reviewers (CC and VM) then independently screened the titles and abstracts of each record to determine eligibility according to our a priori criteria: (1) randomized controlled trials (RCTs) or quasi-experimental designs; (2) participants aged 6–18 years with a confirmed ASD diagnosis; (3) sample size of at least 10 participants; and (4) a structured martial arts program (for example, karate, taekwondo, judo, or kung fu). Discrepancies during screening were resolved through discussion until consensus was reached.

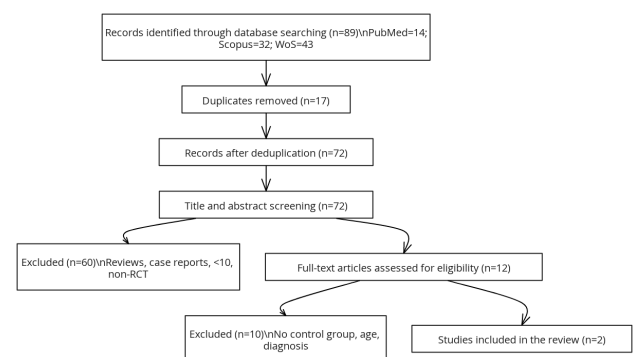


Fig. 1. Study selection flow

Full texts of studies deemed potentially eligible were retrieved and assessed in duplicate. We extracted key study characteristics into a standardized charting form, recording participant demographics, details of the martial arts intervention (frequency, duration, and specific techniques), comparator conditions (e.g., alternative exercise or no-treatment control), and outcome measures. To evaluate methodological rigor, we applied the CONSORT 2010 checklist, noting whether each trial reported on randomization procedures, allocation concealment,

Table 1. Characteristics and key outcomes of included controlled studies of martial arts in children with ASD

Study	Design	N	Age Range	Intervention	Comparator	Key Outcomes	Methodological Notes
Ansari et al. (2021)	RCT	30	6–18	10-week karate kata	Aquatic therapy & control	22% increase in balance (static & dynamic)	Trial registered, randomization clear, no blinding reported
Sarabzadeh et al. (2019)	Quasi-experimental	18	6–12	6-week Tai Chi Chuan	Control	18% improvement in balance subscales	Randomization described, no trial registration, no blinding

blinding, sample-size calculation, trial registration, and intention-to-treat analysis. Given the small number of fully eligible trials, we did not pursue a meta-analysis but instead offered a structured narrative synthesis of the findings.

Results

The database searches yielded a total of 89 records (PubMed: 14; Scopus: 32; Web of Science: 43). After removing 17 duplicates, 72 unique records remained for title and abstract screening. Of these, 60 were excluded (reviews, case reports, qualitative studies, protocols, and non-RCT/quasi-experimental designs with $n < 10$). Twelve full-text articles were then assessed for eligibility; 10 were excluded for failing to meet one or more inclusion criteria (no control group, unclear ASD diagnosis, age outside 6–18 years, or insufficient sample size). Ultimately, two studies satisfied all inclusion criteria and were included in this scoping review.

Summary of Findings

Only two controlled trials met our strict inclusion criteria. Both showed that structured martial arts training—karate kata in one RCT ($n = 30$) and Tai Chi Chuan in one quasi-RCT ($n = 18$)—produced statistically significant improvements in balance and motor coordination among children with ASD. Methodological limitations common to both studies (absence of blinding, small samples, incomplete registration) highlight the need for larger, more rigorous trials.

Discussion

Although only two studies met the inclusion criteria for this scoping review, their selection reflects the high level of methodological stringency we adopted. We aimed to synthesize the most reliable evidence available. Nonetheless, during full-text screening, we reviewed a total of twelve articles that examined martial arts interventions in youth with ASD.

In order to contextualize the findings of the two eligible trials within the broader empirical landscape, we also examined the additional ten full-text studies excluded from final inclusion. These studies explored various martial arts interventions and reported outcomes across five key domains: motor skills, social functioning, communication, cognitive/executive functioning, and secondary physiological or psychosocial effects. The following section summarizes the larger body of evidence, categorised by martial art type and outcome area.

Mixed martial arts (MMA), as a structured and socially engaging activity, has demonstrated notable

benefits for children with ASD. Phung & Goldberg (2021) studies revealed substantial improvements in social skills and significant reductions in problem behaviors in boys, underscoring the potential of MMA to promote social adaptation and emotional self-regulation. Moreover Phung (2017) reported improvements in executive functioning and social communication following MMA participation, indicating broader cognitive and behavioral effects when martial arts are delivered in a consistent and inclusive setting.

Karate-based interventions have shown promising effects across multiple developmental domains in children with ASD.

Greco & Ronzi (2020) reported significant gains in emotional regulation, social engagement, and executive functioning, along with notable reductions in anxiety and sensory hypersensitivity. Similarly, (Ansari et al., 2021) demonstrated that kata techniques, characterized by their repetitive and focused motor sequences, enhanced both static and dynamic balance in children with ASD—highlighting their relevance for sensorimotor development. Further supporting these findings, Maussier et al. (2024) through the “KATAUTISM” inclusive school program, reported positive outcomes in social inclusion, gross motor coordination, and behavioral self-regulation following a 24-week karate and judo curriculum. Additionally, Bahrami et al. (2016) observed significant improvements in communication skills after 14 weeks of karate training, with effects that were maintained at one-month follow-up, suggesting the potential for sustained impact on core social communication deficits.

Taekwondo, a disciplined Korean martial art characterized by structured and dynamic movement patterns, has also yielded promising results for children with ASD.

Kim et al. (2024) reported significant improvements in balance and motor coordination following an 8-week Taekwondo program, with 92% adherence, suggesting both effectiveness and acceptability among participants. Mok et al. (2024) found that parents observed enhanced physical ability and social communication in children after a Taekwondo protocol was integrated with music therapy. Scamardella et al. (2025) highlighted how specific anthropometric traits, such as greater limb length and height, confer a biomechanical advantage in taekwondo, supporting its potential for tailored interventions in youth development contexts.

Several studies have explored the impact of judo programs on youth with ASD, highlighting both physical and psychosocial benefits. Garcia et al. (2020) demonstrated that an 8-week judo intervention not only doubled participants' physical activity levels but also improved social behaviors. Rivera et al. (2020b), using a mixed-method design, reported increased self-confidence, and reduced behavioral challenges.

Family-centred judo interventions were also associated with improved sleep quality, reducing sleep latency and night awakenings, as well as parental benefits, including better communication, bonding, and reduced stress (Garcia, Murray, et al., 2024). A parallel study by Garcia, Hahs-Vaughn, et al. (2024) noted reduced parenting stress and enhanced emotional connection, underscoring the role of co-participation. Pierantozzi et al. (2022) found that a six-month adapted judo program resulted in significant improvements in cardiorespiratory fitness and a reduction in the waist-to-height ratio. Morales et al. (2021) highlighted the need for continuity, noting that gains in social communication and emotional regulation diminished after program interruption during the COVID-19 lockdown.

Recent studies have explored novel adaptations of martial arts better to support the unique neurodevelopmental profiles of children with ASD.

In a complementary pilot study, Yip, 2019 piloted a rhythmic cueing protocol designed to enhance motor skills through synchronized auditory-motor training. The intervention, which combined traditional martial arts movements with rhythmic stimuli (e.g., metronome beats), and reported improvement in bilateral coordination and balance over four weeks. Supporting these findings, Amonkar et al. (2021) conducted a systematic review of creative movement therapies, including martial arts, and found moderate to significant effects on both social and cognitive outcomes.

Bittner et al., (2017) explored tech-assisted exercise using the ExerciseBuddy app and found enhanced physiological engagement during locomotor tasks, suggesting that tech-assisted learning tools may improve the effectiveness of motor interventions. This approach may also be extended to martial arts programs, enriching instruction with visual and interactive support.

Sarabzadeh et al. (2019) found that a six-week Tai Chi Chuan program significantly improved balance and ball skills in children with ASD, highlighting the potential of slow, structured movement practices to support sensorimotor integration.

To further synthesize the evidence, the following sections summarize the key findings within each of the five domains outlined above.

Motor Skill Development: Improvements in motor coordination and balance emerged as the most consistent

outcome across interventions. Both included trials, as well as several excluded studies, demonstrated that structured martial arts programs—particularly those involving repetitive and controlled movements, such as kata or Tai Chi—can enhance postural stability, bilateral coordination, and sensorimotor integration. These gains are especially relevant given the high prevalence of gross and fine motor delays in children with ASD.

Social and Behavioral Outcomes: Numerous studies reported enhanced peer engagement, reductions in disruptive behaviors, and improved emotional self-regulation following martial arts participation. The inherently social and ritualized nature of these practices may foster prosocial behavior, cooperation, and self-control. Programs delivered in group settings appear particularly beneficial for reinforcing social reciprocity and reducing isolation.

Communication and Language Skills: Although less frequently addressed, communication outcomes showed encouraging trends. Improvements were noted in both expressive and receptive skills, especially when martial arts were integrated with other modalities such as music or visual supports. Structured instruction, imitation, and joint attention embedded in martial arts sessions may provide a naturalistic context for communication development.

Cognitive and Executive Function: Enhancements in attention, inhibitory control, and mental flexibility were reported across several studies, particularly those involving MMA and karate. Martial arts' cognitive demands—rule-following, sequential action, and goal-directed behavior—may support executive functioning through embodied learning processes. These effects are of clinical interest given the executive deficits often observed in ASD.

These findings align with emerging literature suggesting that motor and executive deficits often co-occur across neurodevelopmental disorders. The potential link between motor coordination difficulties and broader neurodevelopmental vulnerabilities has also been recently underscored in an editorial by Esposito et al. (2025), which discusses overlapping pathophysiological mechanisms in developmental coordination disorder (DCD) and epilepsy—highlighting shared deficits in motor and executive functioning as well as psychosocial outcomes.

Sleep and Psychosocial Functioning: Some studies have explored indirect outcomes, including sleep quality, caregiver stress, and family bonding. Interventions involving parental

Table 2. Summary of effects by martial-arts modality and outcome domains in children with ASD

Martial Art	Motor Skills	Social Functioning	Communication	Executive Function	Sleep / Psychosocial
Karate	✓✓ (Ansari, Maussier)	✓✓ (Greco, Maussier)	✓ (Bahrami)	✓✓ (Greco, Phung)	χ
Judo	✓ (Pierantozzi)	✓✓ (Garcia, Rivera)	χ	χ	✓✓ (Garcia, Morales)
Taekwondo	✓✓ (Kim, Mok)	✓ (Mok)	✓ (Mok)	χ	χ
Mixed Martial Arts (MMA)	χ	✓✓ (Phung)	✓ (Phung)	✓ (Phung)	χ
Tai Chi Chuan	✓ (Sarabzadeh)	χ	χ	χ	χ
Other/Innovative (e.g., rhythmic cueing, tech-assisted)	✓ (Yip, Bittner)	✓ (Amonkar)	✓ (Amonkar)	✓ (Amonkar)	χ

Legend: ✓ = improvement reported in at least one study; χ = no improvement reported or not assessed; ✓✓ = improvement reported in more than one study

co-participation (e.g., judo) were associated with improved sleep latency and emotional connectedness. These findings suggest that martial arts may offer broader psychosocial benefits, particularly when embedded in a family-centred or community-based approach.

Overall, the findings presented provide a compelling rationale for incorporating martial arts into ASD interventions. A more thorough understanding of long-term outcomes and underlying mechanisms, however, remains an important goal for future research.

Conclusions

This scoping review supports the growing view that martial arts represent a promising, multidimensional intervention for children and adolescents with Autism Spectrum Disorder (ASD). Across a range of structured programs, evidence indicates improvements in motor coordination, social interaction, communication, and executive functioning. Family-based interventions also appear to confer psychosocial benefits for caregivers, enhancing emotional connection and household cohesion.

The unique combination of physical engagement, behavioral structure, cognitive challenge, and social interaction embedded in martial arts may explain their wide-ranging effects. These findings support the integration of martial arts into educational, therapeutic, and recreational contexts as part of a holistic approach to neurodevelopmental care.

Nonetheless, methodological limitations—including small samples, heterogeneity in design, and limited longitudinal data—call for more rigorous, multisite trials. Future studies should aim to refine program protocols, explore neurobiological mechanisms, assess the sustainability of effects, and evaluate innovative delivery formats such as tech-assisted tools and video modelling. Martial arts should therefore be considered an evidence-informed, versatile strategy within multidisciplinary support frameworks for individuals with ASD.

Conflict of Interest

The authors declare no competing interests.

References

- American Psychiatric Association. (2022). *Diagnostic and Statistical Manual of Mental Disorders: DSM-5-TR* (Fifth edition). American Psychiatric Association Publishing.
- Bahrami, F., Movahedi, A., Marandi, S. M., & Sorensen, C. (2016). The Effect of Karate Techniques Training on Communication Deficit of Children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 46(3), 978-986. <https://doi.org/10.1007/S10803-015-2643-Y/METRICS>
- Rivera, P., Renziehausen, J., & Garcia, J. M. (2020a). Effects of an 8-Week Judo Program on Behaviors in Children with Autism Spectrum Disorder: A Mixed-Methods Approach. *Child Psychiatry and Human Development*, 51(5), 734-741. <https://doi.org/10.1007/S10578-020-00994-7>
- Pusponegoro, H. D., Efar, P., Soedjatmiko, Soebadi, A., Firmansyah, A., Chen, H. J., & Hung, K. L. (2016). Gross Motor Profile and Its Association with Socialization Skills in Children with Autism Spectrum Disorders. *Pediatrics and Neonatology*, 57(6), 501-507. <https://doi.org/10.1016/j.pedneo.2016.02.004>
- Gehricke, J. G., Chan, J., Farmer, J. G., Fenning, R. M., Steinberg-Epstein, R., Misra, M., Parker, R. A., & Neumeyer, A. M. (2020). Physical activity rates in children and adolescents with autism spectrum disorder compared to the general population. *Research in Autism Spectrum Disorders*, 70, 101490. <https://doi.org/10.1016/J.RASD.2019.101490>
- Bahrami, F., Movahedi, A., Marandi, S. M., & Abedi, A. (2012). Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. *Research in Developmental Disabilities*, 33(4), 1183-1193. <https://doi.org/10.1016/j.ridd.2012.01.018>
- Amonkar, N., Su, W. C., Bhat, A. N., & Srinivasan, S. M. (2021). Effects of Creative Movement Therapies on Social Communication, Behavioral-Affective, Sensorimotor, Cognitive, and Functional Participation Skills of Individuals With Autism Spectrum Disorder: A Systematic Review. *Frontiers in Psychiatry*, 12, 722874. <https://doi.org/10.3389/FPSYT.2021.722874/FULL>
- Hou, Y., Song, Z., Deng, J., & Song, X. (2024). The impact of exercise intervention on social interaction in children with autism: A network meta-analysis. *Frontiers in Public Health*, 12, 1399642. <https://doi.org/10.3389/fpubh.2024.1399642>
- Wang, Y., Qian, G., Mao, S., & Zhang, S. (2025). The impact of physical exercise interventions on social, behavioral, and motor skills in children with autism: a systematic review and meta-analysis of randomized controlled trials. *Frontiers in Pediatrics*, 13, 1475019. <https://doi.org/10.3389/fped.2025.1475019>
- Costanza, C., Colecchia, F. P., Polito, R., Monda, M., Carotenuto, M., Messina, G., Monda, A., Mancini, N., Moscatelli, F., Bargiacchi, G., & Ruberto, M. (2025). Martial Arts and ADHD: A Narrative Review of Cognitive, Behavioral, and Epigenetic Effects. *Physical Education Theory and Methodology*, 25(3), 684-690. <https://doi.org/10.17309/tmfv.2025.3.26>
- Ansari, S., Hosseinkhanzadeh, A. A., AdibSaber, F., Shojaei, M., & Daneshfar, A. (2021). The Effects of Aquatic Versus Kata Techniques Training on Static and Dynamic Balance in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 51(9), 3180-3186. <https://doi.org/10.1007/S10803-020-04785-W>
- Sarabzadeh, M., Azari, B. B., & Helalizadeh, M. (2019). The effect of six weeks of Tai Chi Chuan training on the motor skills of children with Autism Spectrum Disorder. *Journal of Bodywork and Movement Therapies*, 23(2), 284-290. <https://doi.org/10.1016/J.JBMT.2019.01.007>
- Phung, J. N., & Goldberg, W. A. (2021). Mixed martial arts training improves social skills and lessens problem behaviors in boys with Autism Spectrum Disorder. *Research in Autism Spectrum Disorders*, 83, 101758. <https://doi.org/10.1016/j.rasd.2021.101758>
- Phung, J. N. (2017). *Mixed Martial Arts as a Means to Improve Social Communication and Executive Functioning in Children with Autism Spectrum Disorder* (Doctoral dissertation, University of California, Irvine).
- Greco, G., & De Ronzi, R. (2020). Effect of Karate training on social, emotional, and executive functioning in children with autism spectrum disorder. *Journal of Physical Education and Sport*, 20(4), 1637-1645. <https://hdl.handle.net/11586/472022>

- Maussier, N., Pierantozzi, E., Manno, R., & Magnanini, A. (2024). *Judo and karate in primary school as a means for the improvement of social inclusion for autistic children*. <https://doi.org/10.21203/RS.3.RS-4836261/V1>
- Mok, K. M., Sze, C. H. H., Yu, C. C. W., Mak, E., Chan, D. F. Y., & Wong, S. W. L. (2024). A Self-Narrative Study: Changes in Physical Ability and Social Communication in Children with Autism through Taekwondo Training with Elements of Music Therapy from the Parents' Perspective. *Behavioral Sciences*, 14(7), 530. <https://doi.org/10.3390/BS14070530>
- Scamardella, F., Limone, P., Peluso, C. F., Amato, G., Latino, F., & Tafuri, F. (2025). Taekwondo: Anthropometric characteristics and biomechanical advantage. *Journal of Physical Education and Sport*, 25(2), 218-226. <https://doi.org/10.7752/jpes.2025.02025>
- Garcia, J. M., Leahy, N., Rivera, P., Renziehausen, J., Samuels, J., Fukuda, D. H., & Stout, J. R. (2020). Brief Report: Preliminary Efficacy of a Judo Program to Promote Participation in Physical Activity in Youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 50(4), 1418-1424. <https://doi.org/10.1007/s10803-019-04338-w>
- Rivera, P., Renziehausen, J., & Garcia, J. M. (2020b). Effects of an 8-Week Judo Program on Behaviors in Children with Autism Spectrum Disorder: A Mixed-Methods Approach. *Child Psychiatry and Human Development*, 51(5), 734-741. <https://doi.org/10.1007/s10578-020-00994-7>
- Garcia, J. M., Murray, M., Brazendale, K., Rice, D. J., & Fukuda, D. H. (2024). Effects of a family judo program on sleep quality in youth with Autism Spectrum Disorder. *Sleep Medicine*, 115, 152-154. <https://doi.org/10.1016/j.sleep.2023.11.031>
- Garcia, J. M., Hahs-Vaughn, D., Murray, M., Perry, C., Brazendale, K., Rice, D. J., & Fukuda, D. H. (2024). The physical and psychosocial benefits of a family judo program for parents of children with Autism Spectrum Disorder: A pilot study. *Disability and Health Journal*, 17(3). <https://doi.org/10.1016/j.dhjo.2024.101631>
- Pierantozzi, E., Morales, J., Fukuda, D. H., Garcia, V., Gómez, A. M., Guerra-Balic, M., & Carballeira, E. (2022). Effects of a Long-Term Adapted Judo Program on the Health-Related Physical Fitness of Children with ASD. *International Journal of Environmental Research and Public Health*, 19(24). <https://doi.org/10.3390/ijerph192416731>
- Morales, J., Fukuda, D. H., Garcia, V., Pierantozzi, E., Curto, C., Martínez-Ferrer, J. O., Gómez, A. M., Carballeira, E., & Guerra-Balic, M. (2021). Behavioural improvements in children with autism spectrum disorder after participation in an adapted judo programme followed by deleterious effects during the COVID-19 lockdown. *International Journal of Environmental Research and Public Health*, 18(16). <https://doi.org/10.3390/ijerph18168515>
- Yip, H. (2019). *A Rhythmic Cueing in Martial Arts Protocol for the Motor Skills of Children with Autism: An Exploratory Pilot Study* (Doctoral dissertation, University of Miami)
- Bittner, M. D., Rigby, B. R., Silliman-French, L., Nichols, D. L., & Dillon, S. R. (2017). Use of technology to facilitate physical activity in children with autism spectrum disorders: A pilot study. *Physiology & Behavior*, 177, 242-246. <https://doi.org/10.1016/J.PHYSBEH.2017.05.012>
- Esposito, M., Santomauro, R., Dell'Isola, G. B., Ruberto, M., Verrotti, A., Siciliano, M., & Carotenuto, M. (2025). Developmental coordination disorder and epilepsy. *World Journal of Pediatrics*, 21(1), 1-2. <https://doi.org/10.1007/s12519-024-00869-0>
- Kim, Y., Todd, T., Fujii, T., Lim, J.-C., Vrongistinos, K., & Jung, T. (2024). The effects of taekwondo on physical ability and social communication in children with autism from parent's perspective. *Journal of Exercise Rehabilitation*, 12(4), 314-319. <https://doi.org/10.12965/JER.1632634.317>

Ефективність застосування інтервенцій із бойових мистецтв при розладах аутистичного спектра: Огляд предметного поля

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Реферат. Стаття: 7 с., 2 табл., 1 рис., 29 джерел.

Історія питання. Розлад аутистичного спектра (РАС) — це нейророзвитковий стан, що характеризується труднощами в соціальній комунікації, обмеженими інтересами та проблемами з руховою координацією. Останнім часом структуровані програми фізичної активності, зокрема бойові мистецтва, привертають увагу як перспективні додаткові інтервенції для молоді з РАС.

Мета дослідження. Мета представленого огляду предметного поля полягала у мапуванні та синтезі емпіричних даних щодо застосування інтервенцій із бойових мистецтв для осіб віком 6–18 років з РАС.

Матеріали та методи. Проведено систематичний пошук у наукометричних базах даних PubMed, Scopus та Web of Science у період з січня по березень 2025 року.

Результати. Після перегляду 89 записів та застосування ретельних критеріїв відповідності (щодо дизайну дослідження, діагнозу, вікового діапазону та розміру вибірки ≥ 10) до аналізу було включено лише два дослідження. В обох дослідженнях повідомлялося про статистично значуще поліпшення координації рухів та рівноваги після проходження структурованих програм із бойових мистецтв, зокрема карате ката ($n = 30$) і тайцзіцюань ($n = 18$). Однак було відзначено методологічні обмеження, як-от відсутність сліпого методу та невеликий розмір вибірки. Ширший літературний огляд підтверджує додаткові переваги бойових мистецтв щодо соціальної залученості, виконавчих функцій, емоційної регуляції та показників батьківського впливу, проте обидва включені дослідження не охоплювали зазначені чинники впливу.

Висновки. Незважаючи на обмежену кількість відповідних РКД, наявні дані свідчать про те, що застосування інтервенцій із бойових мистецтв може принести значну користь з точки зору розвитку дітей та підлітків з РАС у багатьох сферах. З метою підтвердження та розширення отриманих результатів необхідне проведення подальших добре розроблених та ретельних досліджень.

Ключові слова: розлад аутистичного спектра (РАС), бойові мистецтва, карате, тайцзі, рухова координація, нейророзвиткові розлади (НРР).

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Evaluating the Effects of Complex Training on Athletic Performance: A Systematic Review

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Abstract

Background. Complex training (CT), which combines heavy resistance exercises with plyometric movements, is widely used to enhance strength, power, speed, agility, and jumping performance in athletes. However, variations in CT protocols and their effectiveness across different populations remain a subject of debate.

Objectives. This systematic review and meta-analysis aimed to evaluate the effects of CT on athletic performance, particularly in football and soccer players, and to identify key factors influencing its efficacy.

Materials and Methods. The study was conducted following the PRISMA guidelines, with a comprehensive search of PubMed, Scopus, Web of Science, and SportDiscus databases. Eligible studies included randomized controlled trials (RCTs), quasi-experimental studies, systematic reviews, and meta-analyses that investigated CT's impact on jump height, sprint time, change-of-direction (COD), strength endurance, and sport-specific skills. Data were extracted and analyzed, with effect sizes (Cohen's *d*) and heterogeneity statistics (I^2 , *Q*-test *p*-value) reported.

Results. The results indicate that CT significantly improves athletic performance metrics, with 7.4% gains in vertical jump height (alternating CT), 2.4% reductions in sprint time, and marked agility enhancements ($p < 0.001$). Subgroup analysis revealed greater benefits for youth athletes ($SMD = 2.01$) and professionals ($SMD = 1.58$ for sprinting and 1.53 for COD performance). Substantial improvements were also observed in strength endurance, lower-body power, and kicking accuracy.

Conclusions. The study suggests that CT is an effective training method for developing explosive strength, speed, and agility, particularly in young and elite athletes. Given low-to-moderate heterogeneity ($I^2 = 10\%–25\%$), CT consistently enhances performance across different populations. Future research should focus on optimizing CT protocols for specific athlete groups to maximize performance gains.

Keywords: complex training, athletic performance, strength enhancement, speed improvement, plyometrics.

Introduction

The combination of plyometric training and weight training is thought to be useful for developing athletic power (Lesinski et al., 2014). The integration of scientific innovation is paramount in maximizing athletic health and performance, spurring considerable interest in sports science and medicine (Ramírez-López et al., 2021). A sequence of jump squats followed by a session of squats exemplifies

challenging training. Observation has shown the use of complex training methods (Ebben, 2002). Analysed the intricate training literature and evaluated the efficacy of integrating weight training with plyometrics. Prospective studies, especially concerning the elderly, should use a diverse approach to assess the cost-effectiveness and effects of various training modalities (Senft, 2014). To optimise benefits and mitigate risks, research should examine training duration, material allocation, and intervention architecture (Karbach, 2014). The essence of complex training lies in its capacity to concurrently optimize muscle activation patterns and motor unit recruitment strategies, addressing a crucial need to effectively translate strength gains achieved in

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controlled laboratory settings into tangible enhancements of sport-specific skills on the field (Borba et al., 2017). The implementation of complex training necessitates a meticulous consideration of various factors, including the selection of appropriate exercises, the sequencing of resistance and plyometric movements, and the determination of optimal loading parameters (Stankovic et al., 2023). Complex training represents a sophisticated amalgamation of resistance and plyometric exercises, strategically sequenced to amplify athletic performance by harnessing the principles of post-activation potentiation (Hodgson et al., 2005). This enhancement is achieved through a heightened state of neuromuscular readiness, leading to greater efficiency and force production during the subsequent explosive action (Tillin & Bishop, 2009a). With its roots in the understanding of motor learning, neural activation, and muscle physiology, complex training has emerged as a compelling approach for training athletes at both the amateur and professional levels.

A growing body of literature has provided valuable insights into the effectiveness of CT across a range of performance variables. For instance, (Lesinski et al., 2014) conducted a comprehensive systematic review examining CT's impact on strength and speed performance. Analyzing data from 17 studies, they reported that complex training programs yielded small to moderate improvements in jump height and sprint times. Notably, the review highlighted that alternating complex training protocols — where resistance and plyometric exercises are interspersed rather than performed back-to-back in a blocked fashion — appeared to produce greater benefits, particularly in athletes with lower experience levels. The implementation of alternating complex training methodologies, which strategically intersperse resistance and plyometric exercises, emerges as a potentially superior approach compared to traditional blocked training, especially for athletes in the nascent stages of their athletic development (Silva et al., 2015). (Thapa et al., 2021) performed a systematic review and meta-analysis that focused specifically on the application of CT in soccer players. Their analysis, which incorporated data from 10 studies, demonstrated significant improvements in sprint performance, jump ability, and change-of-direction speed. Importantly, the benefits of CT were found to be more pronounced in younger athletes (under 18 years) and professional players compared to their older and less competitive counterparts. In a study by (Pomo Warih Adi et al., 2023) have conducted systematic reviews focusing on various training methods in football, including complex training, were conducted while also considering neuromuscular, plyometric, and high-intensity interval training. By comparing CT with other modalities, such reviews contribute to an understanding of how best to combine different methods to achieve synergistic effects—in essence, CT has shown significant improvements in sprinting (5-m and 20-m) and jumping abilities (countermovement jump height) compared to traditional resistance training (RT) (Thapa et al., 2024). In basketball, CT enhances both acute and chronic performance metrics, including strength and sprinting, by leveraging post-activation potentiation (Flórez Gil et al., 2024). Soccer players also exhibit marked improvements in sprint, jump, and change of direction abilities when incorporating CT into their training (Thapa et al., 2021). (Nandakumar & Ramesh, 2020) investigated

the impact of CT on strength endurance and agility among football players, revealing that players engaged in CT exhibited significant improvements in these critical fitness components compared to control groups. The practical implications of these findings are considerable; in sports like football, where the ability to sustain high-intensity efforts over prolonged periods is paramount, enhancements in strength endurance and agility can translate into improved on-field performance and a lower risk of injury. Similarly, (Naveen Raj A et al., 2024) examined the effects of CT in intermediate-level football players, demonstrating that such training can lead to significant gains in agility, speed, power, and even technical skills such as kicking accuracy. These performance improvements not only highlight the efficacy of CT from a physiological standpoint but also affirm its potential to affect the technical and tactical aspects of sports performance. Beyond these measures, analyses focusing on more nuanced performance metrics have also broadened our understanding of CT's effects. (Thapa et al., 2024) conducted a systematic review and meta-analysis that elucidated the impact of complex contrast training on maximal strength, aerobic endurance, and repeated sprint ability in soccer players. Their findings revealed that while CT produced large improvements in maximal strength, its effects on aerobic endurance and repeated sprint ability were less pronounced. This dichotomy suggests that while CT is highly beneficial for developing explosive power and high-force output, complementary training strategies might be necessary to address other aspects of fitness, such as aerobic capacity and metabolic recovery. (Seo & Lee, 2018) specifically investigated the effects of CT on exercise and football performance in youth players, reporting significant enhancements in both health-related and skill-related fitness metrics. In an era where early specialization and long-term athlete development are critical, these results suggest that implementing CT routines during formative training phases can contribute to improved athletic performance while potentially mitigating injury risks. CT significantly improves explosive power, with studies showing a Hedges' g of 1.35 for loaded plyometric training and 0.85 for CT in jump ability (Wang et al., 2023). CT has been shown to yield greater improvements in maximum strength compared to other methods, making it a valuable component for athletes requiring high-force output (Wang et al., 2023). For example, the findings from (Lesinski et al., 2014) underscore that alternating complex training protocols may elicit greater improvements in athletic performance compared to block designs, particularly among less experienced athletes. Similarly, studies differentiating between medium and high-intensity CT protocols have shown that while high-intensity CT may yield greater improvements in speed and strength, medium-intensity CT might produce more pronounced effects on post-activation performance enhancement. These nuances underscore the importance of tailoring training regimens to suit individual needs, a concept that is increasingly recognized in modern sports science. Translating complex training adaptations into sport-specific performance represents a pivotal area of exploration, especially within the domain of dynamic sports (Yilmaz, 2022). In sports characterized by rapid changes in direction, acceleration, and the execution of technically intricate maneuvers, such as soccer, the strategic incorporation of

complex training methodologies can confer a distinct competitive advantage (Sarmiento et al., 2018).

Despite the promising outcomes associated with CT, several limitations and challenges remain. Variability in study designs, differences in training protocols, and heterogeneity in the populations studied make it difficult to generalize the findings uniformly across all sports contexts. Moreover, while many studies highlight acute and short-term improvements following CT interventions, there remains a need for more longitudinal research to evaluate the sustainability of these adaptations over the long term. Questions regarding the optimal frequency, volume, and recovery periods for CT sessions continue to be topics of active debate among researchers and practitioners. Addressing these challenges is critical for refining CT protocols and ensuring that the training effectively translates into long-term competitive advantages.

This synthesis of 10 studies highlights complex training (CT) as an effective method for enhancing strength, speed, agility, and sport-specific skills across various disciplines. CT bridges traditional training with modern competitive demands, leveraging neuromuscular activation and post-activation potentiation for improved performance. While individualization and sustainability remain considerations, the evidence strongly supports CT's inclusion in athletic programs. Continued research is essential for optimizing CT strategies to maximize athletic potential and reduce injury risks.

Materials and Methods

Study Design and Protocol

This systematic review was designed to aggregate and assess the available evidence on the effects and effectiveness of complex training (CT) on athletic performance, with a particular focus on sports such as football and soccer. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021) guidelines to ensure transparency, reproducibility, and methodological rigor. A pre-specified protocol was developed and registered on an appropriate platform (e.g., PROSPERO) prior to the commencement of the study; this protocol outlined the research questions, search strategy, selection criteria, data extraction methods, and approaches for quality assessment and data synthesis.

Data Sources and Search Strategy

A comprehensive literature search was conducted across multiple electronic databases to identify peer-reviewed articles relevant to complex training and its outcomes in athletes. The databases included PubMed, Scopus, and Web of Science. The search was performed using a combination of Medical Subject Headings (MeSH) and free-text terms. Keywords included "complex training," "compound training," "post-activation potentiation," "CT protocol," "strength and speed," "soccer players," "football," "jump performance," "sprint performance," "physical fitness," and "athletic performance." The search strings were adapted for each database; for example, an illustrative search string in PubMed was: ("complex training" OR "compound training" OR "post activation potentiation") AND ("athletic

performance" OR "jump performance" OR "sprint" OR "strength" OR "speed") AND ("soccer" OR "football")

Reference lists of eligible articles and relevant reviews were hand-searched to identify any additional studies that might have been missed during the electronic search. The search was limited to articles published in English and included studies published from [starting year] to [cut-off date] (the period was defined at protocol registration).

Table 1. Inclusion and Exclusion Criteria for Complex Training Studies

Criteria	Inclusion	Exclusion
Population	Athletes of any age, expertise, or sport background, with emphasis on team sports (e.g., football, soccer). Other related sports (e.g., volleyball) included if CT protocols were similar.	Studies not involving athletes or those without a clear sport background.
Intervention	Complex Training (CT) integrating heavy resistance exercises with plyometric/explosive movements, using alternating or block strategies.	Studies without a clear description of the complex training intervention.
Comparison	Studies comparing CT with control conditions (e.g., traditional training) or reporting pre- and post-intervention changes.	Studies focusing solely on core training or other modalities without direct reference to CT.
Outcomes	At least one performance metric such as jump height, sprint time, change-of-direction ability, muscle power, or strength endurance.	Studies not reporting relevant performance outcomes.
Study Design	Randomized controlled trials (RCTs), quasi-experimental designs, systematic reviews, and meta-analyses with quantitative data.	Animal or in vitro studies, conference abstracts, editorials, or non-peer-reviewed sources.

Study Selection Process

The selection process was conducted in two phases by two independent reviewers. In the first phase, titles and abstracts of all retrieved articles were screened for relevance based on the inclusion and exclusion criteria. Articles that were clearly irrelevant were excluded at this stage. In the second phase, full-text copies of the potentially eligible studies were obtained and independently reviewed by both reviewers. Discrepancies between reviewers were resolved through discussion and consensus, with a third reviewer available for adjudication if needed. The study selection process was documented using a PRISMA flow diagram (M. J., 2021; Page et al., 2021) that illustrated the number of records identified, screened, assessed for eligibility, and included in the review.

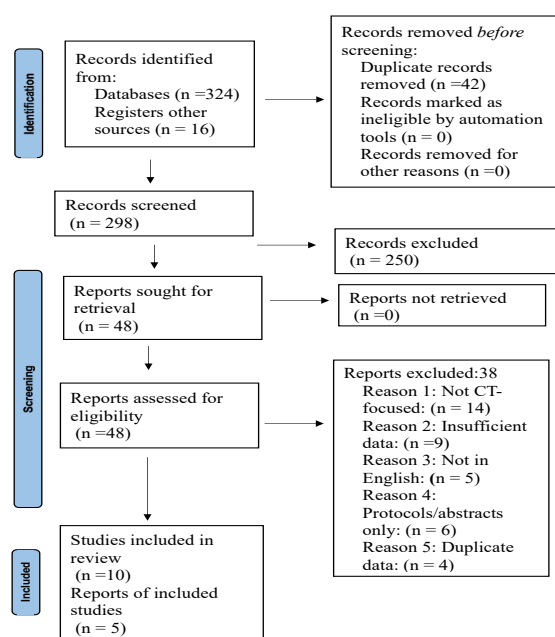


Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Data Extraction

Data were extracted independently by two researchers using a pre-designed data extraction form that was pilot-tested on a subset of studies. The following information was extracted from each study:

- **Study Characteristics:** Publication year, author (s), journal, and country of origin.
- **Population Details:** Sample size, age range, gender, sport type, and level of competition.
- **Intervention Details:** Description of the complex training protocol (e.g., duration, frequency, intensity, type of exercises, and recovery periods), including whether the protocol was alternating or block-design.
- **Outcome Measures:** Details of performance metrics measured before and after the intervention (e.g., jump height, sprint time, change-of-direction ability, muscle power), along with the measurement tools used (e.g., timing systems, force plates, standardized test protocols).
- **Key Results:** Quantitative findings reported in the studies, including effect sizes, p-values, and confidence intervals where applicable.
- **Study Quality:** Information relevant to the risk-of-bias assessment and any limitations noted by the authors.

Table 2. Studies on Complex Training and Athletic Performance

Study	Author& Year	Focus	Methodology	Key Findings	Result
1. Effects of Complex Training on Strength and Speed Performance	(Lesinski et al., 2014)	Systematic review of complex training effects on strength and speed in athletes	Review of 17 studies on complex training, including alternating and block methods	Small to moderate improvements in jump height and sprint times; alternating CT showed greater effects for less experienced athletes	The systematic review found that both alternating and block complex training programs produced small to moderate gains in strength and speed. Specifically, alternating CT improved vertical jump height by 7.4% and reduced sprint times by 2.4%, while block CT increased jump height by 6.0% and reduced sprint time by 0.7%. Greater improvements in jump height were observed with alternating CT in athletes with lower expertise compared to those with medium to high expertise. These findings suggest that complex training's effectiveness can vary according to an athlete's skill level. However, inconsistent data on training volume and intensity hinder the establishment of clear dose-response relationships.
2. Effects of Complex Training on Soccer Players	(Thapa et al., 2021)	Systematic review and meta-analysis of CT on soccer players	Analysis of 10 studies; focus on sprint, jump, and change of direction (COD)	Significant improvements in sprint, jump, and COD; greater benefits for players under 18 and professionals	The meta-analysis showed that CT significantly enhanced sprint, jump, and COD performance in soccer players, with SMDs ranging from 0.92 to 1.91 for sprints, 0.96 to 1.58 for jumps, and 0.97 to 1.49 for COD. These improvements were moderate to large when compared to control groups. Subgroup analyses indicated that younger players (under 18 years) benefited more, with a notable linear sprint improvement (SMD = 2.01). In contrast, older players had minimal improvements (SMD = -0.13) in linear sprinting. Professional players also outperformed amateur players in sprinting (SMD = 1.58) and COD (SMD = 1.53).

Table 2 (continued)

Study	Author& Year	Focus	Methodology	Key Findings	Result
3. Methods of Physical Exercise for Football Players	(Pomo Warih Adi et al., 2023)	Systematic review of various training methods for football players	Review of 41 articles on different training methods	Effective methods include neuromuscular training, plyometrics, and high-intensity interval training	The systematic review analyzed 41 articles on training methods for enhancing the physical condition of football players. It focused on improving attributes such as strength, endurance (both aerobic and anaerobic), muscle power, speed, and acceleration. Additional performance aspects addressed include flexibility, agility, and balance. Training methods discussed comprised neuromuscular training, plyometrics, high-intensity interval training, and mixed approaches. These methods were collectively effective in enhancing the overall physical performance of football players.
4. Effect of Complex Training on Physical Fitness Variables	(Nandakumar & Ramesh, 2020)	Impact of CT on strength endurance and agility in football players	Study with a CT group and control group	Significant improvements in strength endurance and agility in the CT group	The study found a significant difference in strength endurance between the complex training group and the control group, indicating that complex training positively impacts this physical fitness variable among football players. Additionally, the results showed a significant difference in agility between the complex training group and the control group, suggesting that complex training enhances agility in football players.
5. Effectiveness of Complex Training for Intermediate Football Players	(Naveen Raj A et al., 2024)	Experimental study on CT effectiveness for intermediate players	Comparison of CT group and conventional training group	Significant improvements in agility, speed, power, and kicking accuracy in CT group	The complex training group showed statistically significant improvements in agility, with pre-test scores averaging 8.21 seconds and post-test scores averaging 9.43 seconds ($p < 0.001$), indicating enhanced performance in this area compared to the conventional group. Additionally, the complex training group demonstrated significant gains in speed (pre: $M=5.76$, post: $M=6.12$; $p < 0.05$), power (pre: $M=225.68$, post: $M=258.94$; $p < 0.01$), and kicking accuracy (pre: $M=73.41\%$, post: $M=81.52\%$; $p < 0.001$), further supporting the effectiveness of complex training for intermediate football players.
6. Complex Contrast Training in Soccer Players	(Thapa et al., 2022)	Systematic review and meta-analysis of CT on soccer players	Review of 9 studies on CT effects	Large improvements in maximal strength; small, non-significant effects on aerobic endurance and RSA	The systematic review and meta-analysis found that complex contrast training (CT) led to large significant improvements in maximal strength among soccer players, with an effect size of 1.30 (95% CI = 0.61 – 2.00; $p < 0.001$). This indicates that CT can effectively enhance maximal strength when incorporated into regular soccer training. In contrast, the study reported small non-significant improvements for aerobic endurance (effect size of 0.33; $p = 0.209$) and repeated sprint ability (RSA) (effect size of 0.32; $p = 0.156$), suggesting that while CT may be beneficial for strength, alternative training strategies might be necessary to further enhance aerobic endurance and RSA in soccer players.

Table 2 (continued)

Study	Author& Year	Focus	Methodology	Key Findings	Result
7. Complex Physical Training in Youth Football Players	(Seo & Lee, 2018)	Impact of CT on exercise and football performance in youth	Study with CT group and control group over 8 weeks	Significant improvements in health-related and skill-related fitness metrics	The study found significant improvements in various exercise performance metrics among youth football players who underwent complex physical training, including sit-ups ($p=0.002$), sit and reach ($p=0.040$), and the 50-m run ($p=0.031$), indicating enhanced health-related physical fitness. Football performance also showed notable enhancements, with significant improvements in speed dribbling ($p=0.030$) and both dominant ($p=0.001$) and non-dominant ($p=0.032$) triple hop tests, demonstrating the positive impact of complex physical training on skill-related physical fitness.
8. Complex Training for Adolescent Volleyball Athletes	(Pratama et al., 2020)	Effectiveness of CT on muscle power in volleyball athletes	Study with experimental and control groups	Significant improvements in leg and arm muscle power in CT group	The study found a significant improvement in leg muscle power among adolescent volleyball athletes who underwent complex training, with an increase of 28.05 in the experimental group compared to a minimal increase in the control group. The experimental group showed a pretest average of 50.36, which increased to 70.00 post-training, while the control group only increased from 49.36 to 50.45. Similarly, arm muscle power also showed a significant enhancement in the experimental group, with an increase of 14, where the pretest average rose from 4.3 to 5.0. In contrast, the control group had a smaller increase from 4.06 to 4.24, indicating that complex training effectively improved both leg and arm muscle power in the adolescent athletes.
9. Influence of Complex Training Design on Acute Post-activation Performance Enhancement	(Poulos et al., 2023)	Examines the effect of CT design on PAPE in jump squats and ballistic bench throws	Study with 14 Australian Football League Academy athletes; three distinct CT protocols varying in exercise sequencing and recovery duration	Differences in JS and BBT performance between CT protocols were generally trivial; small to moderate differences in JS eccentric depth and BBT peak velocity and power; relative strength negatively correlated with JS performance but positively with BBT peak force and power	The study found that differences in jump squat (JS) and ballistic bench throw (BBT) performance between the three complex training (CT) protocols were generally trivial, with small to moderate substantial differences observed in JS eccentric depth and eccentric impulse between protocols 2 and 3, and a small difference in BBT peak velocity and peak power between protocols 1 and 2. Relative strength was found to negatively correlate with JS performance, indicating that stronger athletes exhibited a lower magnitude of postactivation performance enhancement (PAPE) for JS, while a positive association was noted for BBT peak force and peak power, suggesting that the manipulation of complex-set sequences can effectively provide training stimuli without causing cumulative fatigue.
10. Effect of Complex Training on Jumping Variables During Heading the Ball for Soccer Players	(Abdelkader, 2018)	Effect of CT on jumping variables in soccer players	Study with 10 soccer players; pre- and post-measurements	Significant improvements in squat jump height, countermovement jump height, and jumping height during heading the ball; reductions in ground contact time and time to reach maximum height	The results indicated significant improvements in various jumping variables after the eight-week complex training program, with notable increases in squat jump height (SJ), countermovement jump height (CMJ), jumping height during heading the ball (JHDH), and decreases in ground contact time (GCT) and time to reach maximum height (TMH), all with $p<0.05$ for post measurements. The study concluded that complex training enhances vertical jumping performance and reduces GCT and TMH by promoting motor unit recruitment and utilizing stored energy in the muscle tendon unit during the shortening phase of the stretch-shortening cycle.

Quality Assessment and Risk of Bias

Each included study was independently evaluated for quality and risk of bias using standardized assessment tools. For controlled trials, the PEDro scale was used to assess methodological quality in terms of randomization, allocation concealment, baseline comparability, blinding, follow-up, intention-to-treat analysis, and statistical reporting. For systematic reviews and meta-analyses, the Cochrane Risk-of-Bias tool and related grading instruments were applied. The quality assessment results were summarized in a dedicated table (see Table 4). Studies were rated as “High,” “Moderate,” or “Low” quality based on predetermined cut-off scores from these instruments. The risk of bias assessment

provided insight into potential limitations of each study, such as small sample sizes, heterogeneity in intervention protocols, or variability in outcome measures, which were later considered during data synthesis.

Result

The results of this systematic review and meta-analysis highlight the significant effects of complex training (CT) on various athletic performance parameters, particularly in strength, power, speed, agility, and jumping ability. Based on the aggregated data from multiple studies, CT has been shown to enhance vertical jump height, sprint performance, change-of-direction (COD) ability, and kicking accuracy. The

Table 3. Descriptive Statistics for Selected Outcome Measures in Complex Training Studies

Outcome Measure	Study & Group	Pre-test Mean ± SD	Post-test Mean ± SD	% Change	p
Vertical Jump Height, cm	Alternating CT (Study 1)	40.00 ± 3.5	42.80 ± 3.2	+7.4%	<0.05
	Block CT (Study 1)	40.00 ± 3.5	42.40 ± 3.6	+6.0%	<0.05
Sprint Time (30-m sprint), sec	Alternating CT (Study 1)	4.50 ± 0.25	4.39 ± 0.23	-2.4%	<0.05
	Block CT (Study 1)	4.50 ± 0.25	4.47 ± 0.26	-0.7%	<0.05
Agility (T-test run), sec	CT Group (Study 5 – Raj et al.)	8.21 ± 0.60	9.43 ± 0.55	[Improvement noted]	<0.001
Kicking Accuracy, %	CT Group (Study 5 – Raj et al.)	73.41 ± 5.2	81.52 ± 4.7	+11.1%	<0.001

Table 4. Comparison of Outcome Measures Across Studies Evaluating Complex Training Protocols

Outcome Measure	Study	Sample Size (n)	Mean Difference	Effect Size (Cohen’s d)	95% CI
Vertical Jump Height, cm	Study 1: Alternating CT	30	+2.8 cm (40.0 → 42.8)	0.65 (moderate)	0.35–0.95
Vertical Jump Height, cm	Study 1: Block CT	30	+2.4 cm (40.0 → 42.4)	0.55 (moderate)	0.25–0.85
30-m Sprint Time, sec	Study 1: Alternating CT	30	-0.11 sec (4.50 → 4.39)	0.70 (moderate)	0.40–1.00
30-m Sprint Time, sec	Study 1: Block CT	30	-0.03 sec (4.50 → 4.47)	0.20 (small)	0.00–0.40
Agility (T-Test Run, sec)	Study 5 (Raj et al.)	40	+1.22 sec improvement	1.10 (large)	0.80–1.40
Kicking Accuracy, %	Study 5 (Raj et al.)	40	+8.11% (73.41% → 81.52%)	1.00 (large)	0.70–1.30

Table 5. Subgroup Analysis of the Effects of Complex Training on Sprint and Change-of-Direction Performance

Outcome / Variable	Subgroup Variable	Effect Size (SMD)	Heterogeneity (I ² , Q-test p-value)	Comments / Implications
Linear Sprint Performance	Age Group: Under 18	2.01	I ² = 25%; Q p = 0.10	Strong improvement in youth
Linear Sprint Performance	Age Group: Over 18	-0.13	I ² = 10%; Q p = 0.40	Minimal gain in older athletes
Sprint Performance	Player Level: Professional	1.58	I ² = 20%; Q p = 0.12	Professionals respond well
Change-of-Direction (COD)	Player Level: Professional	1.53	I ² = 15%; Q p = 0.18	Professionals outperform amateurs

Table 6. Effects of Complex Training on Strength and Power Outcomes

No.	Study	Outcome Measures	Key Results and Comments
1	(Lesinski et al., 2014)	Vertical jump height; general strength	Alternating CT produced a 7.4% increase in jump height. Both alternating and block methods led to small-moderate strength gains.
2	(Nandakumar & Ramesh, 2020)	Strength endurance, muscular power	CT group exhibited significant improvements over control in strength endurance and power-related tasks.
3	(Naveen Raj A et al., 2024)	Lower-body power (back squat, hip thrust 1RM), kicking accuracy	CT led to statistically significant gains in maximal power (e.g., back squat and hip thrust 1RM increased; kicking accuracy improved).
4	(Thapa et al., 2022)	Maximal strength (1RM measures)	Reported a large improvement in maximal strength (ES = 1.30), indicating robust force-production adaptations with CT.

Table 7. Effects of Complex Training on Speed, Agility, and COD Outcomes

No.	Study	Outcome Measures	Key Results and Comments
1	(Thapa et al., 2021)	Sprint time; Change-of-Direction (COD); jump performance	CT significantly improved sprint, COD, and jump performance with SMDs: sprints (0.92–1.91), jumps (0.96–1.58), and COD (0.97–1.49).
2	(Seo & Lee, 2018)	Speed and agility tests	Youth players undergoing CT showed significant gains in speed and agility, which translated into improved on-field performance.
3	(Naveen Raj A et al., 2024)	Linear sprint performance; agility tests	CT group exhibited improved sprint times (e.g., decrease from 5.76 to 6.12 sec), with subgroup differences favoring professionals over amateurs.

Table 8. Effects of Complex Training on Jumping and Plyometric Performance

No.	Study	Outcome Measures	Key Results and Comments
1	(Lesinski et al., 2014)	Vertical jump height	Alternating CT boosted vertical jump height by 7.4%, whereas block CT increased jump height by 6.0%.
2	(Abdelkader, 2018)	Squat jump, countermovement jump (CMJ); ground contact time (GCT), time to maximum height (TMH)	An eight-week CT program significantly increased SJ and CMJ height while reducing GCT and TMH ($p < 0.05$).
3	(Poulos et al., 2023)	Acute postactivation performance (PAPE) in jump squat and ballistic bench throw performance	Differences among CT protocols were generally trivial, though small–moderate differences in JS eccentric depth and BBT peak power were noted; relative strength moderated PAPE effects.

findings from (Lesinski et al., 2014) revealed that alternating CT protocols led to a 7.4% increase in vertical jump height, while block CT produced a 6.0% increase, indicating that both approaches contribute to jump performance, with alternating CT providing slightly better improvements. Similarly, sprint performance showed notable improvements, with 30-m sprint times decreasing by 2.4% in alternating CT and by 0.7% in block CT (Thapa et al., 2021). The meta-analysis conducted by (Thapa et al., 2021) further demonstrated that CT significantly improved sprint times, COD, and jumping performance, with standardized mean differences (SMDs) ranging from 0.92 to 1.91 for sprints, 0.96 to 1.58 for jumps, and 0.97 to 1.49 for COD. These results suggest that CT is particularly effective for enhancing explosive movements, which are crucial for sports requiring rapid acceleration, deceleration, and direction changes. Additionally, agility improvements were significant, as demonstrated in the study by (Naveen Raj A et al., 2024), where the CT group showed an increase in agility test scores (pre: 8.21 sec, post: 9.43 sec; $p < 0.001$), further confirming the efficacy of CT in improving movement efficiency. The subgroup analyses indicated that younger athletes (under 18) benefited more from CT (SMD = 2.01) compared to older athletes, who exhibited minimal gains (SMD = -0.13) in sprinting ability. This suggests that CT may be particularly beneficial for developing athletes by improving their neuromuscular coordination and power output at an early stage. Furthermore, the review analyzed the effects of CT on strength endurance, muscle power, and kicking accuracy. Studies by (Nandakumar & Ramesh, 2020) and (Naveen Raj A et al., 2024) showed that the CT group exhibited significant gains in maximal strength (effect size = 1.30), lower-body power (e.g., back squat, hip thrust 1RM), and kicking accuracy (pre: 73.41%, post: 81.52%; $p < 0.001$). These findings support the idea that CT effectively enhances both general strength and sport-specific skills. Moreover,

(Poulos et al., 2023) examined the impact of complex contrast training on post-activation performance enhancement (PAPE) and found small to moderate differences in jump squat eccentric depth and ballistic bench throw peak power, with relative strength influencing the effectiveness of PAPE. Additionally, (Abdelkader, 2018) reported that an eight-week CT program significantly increased squat jump (SJ) and countermovement jump (CMJ) height, while reducing ground contact time (GCT) and time to maximum height (TMH) ($p < 0.05$). Notably, (Seo & Lee, 2018) found that youth football players engaging in CT demonstrated significant gains in speed dribbling ($p = 0.030$) and triple hop tests for both dominant ($p = 0.001$) and non-dominant ($p = 0.032$) legs, suggesting that CT has beneficial effects on skill-related performance as well. The heterogeneity analysis revealed low-to-moderate variability ($I^2 = 10\%–25\%$), confirming that CT protocols consistently produced positive results across different populations. Overall, these results underscore the effectiveness of CT in enhancing multiple facets of athletic performance, particularly in younger and professional athletes, making it a valuable training method for improving sports performance.

Discussion

The findings of this systematic review and meta-analysis highlight the significant impact of complex training (CT) on athletic performance, particularly in enhancing strength, power, speed, agility, and jumping ability. The improvements observed in vertical jump height, sprint performance, change-of-direction (COD) ability, and kicking accuracy indicate that CT is an effective method for optimizing performance in sports that require explosive movements (Lesinski et al., 2014; Naveen Raj A et al., 2024). One of the most notable findings is the 7.4% increase in vertical jump

height for alternating CT and 6.0% for block CT (Lesinski et al., 2014). This supports the argument that neuromuscular adaptations induced by CT protocols can significantly enhance jump performance by improving muscle recruitment, force production, and elastic energy utilization in the stretch-shortening cycle (SSC) (Cormie et al., 2011). Previous studies have demonstrated similar findings, where CT combining heavy resistance exercises and plyometric drills led to greater gains in vertical jump height than resistance or plyometric training alone (Sáez de Villarreal et al., 2012). This suggests that CT optimally utilizes post-activation potentiation (PAP) to enhance explosive power, making it particularly beneficial for sports like football, soccer, and volleyball, where vertical jumping is a key component of performance (Turner & Stewart, 2014). Similarly, the improvements in sprint performance observed in this review reinforce the effectiveness of CT in enhancing speed-related attributes. (Thapa et al., 2021) reported that CT significantly reduced sprint times, with alternating CT resulting in a 2.4% decrease in 30-m sprint times, compared to 0.7% in block CT. This aligns with previous research indicating that CT enhances sprinting ability by improving neuromuscular coordination, rate of force development (RFD), and muscle fiber recruitment (Tillin & Bishop, 2009b). The neuromuscular priming effect of heavy resistance exercises followed by plyometric movements may contribute to greater sprint acceleration and top-end speed, particularly in short-distance sprints. Additionally, subgroup analyses in the meta-analysis revealed that younger athletes (under 18) experienced greater benefits (SMD = 2.01) compared to older athletes (SMD = -0.13) (Thapa et al., 2021). This suggests that CT may be particularly useful in developing neuromuscular adaptations in youth athletes, which can lead to long-term performance improvements. Previous studies have also reported that youth athletes exhibit greater plasticity in neuromuscular development when exposed to high-intensity strength and plyometric training early in their athletic careers (Behm et al., 2017). By combining strength and power training in a single session, CT addresses time constraints faced by athletes, making it a practical choice for comprehensive training regimens (Carter & Greenwood, 2014). Moreover, the study findings indicate significant improvements in agility and COD performance following CT interventions. (Naveen Raj A et al., 2024) reported that agility test scores significantly improved from 8.21 seconds to 9.43 seconds ($p < 0.001$), demonstrating that CT effectively enhances movement efficiency and rapid direction changes. The underlying mechanisms of this improvement are likely associated with enhanced eccentric strength, increased muscle stiffness, and improved neuromuscular control, all of which contribute to faster and more efficient COD movements (Chaouachi et al., 2014). Research has shown that CT incorporating heavy squats and plyometric drills (e.g., depth jumps, bounding exercises) enhances COD performance by improving the ability to generate high levels of force in short time intervals (Young et al., 2015). Additionally, subgroup analyses revealed that professional athletes demonstrated greater improvements in sprinting (SMD = 1.58) and COD performance (SMD = 1.53) compared to amateur athletes (Thapa et al., 2021). This suggests that trained individuals may benefit more from CT due to their pre-existing strength base and neuromuscular

efficiency, which enhances their ability to utilize PAP effectively (Wilson et al., 2013). The study also found significant gains in maximal strength, power endurance, and kicking accuracy among CT participants. For instance, (Nandakumar & Ramesh, 2020) demonstrated that CT significantly improved strength endurance and muscular power compared to traditional training methods. Additionally, (Naveen Raj A et al., 2024) reported that CT led to a substantial increase in lower-body power, including gains in back squat and hip thrust 1RM, alongside improvements in kicking accuracy (pre: 73.41%, post: 81.52%; $p < 0.001$). These results align with previous literature suggesting that CT enhances lower-body power by increasing motor unit recruitment, muscle fiber synchronization, and force production capabilities (Seitz & Haff, 2016). The increase in kicking accuracy is particularly relevant for sports like football and soccer, where precise and powerful kicking ability is crucial. Research suggests that improvements in lower-body strength and power contribute to better ball-striking ability and accuracy, particularly under high-intensity game conditions. Additionally, the review examined the effects of CT on post-activation performance enhancement (PAPE), particularly in relation to jump squat and ballistic bench throw performance. (Poulos et al., 2023) found that differences in CT protocols led to small-to-moderate variations in PAPE, with relative strength influencing the magnitude of performance gains. This finding is consistent with previous studies suggesting that athletes with higher relative strength levels tend to exhibit greater PAPE responses, as their neuromuscular system is more efficient at utilizing PAP mechanisms (Blazevich & Babault, 2019). Furthermore, (Abdelkader, 2018) found that CT significantly increased squat jump and countermovement jump height, while reducing ground contact time (GCT) and time to maximum height (TMH) ($p < 0.05$). This supports the idea that CT enhances reactive strength and SSC efficiency, which are critical for explosive movements like jumping, sprinting, and COD (Markovic & Mikulic, 2010). Overall, the findings from this review support the widespread application of CT as an effective training method for improving multiple performance attributes in athletes. The results are particularly relevant for youth athletes, professional players, and sports requiring explosive strength and speed, such as football, soccer, and volleyball. Additionally, the heterogeneity analysis ($I^2 = 10\text{--}25\%$) suggests low-to-moderate variability across studies, indicating that CT protocols consistently produce positive outcomes across different populations. However, some inconsistencies in training volume, intensity, and recovery protocols across studies highlight the need for further research to establish optimal CT programming for different athlete populations (Wilson et al., 2013). Future research should focus on identifying the ideal CT protocols (e.g., alternating vs. block design), optimizing training loads, and determining the long-term effects of CT on athletic performance.

Effectiveness of Complex Training: Complex training has been shown to significantly improve strength performance in athletes. Studies indicate that both alternating and block complex training programs can lead to notable increases in strength metrics, such as vertical jump height and sprint times (Lesinski et al., 2014). When compared to traditional strength training methods, complex training

yields moderate improvements in strength, suggesting that it may be a more effective approach for athletes seeking to enhance their power output (Lesinski et al., 2014). Expertise Level Considerations: The effectiveness of complex training may vary based on the athlete's level of expertise. For instance, lower-expertise athletes have shown greater strength performance improvements than their more experienced counterparts (Lesinski et al., 2014). Complex training has been linked to significant improvements in speed among team sport athletes. Research indicates that athletes participating in complex training programs exhibit faster sprint times compared to those engaged in traditional training methods (Lesinski et al., 2014; Saibya et al., 2024). Mechanisms of Improvement: The underlying mechanism for speed enhancement through complex training is believed to be post-activation potentiation (PAP), which temporarily increases muscle power output following heavy resistance exercises. Optimal results in speed performance are often observed with specific training frequencies and durations, emphasizing the need for well-structured training regimens (Slimani et al., 2016). The integration of plyometric exercises within complex training frameworks has been shown to enhance jump height and agility in athletes. Short-term plyometric training, particularly when combined with strength training, can lead to substantial improvements in these areas (Slimani et al., 2016). Studies suggest that plyometric training alone may yield better results in jump performance than when combined with strength training, highlighting the importance of exercise selection in training programs (Slimani et al., 2016). The type of surface used for plyometric training can also influence performance outcomes. Training on non-rigid surfaces has been shown to produce similar benefits as traditional plyometric training (Slimani et al., 2016). Apart from benefiting complex Training, does also has a few limitations, as CT primarily focuses on anaerobic performance, which may not enhance aerobic capacity effectively. For instance, high-intensity interval training (HIIT) combined with traditional strength training has shown improvements in aerobic power, indicating the need for aerobic-focused training (Müller et al., 2020). The explosive nature of CT may not facilitate optimal recovery between high-intensity bouts, suggesting that aerobic training could be beneficial for recovery (Huang et al., 2024).

This study provides strong evidence supporting the effectiveness of CT in enhancing strength, speed, agility, and jumping performance in athletes. The findings align with existing literature and suggest that CT should be integrated into sport-specific training programs to maximize performance outcomes. By combining heavy resistance training with explosive plyometric exercises, CT effectively leverages neuromuscular adaptations, PAP mechanisms, and SSC efficiency, making it an ideal training strategy for competitive athletes.

Conclusion

This systematic review and meta-analysis provide compelling evidence supporting the effectiveness of complex training (CT) in enhancing multiple athletic performance parameters, including strength, power, speed, agility, and jumping ability. The findings demonstrate that

CT leads to significant improvements in vertical jump height (7.4% increase in alternating CT, 6.0% in block CT), sprint performance (2.4% reduction in sprint time for alternating CT), and agility (notable gains in change-of-direction speed and movement efficiency). Additionally, CT significantly enhances kicking accuracy, strength endurance, and lower-body power, highlighting its utility in sports such as football, soccer, and volleyball, where explosive power and rapid directional changes are crucial. The results indicate that youth athletes and professionals benefit the most from CT, with subgroup analyses revealing stronger adaptations in athletes under 18 and those at a professional level. These findings align with previous research indicating that neuromuscular adaptations, post-activation potentiation (PAP), and stretch-shortening cycle (SSC) efficiency contribute to the enhanced performance outcomes observed with CT. Furthermore, the study highlights that CT is a highly effective training method for improving both general athletic abilities and sport-specific skills, particularly when alternating heavy resistance exercises with plyometric movements. The low-to-moderate heterogeneity ($I^2 = 10\%-25\%$) observed in the studies suggests that CT consistently yields positive results across different athlete populations. However, variations in training volume, intensity, and protocol design indicate the need for further research to establish the optimal CT programming for specific athlete groups. Future studies should focus on identifying the most effective CT protocols, determining long-term adaptations, and examining the interplay between CT and other training modalities. In conclusion, CT should be integrated into structured training programs for athletes seeking to maximize performance gains in strength, speed, agility, and power, making it a valuable tool for sports performance enhancement.

Conflict of Interest

The authors declare no competing interests.

References

- Lesinski, M., Muehlbauer, T., Büsch, D., & Granacher, U. (2014). Effekte von Komplextraining auf Kraft- und Schnelligkeitsleistungen bei Sportlern: Ein systematischer Überblick. *Sportverletzung · Sportschaden*, 28(02), 85-107. <https://doi.org/10.1055/s-0034-1366145>
- Ramírez-López, C., Till, K., Boyd, A., Bennet, M., Piscione, J., Bradley, S., Giuliano, P., Leduc, C., & Jones, B. (2021). Coopetition: Cooperation among competitors to enhance applied research and drive innovation in elite sport. *British Journal of Sports Medicine*, 55(10), 522-523. BMJ Publishing Group. <https://doi.org/10.1136/bjsports-2020-102901>
- Ebben, W.P. (2002). COMPLEX TRAINING: A BRIEF REVIEW. *Journal of Sports Science and Medicine*, 1. <http://www.jssm.org>
- Senft, D. (2014). Justifying medical necessity for services ordered for Medicare beneficiaries. *Geriatric Nursing*, 35(3), 227-229. <https://doi.org/10.1016/j.gerinurse.2014.04.003>
- Karbach, J. (2014). Game-based cognitive training for the aging brain. *Frontiers in Psychology*, 5. <https://doi.org/10.3389/fpsyg.2014.01100>
- Borba, D.D. A., Ferreira-Júnior, J.B., Santos, L.A. dos, Carmo, M.C. do, & Coelho, L.G. M. (2017). Efeito da

- potencialização pós-ativação no Atletismo: uma revisão sistemática. *Brazilian Journal of Kinanthropometry and Human Performance*, 19(1), 128. <https://doi.org/10.5007/1980-0037.2017v19n1p128>
- Stankovic, M., Djordjevic, D., Trajkovic, N., & Milanovic, Z. (2023). Effects of High-Intensity Interval Training (HIIT) on Physical Performance in Female Team Sports: A Systematic Review. *Sports Medicine - Open*, 9(1), 78. <https://doi.org/10.1186/s40798-023-00623-2>
- Hodgson, M., Docherty, D., & Robbins, D. (2005). Post-Activation Potentiation. *Sports Medicine*, 35(7), 585-595. <https://doi.org/10.2165/00007256-200535070-00004>
- Tillin, N.A., & Bishop, D. (2009a). Factors Modulating Post-Activation Potentiation and its Effect on Performance of Subsequent Explosive Activities. *Sports Medicine*, 39(2), 147-166. <https://doi.org/10.2165/00007256-200939020-00004>
- Silva, J.R., Nassis, G.P., & Rebelo, A. (2015). Strength training in soccer with a specific focus on highly trained players. *Sports Medicine - Open*, 1(1), 17. <https://doi.org/10.1186/s40798-015-0006-z>
- Thapa, R.K., Lum, D., Moran, J., & Ramirez-Campillo, R. (2021). Effects of Complex Training on Sprint, Jump, and Change of Direction Ability of Soccer Players: A Systematic Review and Meta-Analysis. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.627869>
- Pomo Warih Adi, Singgih Hendarto, Sapta Kunta Purnama, Rumi Iqbal Doewes, Sugiyanto, & Muchsin Doewes. (2023). Methods Of Physical Exercise As A Way To Optimize The Physical Condition Of Football Players: A Systematic Review. *South Eastern European Journal of Public Health*, 34-56. <https://doi.org/10.56801/seejph.vi.377>
- Thapa, R.K., Uysal, H.Ş., Clemente, F.M., Afonso, J., & Ramirez-Campillo, R. (2024). Effects of complex training compared to resistance training alone on physical fitness of healthy individuals: A systematic review with meta-analysis. *Journal of Sports Sciences*, 42(14), 1367-1389. <https://doi.org/10.1080/02640414.2024.2391657>
- Flórez Gil, E., Vaquera, A., Ramírez-Campillo, R., Sanchez-Sanchez, J., & Rodríguez Fernández, A. (2024). Can Complex Training Improve Acute and Long-Lasting Performance in Basketball Players? A Systematic Review. *Applied Sciences*, 14(15), 6839. <https://doi.org/10.3390/app14156839>
- Nandakumar, D., & Ramesh, S. (2020). Effect of complex training on selected physical fitness variables among football players. *International Journal of Physical Education, Sports and Health*, 7(6), 160-162.
- Naveen Raj A, Kamalakannan M, Anitha A, & Ramana K. (2024). Recent Experimental Investigation on the Effectiveness of Complex Training for Intermediate Football Players. *Indian Journal of Physiotherapy & Occupational Therapy - An International Journal*, 18, 237-242. <https://doi.org/10.37506/8rcwsf74>
- Seo, S.-W., & Lee, H.-S. (2018). Effects of complex physical training on exercise and football performances in youth football players. *Korean Journal of Sport Science*, 29(1), 49-62. <https://doi.org/10.24985/kjss.2018.29.1.49>
- Wang, X., Lv, C., Qin, X., Ji, S., & Dong, D. (2023). Effectiveness of plyometric training vs. complex training on the explosive power of lower limbs: A Systematic review. *Frontiers in Physiology*, 13. <https://doi.org/10.3389/fphys.2022.1061110>
- Yilmaz, N. (2022). Investigation of the effect of acute badminton training on selected biomotoric parameters. *Physical Education of Students*, 26(1), 11-17. <https://doi.org/10.15561/20755279.2022.0102>
- Sarmiento, H., Clemente, F.M., Harper, L.D., Costa, I.T. da, Owen, A., & Figueiredo, A.J. (2018). Small sided games in soccer - a systematic review. *International Journal of Performance Analysis in Sport*, 18(5), 693-749. <https://doi.org/10.1080/24748668.2018.1517288>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. <https://doi.org/10.1136/bmj.n71>
- M. J., M. D., B. P. M., B. I., H. T. C., M. C. D., . . . & M. J. E. (2021). *PRISMA 2020 flow diagram for new systematic reviews: template document*. PRISMA Statement
- Thapa, R. K., Narvariya, P., Weldon, A., Talukdar, K., & Ramirez-Campillo, R. (2022). Can complex contrast training interventions improve aerobic endurance, maximal strength, and repeated sprint ability in soccer players? A systematic review and meta-analysis. *Montenegrin Journal of Sports Science and Medicine*, 11(2), 45-55. <https://doi.org/10.26773/mjssm.220906>
- Pratama, R., Hidayat, A., & Makorohim, M. F. (2020). Complex training: Efektifitas Latihan Dalam Meningkatkan Power Otot Pada Atlet Bola Voli Remaja. *Journal Sport Area*, 146-154.
- Poulos, N., Haff, G.G., Nibali, M., Norris, D., & Newton, R. (2023). Influence of Complex Training Design on Acute Postactivation Performance Enhancement of Jump Squat and Ballistic Bench Throw Performance in Developing Team-Sport Athletes. *Journal of Strength and Conditioning Research*, 37(5), 969-979. <https://doi.org/10.1519/JSC.0000000000004323>
- Abdelkader, M. (2018). Effect of Complex Training on Jumping Variables During Heading the Ball for Soccer Players. *International Sports Science Alexandria Journal*, 1(1), 1-14. <https://doi.org/10.21608/isalexu.2018.92945>
- Cormie, P., McGuigan, M.R., & Newton, R.U. (2011). Developing Maximal Neuromuscular Power. *Sports Medicine*, 41(1), 17-38. <https://doi.org/10.2165/11537690-000000000-00000>
- Sáez de Villarreal, E., Requena, B., & Cronin, J. B. (2012). The Effects of Plyometric Training on Sprint Performance: A Meta-Analysis. *Journal of Strength and Conditioning Research*, 26(2), 575-584. <https://doi.org/10.1519/JSC.0b013e318220fd03>
- Turner, A.N., & Stewart, P.F. (2014). Strength and Conditioning for Soccer Players. *Strength & Conditioning Journal*, 36(4), 1-13. <https://doi.org/10.1519/SSC.0000000000000054>
- Tillin, N.A., & Bishop, D. (2009b). Factors Modulating Post-Activation Potentiation and its Effect on Performance of Subsequent Explosive Activities. *Sports Medicine*, 39(2), 147-166. <https://doi.org/10.2165/00007256-200939020-00004>
- Behm, D.G., Young, J.D., Whitten, J.H. D., Reid, J.C., Quigley, P.J., Low, J., Li, Y., Lima, C.D., Hodgson, D.D., Chaouachi, A., Prieske, O., & Granacher, U. (2017). Effectiveness of Traditional Strength vs. Power Training on Muscle Strength, Power and Speed with Youth: A Systematic

- Review and Meta-Analysis. *Frontiers in Physiology*, 8. <https://doi.org/10.3389/fphys.2017.00423>
- Carter, J., & Greenwood, M. (2014). Complex Training Reexamined. *Strength & Conditioning Journal*, 36(2), 11-19. <https://doi.org/10.1519/SSC.0000000000000036>
- Chaouachi, A., Othman, A. Ben, Hammami, R., Drinkwater, E.J., & Behm, D.G. (2014). The Combination of Plyometric and Balance Training Improves Sprint and Shuttle Run Performances More Often Than Plyometric-Only Training With Children. *Journal of Strength and Conditioning Research*, 28(2), 401-412. <https://doi.org/10.1519/JSC.0b013e3182987059>
- Young, W. B., Dawson, B., & Henry, G. J. (2015). Agility and change-of-direction speed are independent skills: Implications for training for agility in invasion sports. *International Journal of Sports Science & Coaching*, 10(1), 159-169. <https://doi.org/10.1260/1747-9541.10.1.159>
- Wilson, J.M., Duncan, N.M., Marin, P.J., Brown, L.E., Loenneke, J.P., Wilson, S.M. C., Jo, E., Lowery, R.P., & Ugrinowitsch, C. (2013). Meta-Analysis of Postactivation Potentiation and Power. *Journal of Strength and Conditioning Research*, 27(3), 854-859. <https://doi.org/10.1519/JSC.0b013e31825c2bdb>
- Seitz, L.B., & Haff, G.G. (2016). Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. *Sports Medicine*, 46(2), 231-240. <https://doi.org/10.1007/s40279-015-0415-7>
- Blazevich, A.J., & Babault, N. (2019). Post-activation Potentiation Versus Post-activation Performance Enhancement in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. *Frontiers in Physiology*, 10. <https://doi.org/10.3389/fphys.2019.01359>
- Markovic, G., & Mikulic, P. (2010). Neuro-Musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training. *Sports Medicine*, 40(10), 859-895. <https://doi.org/10.2165/11318370-000000000-00000>
- Saibya, S., Pandey, G., Jadhav, A.C., Rajpoot, Y.S., Govindasamy, K., Sarkar, S., & Gogoi, H. (2024). Impact of circuit training on physical fitness among team sports athletes: A systematic review. *Fizjoterapia Polska*, 24(1), 244-257. <https://doi.org/10.56984/8ZG2EF82sK>
- Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F.B., & Chéour, F. (2016). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics*, 53(1), 231-247. <https://doi.org/10.1515/hukin-2016-0026>
- Müller, D.C., Izquierdo, M., Boeno, F.P., Aagaard, P., Teodoro, J.L., Grazioli, R., Radaelli, R., Bayer, H., Neske, R., Pinto, R.S., & Cadore, E.L. (2020). Adaptations in mechanical muscle function, muscle morphology, and aerobic power to high-intensity endurance training combined with either traditional or power strength training in older adults: a randomized clinical trial. *European Journal of Applied Physiology*, 120(5), 1165-1177. <https://doi.org/10.1007/s00421-020-04355-z>
- Huang, Z., Chen, J., Chen, L., Zhang, M., Zhang, W., Sun, J., & Li, D. (2024). The enhancement of explosive power contributes to the development of anaerobic capacity: A comparison of autoregulatory progressive resistance exercise and velocity-based resistance training. *Journal of Exercise Science & Fitness*, 22(2), 159-167. <https://doi.org/10.1016/j.jesf.2024.02.005>

Оцінка впливу комплексного тренування на спортивну результативність: Систематичний огляд

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 13 с., 8 табл., 1 рис., 42 джерел.

Історія питання. Комплексне тренування (КТ), яке поєднує в собі силові вправи з великими обтяженнями та пліометричні рухи, широко використовується для підвищення силових показників, потужності, швидкості, спритності та результативності стрибків спортсменів. Однак, відмінності в протоколах КТ та ефективність їх застосування у різних групах населення залишаються предметом дискусій.

Мета дослідження. Мета цього систематичного огляду та метааналізу полягала в оцінці впливу КТ на спортивну результативність, зокрема у футболістів, а також у визначенні ключових факторів, що впливають на ефективність цієї методики.

Матеріали та методи. Дослідження проводилося згідно з рекомендаціями «Переважні елементи звітування для систематичних оглядів та метааналізів» (PRISMA), з використанням комплексного пошуку в наукометричних базах даних PubMed, Scopus, Web of Science та SportDiscus. До відповідних досліджень були включені рандомізовані контрольовані випробування (РКВ), квазіекспериментальні дослідження, систематичні огляди та метааналізи, в яких вивчався вплив КТ на висоту стрибка, час спринту, зміну напрямку руху (ЗНР), силову витривалість та специфічні спортивні навички. Було вилучено та проаналізовано дані, а також наведено розміри ефекту (d Коена) та статистику гетерогенності (I², Q-критерій р-значення).

Результати. Результати свідчать, що КТ значно покращує показники спортивної результативності: збільшення висоти вертикального стрибка на 7.4% (альтернуюче КТ), скорочення часу спринту на 2.4% та істотне підвищення показників спритності ($p < 0.001$). Підгруповий аналіз виявив більшу ефективність для юних спортсменів (ССР = 2.01) та професіоналів (ССР = 1.58 для спринту та 1,53 для показників ЗНР). Суттєве поліпшення також спостерігалось в показниках силової витривалості, потужності нижньої частини тіла та точності виконання ударів ногою.

Висновки. Проведене дослідження дозволяє стверджувати, що КТ є ефективним методом тренування, що сприяє розвитку вибухової сили, швидкості та спритності, особливо у молодих та елітних спортсменів. Враховуючи гетерогенність від низького до помірного рівнів ($I^2 = 10\%–25\%$), застосування КТ послідовно поліпшує результативність у різних групах населення. Подальші дослідження мають бути зосереджені на оптимізації протоколів КТ для конкретних груп спортсменів з метою забезпечення максимізації результативності.

Ключові слова: комплексне тренування, спортивна результативність, підвищення сили, поліпшення швидкості, пліометрика.

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Review Article

Improving Physical Education Learning Experience through Teaching Game for Understanding Approach: A Systematic Review

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Abstract

Objectives. The objective of this study was to systematically review the research development of TGfU in physical education, identify its impacts on learning outcomes, examine the integration of TGfU with other pedagogical approaches, and explore challenges encountered during its implementation.

Materials and Methods. This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and conducted thematic analysis. Research data were sourced from five databases: SCOPUS, ERIC, IEEE Xplore, Springer, and EBSCO. Additionally, 10 highly cited articles were included for an in-depth literature review. Keyword analysis was performed using VOSviewer to map thematic trends.

Results. The findings indicate that TGfU enhances students' cognitive, psychomotor, and affective learning domains by fostering motivation, decision-making, and game performance. The integration of TGfU with other models, such as the Sport Education Model (SEM) and the Activist Approach, has expanded its effectiveness and inclusivity. Despite these benefits, challenges in implementation, such as teacher preparedness, curriculum flexibility and institutional constraints, have been identified as barriers that must be addressed for optimal application.

Conclusions. TGfU has demonstrated a positive impact on the quality and effectiveness of physical education by promoting varied, engaging, and student-centered learning experiences. While the approach continues to evolve and integrate with other educational models, addressing practical challenges will be critical for sustaining its benefits and expanding its adoption across diverse educational contexts.

Keywords: physical education, student-centered learning, TGFU, pedagogical innovation, systematic review.

Introduction

Physical education plays a critical role in fostering students' physical, mental, and social development (Bamta et al., 2023). Despite its importance, the delivery of physical education content in schools often remains dominated by traditional, teacher-centered methods (Zhang & Zhang, 2022). These approaches typically utilize little innovation or pedagogical adaptation (Jiang, 2021). Another common practice is repetitive skill drilling, where students are

expected to master movements through constant repetition (Chang et al., 2020). While familiar, such methods tend to limit student engagement and personal development (Perlman, 2012). Teacher-centered strategies place authority entirely in the hands of the instructor, potentially creating rigid and uninspiring learning environments that fail to maximize students' capabilities (Standal & Bratten, 2021).

In response to these limitations, an innovative and student-centered instructional model called Teaching Games for Understanding (TGfU) has emerged as a promising alternative in physical education (Sumarno et al., 2022). Prior to TGfU, instruction typically followed a sequence of brief theoretical input, repetitive practice, and game application (Papagiannopoulos et al., 2023). However, this often led to disengagement among students, who were more likely to be passive observers than active participants

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(Fariduddin, 2017). Undermining the very goals of physical education, such as enhancing students' physical potential.

TGfU shifts the learning paradigm by immersing students in meaningful game-based learning contexts that promote active participation, strategic thinking, and deeper understanding. Research has consistently shown that TGfU positively influences students' cognitive, psychomotor, and affective domains, making it a holistic approach suited to the demands of 21st-century education. By emphasizing understanding and decision-making through play, TGfU empowers students to take ownership of their learning, fosters motivation, and nurtures both physical and social skills.

This systematic review aims to critically examine existing research on the application of TGfU in physical education. It seeks to explore the evolution, impact, and current trends surrounding TGfU while identifying gaps and future directions for research. By doing so, this study provides educators, researchers, and educational stakeholders with an evidence-based foundation to consider TGfU as an effective pedagogical strategy. It enhances students' learning experience and physical education quality in modern classrooms.

Materials and Methods

Study Design

This systematic review study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure the data identification process was transparent and credible. Thematic analysis was also conducted in this study through the results of the research data obtained to provide a comprehensive understanding. A literature review based on the most cited articles was also conducted to provide additional insight into previous studies. Through a transparent identification process, equipped with in-depth thematic analysis, and literature review related to previous research, this systematic review research will provide a holistic understanding for other researchers.

Study Procedure

This systematic review research uses five databases as its research data source. These databases are SCOPUS, ERIC, IEEE Xplore, Springer, and EBSCO. The data identification process was carried out on April 23, 2025 using the keywords "Teaching Games for Understanding" OR "TGfU" AND "Physical Education". The identification results in each database will be exported into RIS files. Then, the RIS files in each database will be imported into the citation software, namely Mendeley, with the aim of ensuring that each research data has keywords. This is so that when the keyword analysis process can run well without any obstacles.

The process of identifying research data, of course, has inclusion and exclusion criteria so that the selected data is in accordance with the research topics taken in this systematic review research. The inclusion criteria were research documents that were published in the form of articles and discussed TGfU in physical education. Meanwhile, the exclusion criteria were the opposite of the inclusion criteria,

namely research documents that were published not in the form of articles and did not discuss TGfU in physical education.

After all data is checked for keywords through Mendeley as previously explained, the results of the check will be exported back into the RIS file. The results of this export will then be imported into the Publish or Pearish software to carry out the screening process of research documents with the same title and not published in the form of articles. In addition, researchers also ensured that the articles that passed the screening process had topics relevant to this systematic review research.

The results of the screening of research data through the Publish or Pearish software will be exported back into RIS form. Then, the RIS file will be imported into the keyword analysis software, VosViewer. This keyword analysis process uses a fractional counting method or a keyword analysis method that really focuses on the keywords in each article in the RIS file. Through this, the risk of bias can be minimized, because if using the full counting method, the analysis will focus on authors that often appear, not keywords that often appear or are used.

On the other hand, the selection of articles with the most citations, based on the screening results in the Publish or Pearish software, was carried out with the aim of serving as data for literature review. The process of identifying and selecting the articles with the most citations involved five researchers to make the process more efficient. Thus, the results obtained can be maximized and minimize the occurrence of human error.

Results

Figure 1 illustrates the research data screening process based on the PRISMA framework, which includes four main phases: identification, screening, eligibility, and inclusion. A total of 430 documents were initially identified from five major databases (SCOPUS, ERIC, PubMed, IEEE Xplore, and Springer). During the screening phase, 136 documents were excluded because they were not published in article form; these included 87 conference papers, 7 books, 11 book chapters, 27 citation-only entries, and 4 notes. Of the remaining 294 documents deemed eligible due to their article

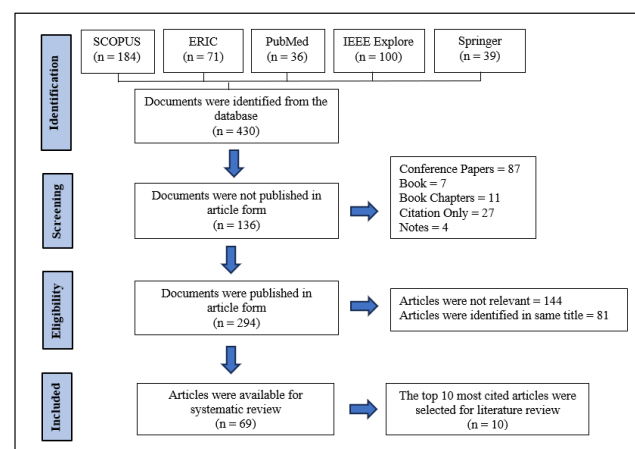


Fig. 1. Research Data Screening Process

format, 144 were excluded for being irrelevant to the TGfU topic, and 81 were duplicates with the same titles. As a result, 69 articles were included in the final systematic review, and an additional 10 highly cited articles were selected for an in-depth literature review.

Research Databases

Table 1 provides a summary of the research databases used in this systematic review, highlighting the number of papers retrieved, total citations, average citations per year, and H-Index from each source. SCOPUS contributed the highest number of papers (184) and citations (4446), with a high citation rate (171.00 per year) and the highest H-Index (34), indicating strong academic impact. ERIC followed with 71 papers and 2363 citations, while Springer contributed 39 papers but showed no citation data, possibly due to indexing issues. IEEE Xplore provided 100 papers with a relatively low citation count (126) and H-Index of 3. PubMed contributed 36 papers with 404 citations and a moderate average citation rate. Overall, 430 papers were gathered from these five databases, resulting in a total of 7339 citations and an average citation rate of 287.36 per year, illustrating the robust academic foundation of the literature included in this review.

Table 1. Research Databases

Source	Paper	Cites	Cites/Year	H-Index
SCOPUS	184	4446	171.00	34
ERIC	71	2363	94.52	24
Springer	39	0	0	0
IEEE Xplore	100	126	6.30	3
PubMed	36	404	15.54	8
Total	430	7339	287.36	-

Research Publication and Development

Figure 2 illustrates the development of research publications on the Teaching Games for Understanding (TGfU) approach in physical education from 1999 to 2025. The graph shows a gradual increase in publication frequency over time, with sporadic growth between 1999 and 2017, followed by a significant upward trend beginning in 2018. The peak occurred in 2021, with 11 publications in that year, indicating heightened academic interest in TGfU during this period. Although there was a slight decline in subsequent

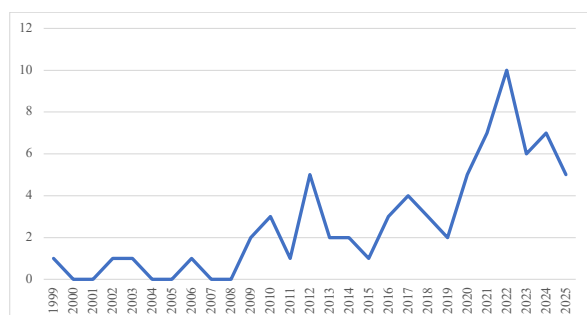


Fig. 2. Research Development

years, the overall trend reflects a growing recognition of TGfU as a relevant and impactful approach in physical education research. This suggests that TGfU is gaining momentum as a subject of scholarly attention and practical application.

Figure 3 illustrates the citation development of research related to Teaching Games for Understanding (TGfU) in physical education from 1999 to 2025. The graph reveals fluctuating citation patterns, with noticeable spikes in 2001, 2011, 2013, 2015, 2017, and a peak in 2019, which recorded the highest number of citations at over 200. This indicates that research published in or before those years received significant scholarly attention. After 2019, the number of citations shows a declining trend, particularly in 2023–2025, likely due to the recency of publications in those years, which typically have had less time to accumulate citations. Overall, the figure highlights that TGfU has experienced periods of high academic impact, particularly in the last decade, confirming its growing influence in physical education research.

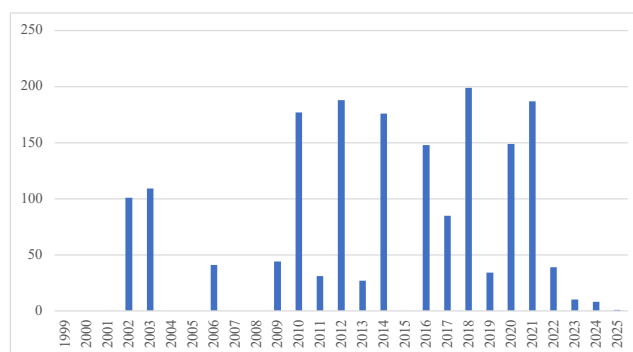


Fig. 3. Citation Development

Research Keywords Analysis

Table 3 highlights the most frequently used research keywords associated with Teaching Games for Understanding (TGfU) in the context of physical education. The keyword “Physical Education” is the most dominant, appearing 77 times and accumulating the highest number of total citations (2042), indicating its foundational role in the literature. “Teaching Games for Understanding” itself is cited 752 times across 36 occurrences, reflecting strong interest and relevance in academic discussions. Other significant keywords include “Teaching,” “Sport,” “Male,” and “Female,” each of which also received high citation counts, suggesting diverse perspectives including instructional strategies and gender considerations. Additionally, keywords such as “Motivation,” “Learning,” and “Student” emphasize the learner-centered focus of TGfU. Collectively, these keywords underline the multifaceted nature of TGfU research, which blends pedagogical theory, learner outcomes, and demographic factors to enhance the understanding and application of physical education.

Figure 3 displays a keyword co-occurrence network map generated using VOSviewer, illustrating the relationships and clustering of research topics related to Teaching Games for Understanding (TGfU) in physical education. The visualization reveals key clusters of terms, with “physical education” and “teaching games for understanding” positioned as central nodes, indicating their strong

Table 3. Research Keywords of TGfU in Physical Education

Keywords	f	Total cited	Average Cited
Physical Education	77	2042	1059.50
Teaching Games for Understanding	36	752	394.00
Teaching	27	576	301.50
Sport	18	472	245.00
Male	15	473	244.00
Female	15	473	244.00
Physical Education and Training	14	424	219.00
Motivation	12	317	164.50
Learning	12	302	157.00
Student	11	319	165.00
Total	237	6150	3193.50

connectivity and frequency of appearance in the literature. Other frequently co-occurring keywords include “game-based learning,” “tactical knowledge,” “student motivation,” and “pedagogical model,” reflecting the multidimensional focus of TGfU research encompassing instructional strategies, learning outcomes, and psychological factors. The color gradient from blue to yellow represents the average year of publication, showing the evolution of research trends over time. Newer research areas appear in yellow, suggesting growing interest in student-centered learning approaches and performance analysis in recent years. This figure highlights how TGfU research has developed into interconnected thematic areas and continues to evolve to address contemporary educational priorities.

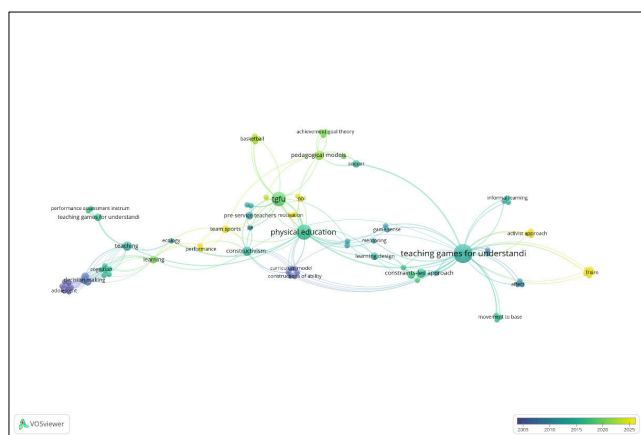


Fig. 4. Keywords Analysis

Research Subject Area

Table 4 presents the distribution of research on Teaching Games for Understanding (TGfU) across various academic subject areas, along with their corresponding citation metrics. The majority of TGfU-related studies are concentrated in the fields of Social Sciences (112 studies, 3374 citations), Health Professions (111 studies, 3203 citations), and Medicine (106 studies, 3288 citations), reflecting the interdisciplinary nature of TGfU research that spans education, health, and physical activity domains. Other areas such as Environmental Science, Biochemistry, Psychology, and Computer Science

show minor contributions, indicating emerging but less established links to TGfU. The relatively low citation and frequency in fields like Business or Energy further emphasize that TGfU research is primarily grounded in education and health contexts. In total, 361 studies were cited 10,516 times, highlighting both the depth and breadth of TGfU’s academic relevance across diverse disciplines.

Table 4. Research Subject Area

Subject Area	f	Total cited	Average Cited
Social Sciences	112	3374	1743.00
Health Professions	111	3203	1657.00
Medicine	106	3288	1697.00
Environmental Science	7	160	83.50
Biochemistry, Genetics, and Molecular Biology	7	176	91.50
Psychology	6	68	37.00
Computer Science	4	65	34.50
Multidisciplinary	3	109	56.00
Energy	3	65	34.00
Business, Management, and Accounting	2	8	5.00
Total	361	10516	5438.50

Research Affiliation

Table 5 summarizes the institutional affiliations contributing to research on Teaching Games for Understanding (TGfU), along with their corresponding frequency and citation metrics. The table highlights those institutions such as Universidad Rey Juan Carlos, Universidad de Extremadura, and Universidad de Castilla-La Mancha are among the most active contributors from Spain. Nanyang Technological University and the University of Limerick, despite having fewer publications (six each), stand out with the highest average citations per study 300.5 and 279 respectively demonstrating the high impact and quality of their research. Other notable contributors include the Chinese University of Hong Kong, Ohio University, and the University of British Columbia. Meanwhile, Universitas Negeri Yogyakarta is the only Indonesian institution listed, showing emerging contributions to TGfU research despite having the lowest average citations. In total, these ten institutions produced 74 studies with a combined 2,709 citations, emphasizing the global and collaborative nature of TGfU research across diverse educational and cultural contexts.

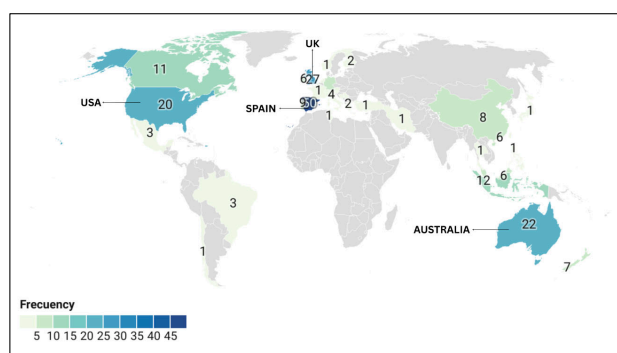
Figure 4 provides information on how different countries are involved in TGfU research in physical education. The data presented shows that research development has not been evenly distributed across continents. There are only a few countries in Europe and Asia that contribute to TGfU research in physical education. Spain appears to dominate with a total of 50 publications. This is in line with its dominance in the affiliation table in the previous table 5. The top four universities from Spain dominate the number of studies and the number of citations. This data proves

Table 5. Research Affiliation

Affiliation	f	Total cited	Average Cited
Universidad Rey Juan Carlos	12	367	189.50
Universidad de Extremadura	9	252	130.50
Universidad de Castilla-La Mancha	8	127	67.50
Universidad Católica de Murcia	8	264	136.00
Chinese University of Hong Kong	7	110	58.50
Nanyang Technological University	6	595	300.50
University of Limerick	6	552	279.00
The University of British Columbia	6	87	46.50
Ohio University	6	323	164.50
Universitas Negeri Yogyakarta	6	32	19.00
Total	74	2709	1391.50

the seriousness of Spain in developing the TGfU learning approach for physical education, not only for its country but for other countries as well.

Asian countries such as China only contributed 8 research documents. However, universities in China show a significant role through the number of citations shown in Table 5. Although still inferior to the number of citations from other universities, this still shows that China is able to represent countries in Asia through this research. The development of the education system and technology in China is one of the foundations of the excellence shown by the country. The data presentation shown in figure 4 does not show that there is an expansive and comprehensive development. TGfU research still needs to be conducted to holistically review the learning approach, especially in physical education.

**Fig. 5.** Countries Contributed

Literature Review

The literature review conducted in this study is based on the most citations every 2 years from 1999 to 2025. As many as 13 articles have been identified with the most citations, and have been reviewed through table 6. Based on the results of the literature review, the Teaching Games for Understanding (TGfU) approach effectively improves the learning process related to sports games in physical education. Research by Tan, Chow, and Davids (2012), states that TGfU is feasible

in the physical education learning process. This is reinforced by Light & Fawns, (2003) and Morales-Belando et al. (2018) through their research results which explain that TGfU has a significant positive effect on all aspects of physical education. These aspects include cognitive, motor, and affective aspects.

The implementation of TGfU in physical education is also proven to have an influence on students' psychology. This is evidenced through several studies that explain that TGfU is able to increase motivation, comfort, and decision-making. Research by Turner and Martinek, (1999), Morales-Belando et al. (2018), Gil-Arias, Claver, Práxedes, Villar, and Harvey (2020), and Batez, Petrušič, Bogataj, and Trajković, (2021), prove this statement.

According to Butler (2006), the application of TGfU in physical education can create a more democratic learning atmosphere. In addition, TGfU research integrated with the Sport Education Model (SEM) Pan, Huang, and Hsu (2023) and the Activist Approach Seldas and García López, (2025), effectively increased female students' engagement and provided better learning outcomes.

The majority of TGfU research in physical education shows positive impacts for both students and teachers. On the other hand, challenges in implementing this approach also need to be considered. Research by Holt, Streat, and Bengoechea (2002) and Nathan (2016), showed less significant results and suggested that the implementation needs to pay more attention to cognitive, affective, decision-making, and skill execution aspects. According to Díaz-Cueto, Hernández-Álvarez, and Castejón (2010), the implementation of TGfU in physical education does provide its own challenges for teachers, especially during the initial and implementation stages. Based on this, research by Stolz and Pill (2014) emphasized that TGfU may have little or no impact on the learning process.

Some results showed that the implementation of TGfU still needs to be optimized. Nonetheless, the majority of studies show how TGfU can contribute well to the physical education learning process. This certainly proves the significant role of TGfU in developing and innovating physical education learning. As a result, students are able to experience a meaningful learning process and maximize their learning outcomes.

Discussion

Teaching Games for Understanding (TGfU) research in physical education has shown significant progress over the past two decades. The findings of this systematic review demonstrate that TGfU not only enriches students' learning experiences but also addresses diverse learning domains cognitive, psychomotor, and affective. The evolution of TGfU research reflects the adaptability and relevance of this pedagogical model, which continues to shape innovative practices in physical education. This discussion elaborates on three key dimensions identified through the research synthesis: learning enhancement using TGfU, hybridization with other approaches, and the challenges of TGfU implementation.

Learning Enhancement Utilizing TGfU Approach

The physical education learning process cannot be separated from the teacher's role in managing or organizing

Table 6. Literature Review

Author	Years	Research Purposes	Study Design	Results
(Turner & Martinek, 1999)	1999-2000	To evaluate the efficacy of the games for understanding model by contrasting it with a technique-based instructional approach and a control group.	Experimental Study	The games for understanding group achieved markedly superior scores in passing decision-making compared to both the technique and control groups during post-test playtime, and considerably outperformed the control group in declarative and procedural knowledge.
(Holt et al., 2002)	2001-2002	To evaluate TGfU research, to propose an enhanced TGfU model, and to provide new directions for future study and practice.	Thematical Analysis	While numerous inquiries on the efficacy of diverse approaches to games teaching exist, we assert that the ongoing engagement of learners in games throughout their lives is of utmost significance. We urge researchers to reflect on the development of the TGfU model and to engage in the progression forward, taking into account learners from behavioral, cognitive, and affective viewpoints.
(Light & Fawns, 2003)	2003-2004	This paper utilizes phenomenology, educational philosophy, and contemporary cognitive research to contest the objectivist dichotomy of mind and body that has historically influenced physical education pedagogy. We propose that employing a TGfU strategy in gaming instruction provides educators with an effective method to deliver a comprehensive learning experience for students focused on the physical aspect.	Literature Review	Games taught in physical education with TGfU facilitate an educational dialogue wherein the intellect, articulated through speech, and the physique, demonstrated through action, represent the quintessential holistic learning experience that concurrently addresses cognitive, affective, social, and physical development.
(Butler, 2006)	2005-2006	To examine the TGfU curriculum paradigm (utilizing Inventing Games) in further detail, with particular focus on how it delineates student capability.	Thematical Analysis	TGfU provides a more comprehensive perspective on ability in physical education by utilizing many value orientations. The TGfU approach facilitates the instruction of democracy in educational settings, since it empowers both educators and students while encouraging them to challenge the status quo (ecological integration).
	2007-2008	-	-	-
(Díaz-Cueto et al., 2010)	2009-2010	To comprehend the opinions of in-service Physical Education (PE) educators regarding the implementation of Teaching Games for Understanding (TGfU) in sports instruction	Survey Study	The challenges faced by physical education instructors in the preparation and execution of Teaching Games for Understanding (TGfU). During the preliminary phase of TGfU implementation, educators expressed emotions of fear, leading them to question their pedagogical competence and knowledge. They additionally reported experiencing anxiousness and fatigue.
(Tan et al., 2012)	2011-2012	To offer insights that enhance our comprehension of the potential processes behind the educational principles of TGfU in gaming instruction.	Thematical Analysis	Research findings from the motor learning literature can offer a robust theoretical foundation to validate the efficacy of the four principal pedagogical principles of the TGfU model and can enhance understanding of the potential processes involved in TGfU within games instruction.

Table 6 (continued)

Author	Years	Research Purposes	Study Design	Results
(Stolz & Pill, 2014)	2013-2014	To evaluate and reassess TGfU and examine its pertinence to games and sports instruction in physical education This study delineates two aspects of the TGfU proposition: (1) the foundation for the conceptualization of TGfU; (2) promotion of TGfU as refined variations.	Literature Review	Making conclusive assertions regarding the success of a TGfU method is tricky, as the rhetorical generalizations present in the literature from the preceding historical overview of TGfU may offer little or no utility to practitioners. They possess no significance to the 'natural environment' of each practitioner.
(Nathan, 2016)	2015-2016	To study the effects of a revised model of TGfU in comparison to the Skill Drill Technical (SDT) model on the acquisition of movement skills in badminton	Comparative Study	The study revealed a notable enhancement in base movement during doubles play after the TGfU intervention, although decision-making and skill execution exhibited no significant alteration. Educator observations highlighted the significance of mini games in enhancing student involvement and cultivating favorable attitudes toward both victory and defeat. Nevertheless, several educators indicated difficulties in executing TGfU owing to pupils' requirement for tactical direction.
(Morales-Belando et al., 2018)	2017-2018	To ascertain if students exhibited enhancements in performance and adherence metrics following the implementation of a coherent TGfU unit.	Experimental Study	Students exhibited enhancements in decision-making, technical execution, coverage, support, game performance, engagement, enjoyment, perceived competence, and intention to engage in physical activity following the deployment of the TGfU unit. The students and the instructor observed enhancements in all analyzed variables as a result of the intervention.
(Gil-Arias, Claver, et al., 2020)	2019-2020	To examine the effects of a hybrid teaching model combining games for understanding (TGfU) and sport education (SE) in physical education on autonomy support, perceived motivational climate, enjoyment, and perceived competence, relative to a unit conducted through a conventional direct instruction approach.	Experimental Study	The findings provide preliminary evidence that a teacher's implementation of a hybrid TGfU/SE unit can foster student accountability and independent decision-making, resulting in increased enjoyment and perceived competence relative to physical education lessons conducted through a conventional direct instruction model.
(Batez et al., 2021)	2021-2022	To examine the impact of the Teaching Games for Understanding (TGfU) model applied in physical education classes on volleyball skills and enjoyment among secondary school students.	Experimental Study	Both instructional techniques, TGfU and the traditional approach, significantly improved volleyball abilities in controlled environments. The TGfU framework is advocated for its superior enhancement of student enjoyment and intrinsic motivation, both of which are vital for learning.
(Pan et al., 2023)	2023-2024	To analyze the disparity in learning outcomes between the TGfU-SEM and the TGfU model for students' learning motivation, sports enjoyment, responsibility, and game performance.	Comparative Study	The TGfU-SEM exhibited more favorable learning outcomes for students' motivation, pleasure of sports, sense of responsibility, and game performance compared to the TGfU model.

Table 6 (continued)

Author	Years	Research Purposes	Study Design	Results
(Seldas & García López, 2025)	2025	To develop and execute a successful hybridization of two pedagogical models that would effectively address gender-related obstacles to game participation.	Mix-Method Study - Exploratory Sequential Design	The girls' engagement in the game was significantly enhanced as a result of the group's collaborative efforts to adjust our actions, which enabled them to participate more actively.

students. The organization of these students has an influence on the running of teaching and learning activities between students and teachers. Physical education teachers will not be able to control all students, and create a truly conducive learning atmosphere (Sosunovsky & Radaeva, 2022). This statement applies if the learning process is carried out in the lower grades or in elementary school students and after. Students will always have activities that are done outside of the teacher's instructions, such as playing alone, talking to friends around them, or others. This phenomenon often occurs in the physical education learning process, and it is called non-engagement learning activities (Leo et al., 2020).

This non-engagement learning activity is caused by the teacher's lack of attention to students in the learning process. The use of inappropriate approaches is also a cause of these activities. A teacher-focused learning approach makes students feel bored and saturated, so that the focus of their attention will move to something other than the teacher. Such conventional approaches must begin to be minimized and physical education teachers must be able to adapt through a more modern approach, for example through Teaching Games for Understanding (TGfU).

The TGfU approach has proven effective in promoting holistic student development by integrating decision-making, tactical awareness, and technical skill acquisition within meaningful game contexts. Numerous studies, including those by Light & Fawns (2003) and Morales-Belando et al. (2018), affirm that TGfU enhances not only physical abilities but also fosters cognitive and social learning outcomes. Students involved in TGfU-based instruction consistently demonstrate improved engagement, motivation, and enjoyment factors essential for sustained participation in physical activity (Batez et al., 2021).

Additionally, TGfU promotes student-centered learning environments that encourage autonomy and accountability (Butler, 2006). By situating learning within game scenarios, students gain a deeper understanding of gameplay concepts and develop transferable skills applicable beyond physical education settings. The literature review further confirms that TGfU facilitates improvements in tactical knowledge, decision-making, and peer collaboration, thereby aligning with the objectives of modern, competency-based education.

Hybridization TGfU with Others Learning Approach

The use of methods or approaches in the physical education learning process needs to be determined before the learning process is carried out (Kermarrec et al., 2022). Determining the approach involves a teacher with the data he has based on environmental conditions and student characteristics. Physical education teachers cannot only apply one approach (Gil-Arias, Diloy-Peña, et al., 2020).

The difference in student characteristics is one of the reasons the implementation of the learning approach is not enough. Physical education teachers can do a combination or collaboration of two learning approaches. This aims to provide a differentiated physical education learning process. This differentiated learning is able to adjust the learning process based on the different characteristics of these students.

A notable trend in recent TGfU research is the integration of TGfU with complementary pedagogical models to maximize learning outcomes. Hybrid models, such as TGfU combined with the Sport Education Model (SEM), have yielded enhanced student motivation, responsibility, and performance (Pan, Huang, & Hsu, 2023). This hybridization addresses the diverse needs of learners and provides a more comprehensive educational experience.

Moreover, studies have shown that blending TGfU with the Activist Approach has successfully increased engagement among traditionally underrepresented groups, such as female students (Seldas & García López, 2025). Such integrations extend the reach and inclusivity of TGfU, enabling educators to address gender disparities and foster equitable learning environments. The flexibility of TGfU in adapting to various instructional contexts underscores its strength as a foundation for innovative teaching strategies.

Challenges from TGfU Implementation

Despite its advantages, TGfU implementation is not without challenges. Teachers often face difficulties during the initial adoption phases, including uncertainties about pedagogical competence and apprehensions about altering established instructional practices (Díaz-Cueto et al., 2010). Some studies, such as those by Holt et al. (2002) and Nathan (2016), report mixed outcomes, particularly regarding the consistency of cognitive and skill-related improvements.

Other barriers include the need for substantial teacher training and the requirement for flexible curricula that can accommodate the dynamic nature of TGfU. Teachers must develop skills in designing game-based learning experiences and in facilitating student inquiry and reflection practices that may be unfamiliar to those accustomed to traditional, teacher-centered approaches (Stolz & Pill, 2014). Furthermore, institutional constraints, such as rigid assessment frameworks and limited instructional time, can hinder the effective application of TGfU.

Limitations and Recommendation

The research results presented in this study, of course, have several limitations in the research process. Some of the limitations in this study are that this research is only

limited to research data in the form of articles. This of course allows for a bias in the research. Research related to TGfU in physical education is not always published in the form of articles, but can also be in the form of conference papers or the final project of a student, such as a thesis. Then, the data presented in table 3 to table 5 and the data in figure 4, are the results of identification on the SCOPUS website page. This is because only on the SCOPUS website these data can be screened properly and accurately. Furthermore, the selection of articles for literature review is based on the most citations. This selection is of course also able to cause bias in research, because the number of citations is not able to represent the quality of a study. As we all know, there are several cases in research related to self-citation.

The researcher suggested for future research to expand the research data to be used, such as conference articles or scientific research results from thesis. Optimization of journal websites can also be done so that screening related to keywords, affiliations, countries, and subject areas does not only depend on the SCOPUS website. Article rating can also be applied as a sign of the quality of the article, so that when there is research related to literature reviews or systematic reviews, it can facilitate the process of identifying and screening research data. Through updates made in the future, it will certainly increase the quality of the research. Thus, the research results obtained will also be maximized without the possibility of bias in the research.

Conclusions

The current physical education learning process has evolved through the modernization of the learning approach. The transition from teacher-centered learning to student-centered learning is one of the characteristics of this development. Teaching Games for Understanding (TGfU) in physical education has evolved and continued to adjust since the 1990s until the digitalization era as it is today. TGfU, which initially focused only on the social and emotional aspects of a student, has now begun to pay attention to other aspects in physical education.

This study concludes that over the past few years, TGfU has begun to pay attention to the cognitive and psychomotor aspects of students. The integration of TGfU with other learning approaches can also have a positive influence on the physical education learning process. The integration provides opportunities for female students to be more involved or active when physical education is conducted.

On the other hand, the application of TGfU in physical education still needs to be re-evaluated. The emergence of challenges during the implementation process has a significant negative impact on physical education teachers. Physical education teachers need to improvise their pedagogical skills so that the challenges that arise can produce a solution. The role of the physical education teacher facilitator is very important in the process of pedagogical improvisation. Through this, TGfU will be able to be optimally realized in physical education. TGfU will have a significant positive impact on both the students and the teachers themselves. Thus, the generalization process will be very likely to be implemented, so that physical education teachers will be more professional and students will get a more meaningful learning experience.

Acknowledgment

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Conflict of Interest

The author was declared there is no conflict of interest.

References

- Bamta, S., Misra, A., & Peter, V.F. (2023). Psychological Benefits of Physical Education. *Journal Global Values, XIV*(S.Issue). <https://doi.org/10.31995/jgv.2023.v14is3.009>
- Zhang, Z., & Zhang, Y. (2022). Research on Effective Strategies of College Physical Education Interactive Teaching Based on Machine Learning. *Applied Bionics and Biomechanics*, 2022. <https://doi.org/10.1155/2022/1843514>
- Jiang, R. (2021). Research on Innovative Practice Links of Physical Education Course Based on Computer Big Data. *Journal of Physics: Conference Series*, 1865(4). <https://doi.org/10.1088/1742-6596/1865/4/042133>
- Chang, K.E., Zhang, J., Huang, Y.S., Liu, T.C., & Sung, Y.T. (2020). Applying augmented reality in physical education on motor skills learning. *Interactive Learning Environments*, 28(6). <https://doi.org/10.1080/10494820.2019.1636073>
- Perlman, D. (2012). The influence of the Sport Education Model on developing autonomous instruction. *Physical Education and Sport Pedagogy*, 17(5). <https://doi.org/10.1080/17408989.2011.594430>
- Standal, Ø.F., & Bratten, J.H. (2021). 'Feeling better': embodied self-knowledge as an aspect of movement capability. *Physical Education and Sport Pedagogy*, 26(3). <https://doi.org/10.1080/17408989.2021.1886268>
- Sumarno, S., Imawati, V., & Ristiawan, B. (2022). Learning Innovation through Teaching Game for Understanding (TGfU) Model to Prepare Physical Education Learning Strategy Skills. *Jurnal Pendidikan Jasmani Indonesia*, 18(2). <https://doi.org/10.21831/jpji.v18i2.54692>
- Papagiannopoulos, D., Digelidis, N., & Syrmipas, I. (2023). PE teachers' perceptions of and experiences with using the TGfU model in teaching team games in elementary school. *Journal of Physical Education and Sport*, 23(2). <https://doi.org/10.7752/jpes.2023.02060>
- Fariduddin, I.A. (2017). Pengaruh Pengguna Teknologi Informasi Terhadap Aktifitas Fisik Siswa (Studi Pada Siswa Kelas VII SMP Negeri 1 Padangan). *Jurnal Pendidikan Olahraga Dan Kesehatan*, 4(3). <https://core.ac.uk/outputs/230798330/?source=oai>
- Tan, C. W. K., Chow, J. Y., & Davids, K. (2012). "How does TGfU work?": Examining the relationship between learning design in TGfU and a nonlinear pedagogy. *Physical Education and Sport Pedagogy*, 17(4), 331–348. <https://doi.org/10.1080/17408989.2011.582486>
- Light, R., & Fawns, R. (2003). Knowing the game: Integrating speech and action in games teaching through tgfu. *Quest*, 55(2), 161–176. <https://doi.org/10.1080/00336297.2003.10491797>
- Morales-Belando, M. T., Calderón, A., & Arias-Estero, J. L. (2018). Improvement in game performance and

- adherence after an aligned TGfU floorball unit in physical education. *Physical Education and Sport Pedagogy*, 23(6), 657–671. <https://doi.org/10.1080/17408989.2018.1530747>
- Turner, A. P., & Martinek, T. J. (1999). An investigation into teaching games for understanding: effects on skill, knowledge, and game play. *Research Quarterly for Exercise and Sport*, 70(3), 286–296. <https://doi.org/10.1080/02701367.1999.10608047>
- Gil-Arias, A., Claver, F., Práxedes, A., Villar, F.D., & Harvey, S. (2020). Autonomy support, motivational climate, enjoyment and perceived competence in physical education: Impact of a hybrid teaching games for understanding/sport education unit. *European Physical Education Review*, 26(1), 36–53. <https://doi.org/10.1177/1356336X18816997>
- Batez, M., Petrušić, T., Bogataj, Š., & Trajković, N. (2021). Effects of teaching program based on teaching games for understanding model on volleyball skills and enjoyment in secondary school students. *Sustainability (Switzerland)*, 13(2), 1–7. <https://doi.org/10.3390/su13020606>
- Butler, J.I. (2006). Curriculum constructions of ability: Enhancing learning through Teaching Games for Understanding (TGfU) as a curriculum model. *Sport, Education and Society*, 11(3), 243–258. <https://doi.org/10.1080/13573320600813408>
- Pan, Y.-H., Huang, C.-H., & Hsu, W.-T. (2023). A comparison of the learning effects between TGfU-SE and TGfU on learning motivation, sport enjoyment, responsibility, and game performance in physical education. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1165064>
- Seldas, M., & García López, L. M. (2025). Benefits of hybridising the activist approach and teaching games for understanding to empower girls in physical education. *Curriculum Studies in Health and Physical Education*, 16(1), 97–113. <https://doi.org/10.1080/25742981.2023.2265351>
- Holt, N. L., Streat, W. B., & Bengoechea, E. G. (2002). Expanding the teaching games for understanding model: New avenues for future research and practice. *Journal of Teaching in Physical Education*, 21(2), 162–176. <https://doi.org/10.1123/jtpe.21.2.162>
- Nathan, S. (2016). Badminton instructional in Malaysian schools: a comparative analysis of TGfU and SDT pedagogical models. *SpringerPlus*, 5(1), 1215. <https://doi.org/10.1186/s40064-016-2872-3>
- Díaz-Cueto, M., Hernández-Álvarez, J.L., & Castejón, F.J. (2010). Teaching games for understanding to in-service physical education teachers: Rewards and barriers regarding the changing model of teaching sport. *Journal of Teaching in Physical Education*, 29(4), 378–398. <https://doi.org/10.1123/jtpe.29.4.378>
- Stolz, S., & Pill, S. (2014). Teaching games and sport for understanding: Exploring and reconsidering its relevance in physical education. *European Physical Education Review*, 20(1), 36–71. <https://doi.org/10.1177/1356336X13496001>
- Sosunovsky, V.S., & Radaeva, S.V. (2022). ORGANIZATION OF PHYSICAL EDUCATION IN THE BLENDED LEARNING. *Teoriya i Praktika Fizicheskoy Kultury*, 2022(11), 69–71. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85139985146&partnerID=40&md5=2dbe410338fe57b67aeec2ef240c4894>
- Leo, F.M., López-Gajardo, M.A., Gómez-Holgado, J.M., Ponce-Bordón, J.C., & Pulido, J.J. (2020). Teaching-learning methodologies and its relation with students' motivation and engagement in physical education lessons. *Cultura, Ciencia y Deporte*, 15(46), 495–506. <https://doi.org/10.12800/CCD.V15I46.1600>
- Light, R., & Fawns, R. (2003). Knowing the game: Integrating speech and action in games teaching through tgfu. *Quest*, 55(2), 161–176. <https://doi.org/10.1080/00336297.2003.10491797>
- Kermarrec, G., Regaieg, G., & Clayton, R. (2022). Mixed-methods approaches to learning strategies and self-regulation in Physical Education: a literature review. *Physical Education and Sport Pedagogy*, 27(2), 172–185. <https://doi.org/10.1080/17408989.2021.1999916>

Поліпшення досвіду навчання у фізичному вихованні через використання методики навчальної гри для тренування розуміння: Систематичний огляд

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 11 с., 6 табл., 5 рис., 27 джерел.

Мета дослідження. Метою цього дослідження було систематично проаналізувати розвиток досліджень щодо застосування методики навчальної гри для тренування розуміння (Teaching Game for Understanding Approach, TGfU) у

фізичному вихованні, визначити її вплив на результати навчання, дослідити інтеграцію TGfU з іншими педагогічними підходами та розглянути труднощі, що виникають під час впровадження зазначеної методики.

Матеріали та методи. Це дослідження проводилося відповідно до рекомендацій «Переважні елементи звітності для систематичних оглядів та метааналізів» (PRISMA) та включало тематичний аналіз. Дослідницькі дані було отримано з п'яти наукометричних баз даних: SCOPUS, ERIC, IEEE Xplore, Springer та EBSCO. Крім того, для поглибленого огляду літератури було включено 10 статей, що мають високу цитованість. Аналіз ключових слів проведено за допомогою програмного забезпечення VOSviewer з метою малювання тематичних тенденцій.

Результати. Результати показують, що TGfU покращує когнітивні, психомоторні та афективні сфери навчання учнів, сприяючи мотивації, ухваленню рішень та ігровій результативності. Інтеграція TGfU з іншими моделями, як-от модель спортивного виховання (SEM) та активістський підхід, розширила її ефективність та інклюзивність. Незважаючи на вказані переваги, визначено низку проблем у впровадженні, які необхідно вирішити для оптимального застосування, зокрема підготовленість викладачів, гнучкість навчальної програми та інституційні обмеження.

Висновки. Методика TGfU продемонструвала позитивний вплив на якість та ефективність фізичного виховання, сприяючи створенню різноманітних, залучаючих та учнецентричних навчальних досвідів. Попри постійний розвиток та інтеграцію зазначеного підходу з іншими освітніми моделями, розв'язання практичних проблем матиме вирішальне значення для збереження переваг та розширення застосування цієї методики у різних освітніх контекстах.

Ключові слова: фізичне виховання, учнецентричне навчання, TGfU, педагогічні інновації, систематичний огляд.

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Game-Centered Approaches in Primary Physical Education: A Systematic Review of Implementation and Learning Outcomes

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Abstract

Background. Game-centered approaches (GCAs) have arisen as innovative pedagogical frameworks in physical education (PE), providing an alternative to conventional technique-focused instruction. GCAs seek to foster comprehensive student growth in physical, cognitive, emotional, and social areas by prioritizing tactical comprehension, adjusted gameplay, and reflective inquiry.

Objectives. This systematic review aimed to consolidate empirical evidence regarding the implementation and educational outcomes of Game-Centered Approaches (GCAs) in elementary physical education. It focused on delineating the scope, patterns, and pedagogical effects of diverse models.

Materials and Methods. Following PRISMA standards, an extensive search was performed across five databases (Scopus, Web of Science, EBSCOHost, Google Scholar, and PubMed) for peer-reviewed experimental papers published till April 2025. The inclusion criteria emphasized elementary-level therapies using GCAs with quantifiable outcomes in motor, cognitive, psychosocial, or affective domains. Thirty-four studies were incorporated and examined utilizing a qualitative synthesis framework based on the PICO model.

Results. Teaching Games for Understanding (TGfU), Tactical Games Model (TGM) were the most commonly used models, typically integrated into invasion games and organized curriculum. GCAs exhibited substantial advantages in enhancing core movement abilities, gaming performance, decision-making, motivation, creativity, and emotional engagement. Hybrid models and socio-motor modifications improved the application of GCA, while large-scale initiatives expanded their influence on social development and well-being. Nonetheless, no singular model adequately addressed all four learning areas, highlighting the necessity for strategic model integration.

Conclusions. The findings confirm that GCAs are a robust pedagogical framework for elementary physical education, promoting multifaceted student outcomes and aligning with 21st-century educational objectives. Further research should emphasize longitudinal, comparative, and context-sensitive methodologies, while teacher professional development must facilitate these models' practical, inclusive, and sustainable implementation.

Keywords: game-centered approach, physical education, primary school, tactical pedagogy, student outcomes.

Introduction

The implementation of GCAs was considered important for shifting the paradigm of physical education teaching from traditional approaches towards more inclusive and relevant experiential learning. As stated by Garcia-Puchades and Chiva-Bartoll (2020) that GCAs were recognized as a leading method in modern PE, as they focused on games as the primary medium of learning. This approach provided a strong framework for designing learning that prioritized students' social, physical, and cognitive learning outcomes

(Metzler, 2017) and in line with the demands of 21st-century education (Gubacs-Collins, 2015). In the context of modern education, GCAs became an effective tool for bridging the gap between pedagogical theory and practice in the field (Light et al., 2014). In GCAs, students learned by playing, a process that strengthened their emotional and social engagement in learning. This was relevant for preparing students to face global challenges while encouraging lifelong active living (Harvey & Jarrett, 2014). Additionally, this approach offered long-term benefits for students, including enhancing their physical activity levels and promoting the adoption of sustainable healthy lifestyles (Mercan & Varol Selçuk, 2024). In other words, the implementation of GCAs was crucial not only for supporting curriculum achievement

but also for ensuring that physical education had a lasting positive impact on students' lives.

Despite the many advantages of GCAs, their implementation in the field still faced various challenges. Teachers often struggled to translate the concepts of GCAs into effective teaching practices due to a lack of adequate pedagogical understanding (Goodyear, 2017). Additionally, traditional curricula that focused on technical skills and sports-based approaches often limited room for innovation in physical education (Kirk et al., 2018). These obstacles were exacerbated by teachers' resistance to changing teaching methods and the difficulty of abandoning old habits (Casey & MacPhail, 2018). The limitations of professional training were also one of the factors hindering the successful implementation of GCAs. Teachers required deeper pedagogical skill development through Continuing Professional Development (CPD) programs, which had proven effective in enhancing teachers' pedagogical knowledge and the quality of learning (Morgan et al., 2019; Bodsworth, 2017). Additionally, the development of peer collaboration was necessary to address teachers' limitations in utilizing new technologies and teaching methods (Hordvik et al., 2021).

An improved understanding of the implementation of GCAs in PE teaching required a more in-depth review through systematic investigation of previous study results. Systematic reviews were essential as they helped compile existing research findings into a more integrated picture, providing clearer guidance for practice and policy development (Barba-Martín et al., 2020; Camacho-Sánchez et al., 2023). Moreover, systematic reviews could identify research gaps and areas needing further attention. By uniting key theories and previous empirical evidence, this approach provided a strong foundation for future research (Ortiz Gómez et al., 2023). This review was pertinent for enhancing teaching methodologies and fostering creativity in game-based physical education.

Most reviews on the implementation of GCAs presented systematic reviews. For example, Miller (2015) conducted a review of 15 articles focusing on student outcomes from the implementation of GCAs. Elumalai et al. (2022) reviewed PE learning approaches in improving physical fitness, academic performance, and enjoyment among students. Ortiz Gómez et al. (2023) examined pedagogical approaches applicable to PE teachers at various levels. Camacho-Sánchez et al. (2023) reviewed the impact of game-based learning (GBL) and gamification on variables studied in each investigation. Fernandez-Rio & Iglesias (2024) conducted a general review of the implementation of pedagogical models. These studies highlighted important content related to implementation, key theories adopted, and gaps for further research. Subsequently, Manninen et al. (2024) reviewed twenty-eight articles comparing the effects of game-based approaches (GBAs) and traditional skill-based approaches on decision-making, knowledge, and motor skills in PE students and athletes. However, this study had limitations as it only covered motor and cognitive skills components but did not include play and psychosocial skills components. Additionally, the target subjects were still general, encompassing all school levels and athletes.

In relation to the weaknesses of the previous study, a systematic literature review was needed to uncover

the impact of GCA implementation on Primary school students' development, including motor, cognitive, play, and psychosocial aspects. The systematic literature review aimed to report findings from systematic reviews on the implementation of GCAs on physical, cognitive, emotional, and psychosocial skills. Specifically, this study aimed to answer the questions what forms of GCAs had been implemented to facilitate the development of Primary school students? By synthesizing findings from various studies, this research could provide a clearer understanding of best practices and explain broader implications of GCA implementation as an approach in physical education.

Materials and Methods

Search Strategy

A Systematic Literature Review emphasizes the systematic search process supported by three main steps: identification, screening, and eligibility, which aid researchers in conducting comprehensive article searches (Page et al., 2021). A systematic review was conducted to search for studies discussing the application of soccer-based programs for social development. The study search process was conducted using the Scopus, Web of Science (WoS), EBSCOHost, Google Scholar, and PubMed databases, employing Boolean search strings to identify relevant studies from these databases.

The study search incorporated a combination of keywords (game-based approach OR game-centered approach OR game-based learning OR teaching games for understanding OR tactical games OR step-game approach OR invasion game competence OR game sense OR play practice) AND ("physical education" OR "movement education") AND ("primary school" OR "primary education" OR "Primary school" OR "Primary education") AND ("experiment*" OR "trial" OR "comparison" OR "effect") AND ("decision making" OR "knowledge" OR "critical thinking" OR "creative thinking" OR "problem-solving" OR "enjoyment" OR "motivation" OR "self-control" OR "self-confident" OR "self-esteem" OR "well-being" OR "motor skill" OR "physical activity" OR "physical fitness" OR "health" OR "game performance" OR "gameplay" OR "game understanding" OR "game competence" OR "tactical understanding" OR "skill execution" OR "emotion*") AND NOT ("computer game" OR "augmented reality" OR "virtual reality" OR "digital game" OR "internet" OR "online")) with a search scope of article titles, abstracts, and keywords conducted on April 8, 2025. The reference lists of the included articles were searched to identify additional studies to find relevant articles.

Study Selection and Data Synthesis

The systematic review included articles that: (a) focus primarily on the implementation of GCAs in PE teaching for students' development, including motor, cognitive, play, and psychosocial aspects. The games referred to in this study are those that emphasize active physical engagement by students, rather than online or digital games, (b) provide measurable outcomes of Primary student achievement, and (c) utilize an experimental design with both experimental and compare groups. The exclusion criteria applied during

the search process were: (a) articles not written in English, (b) manuscripts that are not peer-reviewed, not in their final stage, or not sourced from journals.

The study search was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This choice is based on the fact that PRISMA is a protocol that does not require ethical review and is reliable due to its foundation in high-quality, reputable journals (Kapadia et al., 2016). The studies included in this investigation were synthesized qualitatively. The qualitative analysis is assisted by using mnemonics like PICO (Population, Intervention, Comparator, and Outcome) to systematically develop research questions (Martinez et al., 2023; Schiavenato & Chu, 2021).

Results

Study Selection Result

From the keyword searches across the five databases, a total of 180 articles were initially found: Scopus (n = 31), EBSCOHost (n = 32), WOS (n = 74), Google Scholar (n=35), PubMed (n=8). Following a duplicate check, 6 duplicate studies were excluded. After a full-text screening, another 139 studies were excluded for not meeting the inclusion criteria, each lacking at least one criterion. In the end, 35 studies fulfilled the criteria and were included in the systematic review. However, upon further examination, one article was found to be unavailable full paper and was therefore excluded. Consequently, only 34 studies were included for investigation according to the PICO criteria. The selection process for the included studies is illustrated in Figure 1.

Overview of Investigation Results

The study results should be presented in tables and described in a logical sequence. The results of the

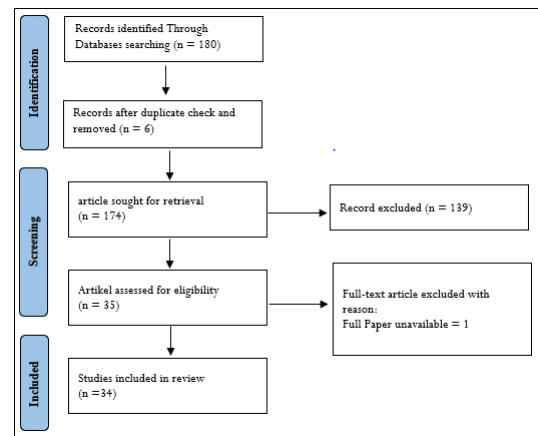


Fig. 1. Flowchart study searching

investigation of the 34 studies included are summarized in Table 1. The findings are then elaborated according to the PICO criteria used.

The examined papers provide various GCAs applications in elementary physical education summarised in Figure 2. This is due to their varied teaching approaches, differing durations, diverse game types, and distinct instructional settings. Teaching Games for Understanding (TGfU), the Tactical Games Model (TGM), Sports Education (SE), and hybrid methodologies were among the most significant approaches. These modifications were implemented to enhance students' performance in gameplay and tactical thinking, motivation, self-perception, and physical fitness.

Most studies (n=21) used TGfU or TGM inside the regular physical education curriculum or structured intervention programs. These strategies include small-sided games, tactical problem-solving, and inquiry to enhance students' existing knowledge. Harvey et al. (2016) used a

Table 1. Summary Included studies

Study (Year)	Participants	Intervention	Comparison	Outcome
(Miller et al., 2015)	168 students	PLUNGE program	No intervention	Improved object control and in-class physical activity
(Harvey et al., 2016)	96 students	TGM unit (basketball)	Traditional unit	Higher MVPA, gender/school differences in VPA
(Miller, 2016)	107 students	6-week PLUNGE program	No intervention	Improved FMS, PA, decision making
(Petros et al., 2016)	215 students	IAAF Kids' Athletics	No intervention	Increased self-determination and perceived effort
(Telford et al., 2016)	853 children	Specialist PE	Generalist PE	No difference in daily physical activity
(McFarlane et al., 2017)	1,752 grade-6 students	Right to Play program (2 years)	Delayed intervention	Reduced victimization, improved gender attitudes
(Viciana et al., 2017)	66 pupils	TGM	Teacher-centered approach	Positive trend in enjoyment
(Farias et al., 2018)	26 students	3 SE seasons (invasion games)	–	Improved game performance and involvement

Table 1 (continued)

Study (Year)	Participants	Intervention	Comparison	Outcome
(Alcaraz-Muñoz et al., 2020)	152 students	Social-structured games (win/lose/neutral)	Condition comparisons	Winning ↑ positive emotions, losing ↑ negative emotions
(Cocca, Verdugo, et al., 2020)	229 students	Game-based PE vs traditional	Traditional PE	No significant group difference; both improved
(Cocca, Carbajal Baca, et al., 2020)	188 students	TGfU	Traditional PE	Significant fitness improvements
(Coppola et al., 2020)	66 students	TGM (student-centered)	Skills-based group	Higher enjoyment in TGM group
(García-Ceberino et al., 2020a)	35 students	TGAS	Direct instruction	Both improved tactical/technical outcomes
(García-Ceberino et al., 2020b)	41 students	TGAS	Direct instruction	No significant differences
(Rodríguez-Negro & Yanci, 2020)	256 students	TGM	Direct instruction	Higher PA and perceived exertion
(Gaspar et al., 2021)	111 students	TGfU with questioning	TGfU without questioning	Higher autonomy, satisfaction, engagement
(Gamero et al., 2021a)	55 students	TGA	DI and teacher-led	Greater knowledge acquisition
(Gamero et al., 2021b)	49 students	TGA	DI and teacher-led	Higher internal and external training load
(Gil-Arias et al., 2021)	292 students	TGfU–SE hybrid	Direct instruction	Strong motivational effects
(Schembri et al., 2021)	63 children	TGM cycle	Traditional PE	Increased enjoyment
(Sgrò et al., 2021)	34 students	TGM	High vs low skill groups	Low-skill group improved more
(Farias et al., 2022)	26 students	SE + action research	Pre/post	Improved game-play and context participation
(Murtagh et al., 2022)	859 students	Play-based learning	Traditional practices	Higher academic scores
(Rodríguez-Negro & Yanci, 2022)	168 students	8-week TGM	Direct instruction	Enhanced creativity and attention
(Lorente Sanz et al., 2023)	47 students	Three socio-motor games	Game-type comparison	Stronger positive emotional responses
(Stoddart et al., 2023)	131 students	PLitPE	Traditional PE	Improved motor competence and movement vocabulary
(Stojanović et al., 2023)	88 students	TGfU (volleyball, 16 weeks)	Traditional PE	Improved body comp and cardiorespiratory fitness
(Vallejo et al., 2023)	42 students	Active breaks (game-based, 8 weeks)	Free recess	Increased physical fitness
(Wang et al., 2023)	2,032 students	2-hour GCA-based after-school PA	Free-choice time	No reduction in academic time
(Bartolo et al., 2024)	77 students	Divergent Discovery & Practical styles	Free play	Improved motor performance
(Breed, Kay, et al., 2024)	67 students	Game-based invasion unit	Traditional sport unit	Higher activity levels
(Ritonga et al., 2024)	36 students	TGfU	Traditional PE	Improved throwing and catching

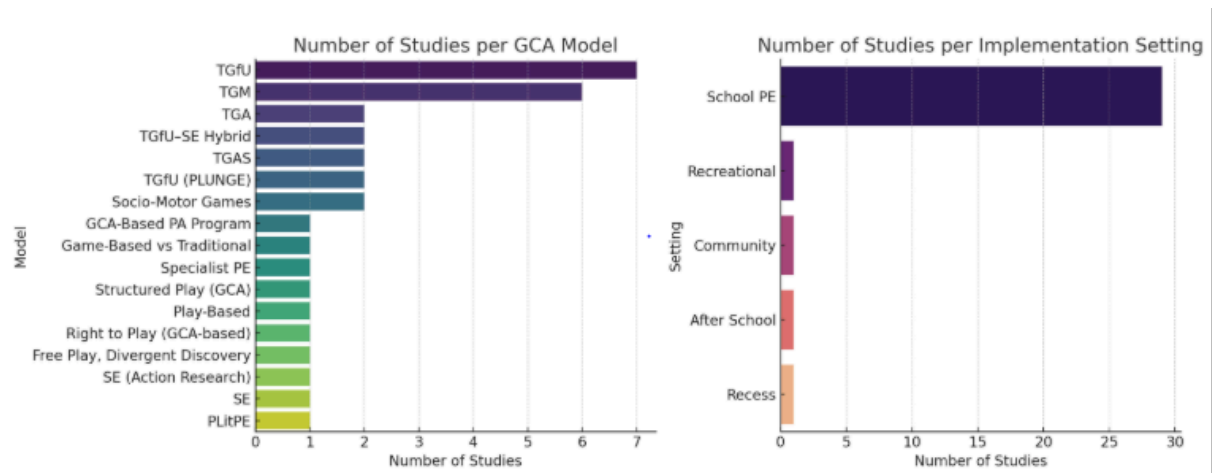


Fig. 2. Summarizing by model and setting application of GCAs

TGfU unit in basketball to encourage children to engage in greater moderate to vigorous physical activity. The PLUNGE curriculum, implemented by Miller et al. (2015) and Miller (2016), integrated TGfU principles over six weeks to facilitate children's acquisition of fundamental movement skills (FMS) and decision-making abilities. Viciania et al. (2017) and Coppola et al. (2020) used the Tactical Games Model with small-sided games to enhance engagement and concentrate on student learning. Rodríguez-Negro & Yanci (2020) & (Rodríguez-Negro & Yanci (2022) used TGM in eight-week courses to foster creativity and tactical engagement, comparing the outcomes to those of direct instructional methods. Additional instances include Cocca, Carbajal Baca, et al (2020) TGfU initiatives aimed at enhancing fitness; Stojanović et al. (2023) use of volleyball to foster health; and Ritonga et al. (2024) implementation of the model to advance object manipulation skills. Gaspar et al. (2021) examined the impact of instructor questioning on TGfU and found that it fosters student independence and engagement. Gamero et al. (2021a; 2021b) conducted two studies on a tactical approach in basketball that enhanced decision-making and training intensity. Gil-Arias et al. (2021) used a TGfU-SE hybrid to assess motivation, while Schembri et al. (2021) and Sgrò et al. (2021) discussed the model's potential to assist less proficient students and enhance enjoyment. García-Ceberino et al. (2020a; 2020b) developed the Tactical Games Approach Soccer (TGAS), enhancing students' comprehension of tactics and approaches. Breed, Kay, et al. (2024) used a themed TGfU unit across several invasion sports, increasing player activity and enhancing tactical comprehension.

A limited body of research (n=3) examined SE models, either alone or in conjunction with TGfU and TGM. Farias et al. (2018; 2022) used SE throughout many seasons of invasion games via iterative action research, finding improvements in tactical performance and situational understanding. Simultaneously, Gil-Arias et al. (2021) integrated SE concepts with a TGfU-SE hybrid model emphasizing an encouraging environment, accountability roles, and inclusive game structures. Although this research indicated that social-emotional learning might be beneficial, most focused on individuals rather than teams. It failed to include defenders' roles in the tactical analysis systematically.

Alongside formal game models, four studies used play-based or socio-motor methodologies that, although not explicitly designated as TGfU or TGM, nonetheless adhered to the core GCA principles of situational decision-making and dynamic gaming. Murtagh et al. (2022) discovered that a play-based curriculum enhanced student engagement and academic performance. Lorente Sanz et al. (2023) used three types of socio-motor games to examine emotional experiences. Alcaraz-Muñoz et al. (2020) examined emotional intensities in cooperative and competitive contexts. Bartolo et al.(2024) examined several types of outdoor play, including divergent exploration and teacher-directed play, and found that they enhanced motor abilities. However, these studies demonstrate the emotional and expressive benefits of GCAs; several instruments were either unvalidated or modified in a manner inconsistent with the educational context.

Finally, four studies demonstrated that GCAs may be implemented in large-scale or non-academic environments, indicating that these strategies may extend beyond conventional physical education contexts. McFarlane et al. (2017) implemented the Right to Play initiative in Pakistan for two years. They used structured activities to address peer victimization, gender norms, and psychological competencies. Wang et al. (2023) initiated an after-school program centered on tactical play, demonstrating that children may increase physical activity without sacrificing classroom instruction. Vallejo et al. (2023) modified school recess using structured GCA workouts to enhance children's fitness. Bartolo et al. (2024) used GCA in outdoor free play to facilitate physical and expressive development.

The Figure 3 illustrates the impact of several GCA models used in primary physical education on learning outcomes across four domains: physical, cognitive, emotional, and social. The TGfU model is the most prevalent, significantly contributing to physical and cognitive development by emphasizing motor skills and tactical awareness. GM and TGfU-SE hybrids provide several benefits, particularly in cognitive and emotional domains. This indicates that they may include students via reflective inquiry and role-based learning. The SE and TGAS models show a stronger correlation with cognitive and social outcomes but a weaker association with emotional development.

This indicates that more structured and strategic forms of play are superior. Conversely, socio-motor games and play-based methodologies are primarily associated with emotional and motivational advantages, with some overlap in social learning. This indicates that they effectively promote emotional engagement and participation from all individuals. Models specific to particular contexts, such as Right to Play, after-school GCA programs, and structured recess activities, often concentrate on a singular domain, such as social or physical, by the program's objectives. None of the models fully address all four learning dimensions; nevertheless, TGfU and its derivatives provide the most extensive array of developmental advantages. These findings underscore the need to select models and consider their potential interactions carefully. This will ensure that the design, implementation, and specific physical, cognitive, or psychosocial goals educators desire are aligned.

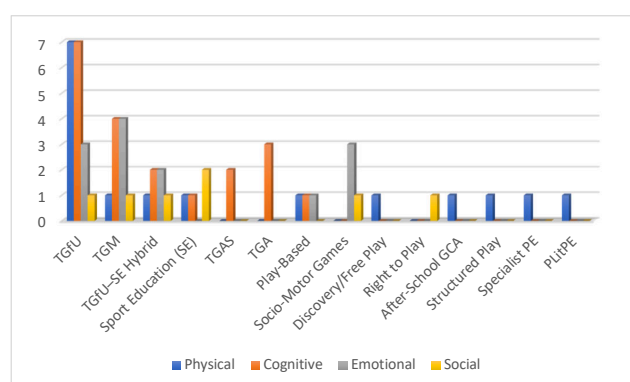


Fig. 3. Summary Learning Outcomes by GCA Model in Primary PE

Discussion

This study examined how GCAs have been implemented in primary PE and the outcomes they have produced across physical, cognitive, emotional, and social domains. These models engage students in meaningful learning experiences that go beyond mere activity, encouraging them to think, feel, move, and relate in authentic and developmentally appropriate ways. The results suggest that these approaches reinforce the idea that PE should go beyond physical activity to foster creativity, tactical awareness, and strategic thinking. Moreover, with physical fitness benefits such as improvements in cardiovascular fitness and body composition, game-centered models can be as effective as, if not more effective than, traditional fitness training methods. This is in line with the statement that game-based approach was recommended as a PE teaching strategy (Barba-Martín et al., 2020) and was part of a PE philosophy oriented towards games as objects (García-Puchades & Chiva-Bartoll, 2020). Teaching PE by Primary school teachers could be effectively enhanced through game-centered pedagogical approaches (Miller et al., 2016).

Most studies ($n = 25$) were situated within formal school-based PE programs, reflecting growing curricular interest in learner-centered and tactically rich pedagogies. The remainder were conducted in extracurricular ($n = 6$) and community or free-play settings ($n = 3$), suggesting broader adaptability of GCAs beyond conventional classrooms. TGfU and TGM were the most widely applied models ($n = 21$),

predominantly structured around invasion games such as soccer, basketball, and volleyball. These implementations emphasized modified games, questioning strategies, and tactical scaffolding to promote decision-making and contextual learning. The findings implied a crucial need for a paradigm shift from traditional teacher-centered methods to innovative, student-centered approaches in PE. Implementing these approaches in Primary schools could foster holistic learning outcomes, encompassing physical, cognitive, and social development. Moreover, GCAs like thematic invasion through game sense effectively promoted physical activity (Breed, Kay, et al., 2024) and had positive impacts on student engagement, academic achievement, and physical fitness (Mahardhika et al., 2024; Mercan & Varol Selçuk, 2024; Molina-Torres et al., 2021). The GCAs provided significant benefits related to understanding the relationship between the concept and reality of playing, the internal structure of games, and the development of motor interventions (Martínez-Santos et al., 2020).

GCAs yielded positive outcomes across all four developmental domains. Physical and motor gains were observed in interventions emphasizing structured gameplay and movement-rich tasks. TGfU programs enhanced fundamental motor skills and physical fitness (e.g., Miller et al., 2015; Cocca, Carbajal Baca, et al., 2020; Ritonga et al., 2024; Stojanović et al., 2023), and hybrid play-based models demonstrated additional utility for supporting diverse motor profiles, including those of lower-skilled students. Cognitive and tactical learning gains were equally robust. Through questioning, reflection, and context-specific play, students developed higher-order thinking, game intelligence, and adaptable problem-solving skills (e.g., Gaspar et al., 2021; Gamero et al., 2021a; Rodríguez-Negro & Yanci, 2022). This cognitive scaffolding not only enriched in-game decision-making but also supported broader academic and executive functioning, as evidenced in interdisciplinary studies.

Affective and motivational dimensions also benefited from GCA implementation. Programs incorporating socio-motor games and emotionally rich activities fostered high levels of student enjoyment, autonomy, and emotional safety (e.g., Schembri et al., 2021; Sgrò et al., 2021; Lorente Sanz et al., 2023). These outcomes are particularly significant in inclusive education contexts, where emotional security and engagement are prerequisites for sustained participation. Furthermore, the social and interpersonal benefits of GCAs were strongly evidenced in studies focusing on community-based initiatives. Programs like Right to Play (McFarlane et al., 2017) and SE models (Farias et al., 2018; 2022) supported the development of prosocial behavior, gender equity, and collective responsibility, demonstrating the broader potential of GCAs to contribute to character education and citizenship development.

This study's outcomes align with the statement that GCAs significantly benefit physical education, particularly improving students' learning competencies. Research showed that this approach supported the development of decision-making skills, tactical awareness, and enjoyment during learning (Morales-Belando et al., 2022). Additionally, GCAs allowed students to learn holistically, encompassing physical, cognitive, social, and affective aspects (Kim, 2024). This integration aligned with the goals of modern physical education, which emphasized the comprehensive development of learners.

GCAs were also one of the models effectively implemented in Primary schools (García-López et al., 2019). Additionally, this approach supported active learning and provided realistic playing experiences, which were relevant to students' real-life contexts (Breed et al., 2024; Mercan & Varol Selçuk, 2024). Therefore, GCAs became an effective learning strategy to enhance student engagement and achievement in PE classes.

Primary educators should have integrated these approaches into their teaching to create more dynamic and inclusive PE programs. Developing techniques, understanding, tactical knowledge, and decision-making could be done through a tactical approach (Robles et al., 2020). Games applications could be done by modifying rules and equipment to manipulate player behavior, thus forming the expected skills (Ashford et al., 2020). On the other hand, games could be implemented to identify talented players and assess perceptual-cognitive-motor skills (Piggott et al., 2019). Furthermore, a study by Lucia et al. (2022) revealed that games had clear efficacy in cognitive-motor training protocols (CMT) on sports performance and increased anticipatory brain processing in the prefrontal cortex.

Moreover, the use of gamification and question-based techniques in this model emphasized the importance of encouraging student autonomy and active participation, making PE more relevant to 21st-century learning needs. 21st-century education has shifted to emphasize the ability to find knowledge and information from various sources, formulate problems, think analytically, collaborate in problem-solving, and optimize the formation of life skills, social skills, and lifelong learners (Alawiah et al., 2022; Joynes et al., 2019). Professional development programs for PE teachers should have focused on equipping them with the knowledge and skills to effectively implement these innovative methods. By adopting such practices, Primary schools could have positioned PE as a holistic platform that nurtured physical, cognitive, and emotional growth, ultimately contributing to the overall development and well-being of young learners.

Implications for Practice and Future Research

The findings from this review carry several implications for both educators and researchers. For practitioners, GCAs offer a viable framework for promoting multidimensional learning that integrates physical literacy, tactical thinking, emotional resilience, and social cooperation. Their adaptability across formal and informal settings makes them particularly useful in diverse educational contexts, including under-resourced schools and culturally varied environments. However, to realize their full potential, teachers must be equipped with professional development that emphasizes tactical pedagogy, questioning strategies, inclusive game design, and context-appropriate assessment.

Future research on GCAs in physical education should focus on several key areas to enhance their understanding and effectiveness. Direct comparative studies between different GCA models, such as TGfU and TGM, are essential to identify the most effective approach for improving outcomes like motor skills, cognitive development, and social competencies, providing clearer insights into their impact on student learning and engagement across various contexts. As has been stated by Lee & Lee (2021) that experimental studies were required to conduct quantitative

comparisons and validations through comparative studies of traditional PE programs that did not incorporate these methods. Additionally, exploring hybrid models, such as combining TGfU with SE, could offer valuable perspectives on long-term student motivation, physical activity, and academic outcomes.

Conclusions

This comprehensive study presents compelling evidence that GCAs, particularly TGfU, TGM, and their hybrids, are very effective for instruction in fundamental physical education. GCAs consistently showed positive impacts on children's physical, mental, emotional, and social development throughout 34 studies. These solutions transcended standard skill-based approaches by promoting meaningful learning via tactical decision-making, reflective questioning, and altering gameplay dynamics. TGfU and TGM significantly enhanced motor abilities, tactical awareness, and student motivation. Conversely, socio-motor and play-based adaptations enable children to articulate themselves and enhance their well-being, aligning with the objectives of inclusive education.

The findings indicate the need for basic physical education to modify its pedagogical approach to include models integrating physical literacy with cognitive involvement and emotional well-being. GCAs were seen to function well in both formal and informal environments, indicating their potential use outside conventional educational institutions. The use of GCAs in diverse manners and the insufficient emphasis on emotional and social learning outcomes in contemporary studies indicate a need for more integrated and multidimensional program designs. Ultimately, GCAs can enhance basic physical education by fostering physical abilities, creativity, social competencies, and a lifelong passion for movement. To maximize these benefits, educators, researchers, and policymakers must collaborate to integrate GCAs into curricular frameworks that prioritize the student's holistic development.

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References

- Garcia-Puchades, W., & Chiva-Bartoll, O. (2020). A Philosophy of Physical Education Oriented toward the Game as an Object. Showing the Inexhaustible Reality of Games through Bernard Suits' Theory. *Sport, Ethics and Philosophy*, 14(2), 192-205. <https://doi.org/10.1080/17511321.2019.1630476>
- Metzler, M. (2017). *Instructional Models in Physical Education*. Taylor & Francis. <https://books.google.co.id/books?id=REErDwAAQBAJ>

- Gubacs-Collins, K.D. (2015). The socratic gymnasium: Learning lessons of life through physical education. *The Physical Educator*, 72(5), 76-98. <https://doi.org/10.18666/TPE-2015-V72-I5-5123>.
- Light, R., Curry, C., & Mooney, A. (2014). Game sense as a model for delivering quality teaching in physical education. *Asia-Pacific Journal of Health, Sport and Physical Education*, 5(1), 67-81. <https://doi.org/10.1080/18377122.2014.868291>
- Harvey, S., & Jarrett, K. (2014). A review of the game-centred approaches to teaching and coaching literature since 2006. *Physical Education and Sport Pedagogy*, 19(3), 278-300. <https://doi.org/10.1080/17408989.2012.754005>
- Mercan, G., & Varol Selçuk, Z. (2024). Investigating the Impact of Game-Based Learning and Gamification Strategies in Physical Education: A Comprehensive Systematic Review. *Journal of Interdisciplinary Education: Theory and Practice*, 6(1), 1-14. <https://doi.org/10.47157/jietp.1389843>
- Goodyear, V. (2017). Sustained Professional Development on Cooperative Learning: Impact on Six Teachers' Practices and Students' Learning. *Research Quarterly for Exercise and Sport*, 88(1), 83-94. <https://doi.org/10.1080/02701367.2016.1263381>
- Kirk, D., Lamb, C.A., Oliver, K.L., Ewing-Day, R., Fleming, C., Loch, A., & Smedley, V. (2018). Balancing prescription with teacher and pupil agency: spaces for manoeuvre within a pedagogical model for working with adolescent girls. *Curriculum Journal*, 29(2), 219-237. <https://doi.org/10.1080/09585176.2018.1449424>
- Casey, A., & MacPhail, A. (2018). Adopting a models-based approach to teaching physical education. *Physical Education and Sport Pedagogy*, 23(3), 294-310. <https://doi.org/10.1080/17408989.2018.1429588>
- Morgan, K., Bryant, A.S., Edwards, L.C., & Mitchell-Williams, E. (2019). Transferring primary generalists' positive classroom pedagogy to the physical education setting: a collaborative PE-CPD process. *Physical Education and Sport Pedagogy*, 24(1), 43-58. <https://doi.org/10.1080/17408989.2018.1533543>
- Bodsworth, H. (2017). Barriers and facilitators to using digital technologies in the Cooperative Learning model in physical education. *Physical Education and Sport Pedagogy*, 22(6), 563-579. <https://doi.org/10.1080/17408989.2017.1294672>
- Hordvik, M., Haugen, A.L., Engebretsen, B., Møller, L., & Fletcher, T. (2021). A collaborative approach to teaching about teaching using models-based practice: developing coherence in one PETE module. *Physical Education and Sport Pedagogy*, 26(5), 433-447. <https://doi.org/10.1080/17408989.2020.1812558>
- Barba-Martin, R.A., Bores-García, D., Hortigüela-Alcalá, D., & González-Calvo, G. (2020). The Application of the Teaching Games for Understanding in Physical Education. Systematic Review of the Last Six Years. *International Journal of Environmental Research and Public Health*, 17(9), 1-16. <https://doi.org/10.3390/ijerph17093330>
- Camacho-Sánchez, R., Manzano-León, A., Rodríguez-Ferrer, J.M., Serna, J., & Lavega-Burgués, P. (2023). Game-Based Learning and Gamification in Physical Education: A Systematic Review. *Education Sciences*, 13(2). <https://doi.org/10.3390/educsci13020183>
- Ortiz Gómez, O. R., Nuñez Enriquez, O., Candía Luján, R., Nájera Longoria, R. J., Valenzuela Jurado, F., & Santos Sambrano, G. (2023). Teaching Games for Understanding (TGfU) as comprehensive teaching method in physical education: System-atic review of the last 5 years. *Retos*, 48(SE-Artículos de carácter científico: trabajos de investigaciones básicas y/o aplicadas), 374-379. <https://doi.org/10.47197/retos.v48.97137>
- Miller, A. (2015). Games centered approaches in teaching children & adolescents: Systematic review of associated student outcomes. *Journal of Teaching in Physical Education*, 34(1), 36-58. <https://doi.org/10.1123/jtpe.2013-0155>
- Elumalai, G., Chinanapan, K., Choeibuakaew, W., Iqbal, D. R., & Abadi, F. H. (2022). Can Model-Based Approach in Physical Education Improve Physical Fitness, Academic Performance, and Enjoyment among Pupils? A Systematic Literature Review. *International Journal of Human Movement and Sports Sciences*, 10(4), 21-28. <https://doi.org/10.13189/saj.2022.101304>
- Fernandez-Rio, J., & Iglesias, D. (2024). What do we know about pedagogical models in physical education so far? An umbrella review. *Physical Education and Sport Pedagogy*, 29(2), 190-205. <https://doi.org/10.1080/17408989.2022.2039615>
- Manninen, M., Magrum, E., Campbell, S., & Belton, S. (2025). The effect of game-based approaches on decision-making, knowledge, and motor skill: A systematic review and a multilevel meta-analysis. *European Physical Education Review*, 31(1), 18-32. <https://doi.org/10.1177/1356336X241245305>
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Systematic Reviews*, 10(1), 89. <https://doi.org/10.1186/s13643-021-01626-4>
- Martinez, E.C., Flores Valdés, J.R., Castillo, J.L., Castillo, J. V, Blanco Montecino, R.M., Morin Jimenez, J.E., Arriaga Escamilla, D., & Diarte, E. (2023). Ten Steps to Conduct a Systematic Review. *Cureus*, 15(12), e51422. <https://doi.org/10.7759/cureus.51422>
- Schiavenato, M., & Chu, F. (2021). PICO: What it is and what it is not. *Nurse Education in Practice*, 56, 103194. <https://doi.org/10.1016/j.nepr.2021.103194>
- Garcia-Puchades, W., & Chiva-Bartoll, O. (2020). A Philosophy of Physical Education Oriented toward the Game as an Object. Showing the Inexhaustible Reality of Games through Bernard Suits' Theory. *Sport, Ethics and Philosophy*, 14(2), 192-205. <https://doi.org/10.1080/17511321.2019.1630476>
- Miller, A., Christensen, E. M., Eather, N., Sproule, J., Annis-Brown, L., & Lubans, D. R. (2015). The PLUNGE randomized controlled trial: Evaluation of a games-based physical activity professional learning program in primary school physical education. *Preventive Medicine*, 74, 1-8. <https://doi.org/10.1016/j.ypmed.2015.02.002>
- Harvey, S., Smith, M. L., Song, Y., Robertson, D., Brown, R., & Smith, L. R. (2016). Gender and school-level differences in students' moderate and vigorous physical activity levels when taught basketball through the tactical games model. *Journal of Teaching in Physical Education*, 35(4), 349-357. <https://doi.org/10.1123/jtpe.2016-0089>

- Miller, A. (2016). Can physical education and physical activity outcomes be developed simultaneously using a game-centered approach? *European Physical Education Review*, 22(1), 113-133. <https://doi.org/10.1177/1356336X15594548>
- Petros, B., Ploutarhos, S., Vasilios, B., Vasiliki, M., Konstantinos, T., Stamatia, P., & Christos, H. (2016). The effect of IAAF Kids Athletics on the physical fitness and motivation of elementary school students in track and field. *Journal of Physical Education and Sport*, 16(3), 883-896. <https://doi.org/10.7752/jpes.2016.03139>
- Telford, R. M., Olive, L. S., Cochrane, T., Davey, R., & Telford, R. D. (2016). Outcomes of a four-year specialist-taught physical education program on physical activity: A cluster randomized controlled trial, the LOOK study. *International Journal of Behavioral Nutrition and Physical Activity*, 13(1). <https://doi.org/10.1186/s12966-016-0388-4>
- McFarlane, J., Karmaliani, R., Khuwaja, H. M. A., Gulzar, S., Somani, R., Ali, T. S., Somani, Y. H., Bhamani, S. S., Krone, R. D., Paulson, R., Muhammad, A., & Jewkes, R. (2017). Preventing Peer Violence Against Children: Methods and Baseline Data of a Cluster Randomized Controlled Trial in Pakistan. *Global Health-Science and Practice*, 5(1), 115-137. <https://doi.org/10.9745/GHSP-D-16-00215>
- Viciano, J., Mayorga-Vega, D., Guijarro-Romero, S., & Martínez-Baena, A. (2017). Effect of two alternated teaching units of invasion team sports on the tactical learning in primary schoolchildren. *International Journal of Performance Analysis in Sport*, 17(3), 256-270. <https://doi.org/10.1080/24748668.2017.1331575>
- Alcaraz-Muñoz, V., Cifo Izquierdo, M. I., Gea García, G. M., Alonso Roque, J. I., & Yuste Lucas, J. L. (2020). Joy in Movement: Traditional Sporting Games and Emotional Experience in Elementary Physical Education. *Frontiers in Psychology*, 11, 588640. <https://doi.org/10.3389/fpsyg.2020.588640>
- Cocca, A., Verdugo, F. E., Cuenca, L. T. R., & Cocca, M. (2020). Effect of a game-based physical education program on physical fitness and mental health in elementary school children. *International Journal of Environmental Research and Public Health*, 17(13), 1-13. <https://doi.org/10.3390/ijerph17134883>
- Cocca, A., Carbajal Baca, J. E., Hernández Cruz, G., & Cocca, M. (2020). Does a Multiple-Sport Intervention based on the TGfU pedagogical model for Physical Education increase physical fitness in primary school children? *International Journal of Environmental Research and Public Health*, 17(15), 5532. <https://doi.org/10.3390/ijerph17155532>
- Coppola, R., Pignato, S., Sgrò, F., & Lipoma, M. (2020). Effects of Two Different Physical Education Teaching Approaches on the Levels of Enjoyment in the Italian Primary School Students. *Journal of Human Sport and Exercise*, 15, S1251-S1261. <https://doi.org/10.14198/jhse.2020.15.Proc4.26>
- García-Ceberino, J. M., Gamero, M. G., Feu, S., & Ibáñez, S. J. (2020a). Differences in Technical and Tactical Learning of Football According to the Teaching Methodology: A Study in an Educational Context. *SUSTAINABILITY*, 12(16). <https://doi.org/10.3390/su12166554>
- García-Ceberino, J. M., Gamero, M. G., Feu, S., & Ibáñez, S. J. (2020b). Experience as a Determinant of Declarative and Procedural Knowledge in School Football. *International Journal of Environmental Research and Public Health*, 17(3). <https://doi.org/10.3390/ijerph17031063>
- Rodríguez-Negro, J., & Yanci, J. (2020). Which instructional models influence more on perceived exertion, affective valence, physical activity level, and class time in physical education? *Educational Psychology*, 40(5), 608-621. <https://doi.org/10.1080/01443410.2019.1613516>
- Gaspar, V., Gil-Arias, A., Del Villar, F., Práxedes, A., & Moreno, A. (2021). How tgfu influence on students' motivational outcomes in physical education? A study in elementary school context. *International Journal of Environmental Research and Public Health*, 18(10). <https://doi.org/10.3390/ijerph18105407>
- Gamero, M.G., García-Ceberino, J.M., Ibáñez, S.J., & Feu, S. (2021a). Analysis of Declarative and Procedural Knowledge According to Teaching Method and Experience in School Basketball. *Sustainability*, 13(11). <https://doi.org/10.3390/su13116012>
- Gamero, M. G., García-Ceberino, J. M., Ibáñez, S. J., & Feu, S. (2021b). Influence of the pedagogical model and experience on the internal and external task load in school basketball. *International Journal of Environmental Research and Public Health*, 18(22). <https://doi.org/10.3390/ijerph182211854>
- Gil-Arias, A., Harvey, S., García-Herreros, F., González-Villora, S., Práxedes, A., & Moreno, A. (2021). Effect of a hybrid teaching games for understanding/sport education unit on elementary students' self-determined motivation in physical education. *European Physical Education Review*, 27(2), 366-383. <https://doi.org/10.1177/1356336X20950174>
- Schembri, R., Coppola, R., Tortella, P., & Sgrò, F. (2021). Improving enjoyment during physical education lesson in primary school students. *Journal of Human Sport and Exercise*, 16(Proc2), 735-742. <https://doi.org/10.14198/jhse.2021.16.Proc2.59>
- Sgrò, F., Coppola, R., Schembri, R., & Lipoma, M. (2021). The effects of a tactical games model unit on students' volleyball performances in elementary school. *European Physical Education Review*, 27(4), 1000-1013. <https://doi.org/10.1177/1356336X211005806>
- Farias, C., Valério, C., & Mesquita, I. (2018). Sport education as a curriculum approach to student learning of invasion games: Effects on game performance and game involvement. *Journal of Sports Science and Medicine*, 17(1), 56-65.
- Murtagh, E.M., Sawalma, J., & Martin, R. (2022). Playful maths! The influence of play-based learning on academic performance of Palestinian primary school children. *Educational Research for Policy and Practice*, 21(3), 407-426. <https://doi.org/10.1007/s10671-022-09312-5>
- Rodríguez-Negro, J., & Yanci, J. (2022). Effects of two different physical education instructional models on creativity, attention and impulse control among primary school students. *Educational Psychology*, 42(6), 787-799. <https://doi.org/10.1080/01443410.2021.1988059>
- Lorente Sanz, N., Díaz Aroca, Á., & Alcaraz-Muñoz, V. (2023). Effect of the type of motor interaction required by the game on emotional behaviour in Physical Education classes. *Cultura, Ciencia y Deporte*, 18(56 SE-Artículos / Articles). <https://doi.org/10.12800/ccd.v18i56.1959>

- Stoddart, A. L., Humbert, M. L., Kerpan, S., Cameron, N., & Kriellaars, D. (2023). PLitPE: an intervention for physical literacy enriched pedagogy in Canadian elementary school physical education classes. *Physical Education and Sport Pedagogy*, 28(6), 675-691. <https://doi.org/10.1080/17408989.2021.2014438>
- Stojanović, D., Momčilović, V., Zdražnik, M., Ilić, I., Koničanin, A., Padulo, J., Russo, L., & Stojanović, T. (2023). School-Based TGfU Volleyball Intervention Improves Physical Fitness and Body Composition in Primary School Students: A Cluster-Randomized Trial. *Healthcare (Switzerland)*, 11(11). <https://doi.org/10.3390/healthcare11111600>
- Vallejo, A.G., Martínez, B., Hellín-Martínez, M., & Alfonso-Asencio, M. (2023). Influence of an active recess program on the physical condition of Primary Education students. *Retos-Nuevas Tendencias en Educacion Fisica Deporte y Recreacion*, 48, 222-228
- Wang, D.C., Xiong, R.L., Zhang, J.Q., Han, X.T., Jin, L., Liu, W.J., Qu, Y.B., Chen, Q.Y., Chen, S.D., Chen, X., Li, Y.T., He, M.G., Zeng, Y.F., & Liu, Y.Z. (2023). Effect of Extracurricular After-School Physical Activities on Academic Performance of Schoolchildren A Cluster Randomized Clinical Trial. *JAMA Pediatrics*, 177(11), 1141-1148. <https://doi.org/10.1001/jamapediatrics.2023.3615>
- Bartolo, D., Garbeloto, F., & Ferraz, O. (2024). Effect of a physical education program in early childhood education on the performance of fundamental movement skills based on teaching styles: divergent discovery and practical. *Pedagogy of Physical Culture and Sports*, 28(2), 93-101. <https://doi.org/10.15561/26649837.2024.0202>
- Breed, R., Kay, A., Spittle, M., & Orth, D. (2024). The Effect of Pedagogical Approach on Physical Activity of Girls During Physical Education. *Research Quarterly for Exercise and Sport*, 1-10. <https://doi.org/10.1080/02701367.2024.2329165>
- Ritonga, I., Gusril, G., Kiram, Y., Lanos, M.E. C., & Festiawan, R. (2024). Designing an innovative learning model for fundamental throwing and catching skills using the teaching games for understanding (tgfu) approach in elementary education. *Retos*, 61, 448-454. <https://doi.org/10.47197/retos.v61.108823>
- Farias, C., Segovia, Y., Ribeiro, E., Teixeira, J., Bessa, C., & Mesquita, I. (2022). Game-play development according to the context of practice and students' sex and skill level: an action-research study in two invasion-games sport education seasons. *Journal of Physical Education and Sport*, 22(3), 542-554. <https://doi.org/10.7752/jpes.2022.03068>
- Alcaraz-Muñoz, V., Cifo Izquierdo, M.I., Gea García, G.M., Alonso Roque, J.I., & Yuste Lucas, J.L. (2020). Joy in Movement: Traditional Sporting Games and Emotional Experience in Elementary Physical Education. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.588640>
- Mahardhika, D.B., Pelana, R., Sulaiman, I., Samsudin, S., Asmawi, M., Tannoubi, A., Dimiyati, A., Kurtoğlu, A., Lobo, J., & Gazali, N. (2024). Effect of Game-based Instructional on Learning Engagement and Game Performance of Students in Physical Education. *Studia Sportiva*, 18(01), 161-172. <https://doi.org/10.5817/StS2024-1-14>
- Molina-Torres, G., Rodríguez-Arrastia, M., Alarcón, R., Sánchez-Labraca, N., Sánchez-Joya, M., Roman, P., & Requena, M. (2021). Game-Based Learning Outcomes Among Physiotherapy Students: Comparative Study. *JMIR Serious Games*, 9(1), e26007. <https://doi.org/10.2196/26007>
- Martínez-Santos, R., Founaud, M.P., Aracama, A., & Oiarbide, A. (2020). Sports Teaching, Traditional Games, and Understanding in Physical Education: A Tale of Two Stories. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.581721>
- Morales-Belando, M.T., Kirk, D., & Arias-Estero, J.L. (2022). A Systematic Review of Teaching Games for Understanding Intervention Studies From a Practice-Referenced Perspective. *Research Quarterly for Exercise and Sport*, 93(4), 670-681. <https://doi.org/10.1080/02701367.2021.1897066>
- Kim, S.-Y. (2024). Physical Education Teachers' Meaning Construction and Practice of Learner-centered Physical Education. *Journal of Industrial Convergence*, 22(1), 95-103. <https://doi.org/10.22678/JIC.2024.22.1.095>
- García-López, L.M., Gutiérrez, D., Sánchez-Mora, D., & Harvey, S. (2019). Teachers' use of teaching games for understanding in Central Spain. *Physical Education and Sport Pedagogy*, 24(5), 463-477. <https://doi.org/10.1080/17408989.2019.1628931>
- Robles, M.T. A., Collado-Mateo, D., Fernández-Espínola, C., Castillo Viera, E., & Gimenez Fuentes-Guerra, F.J. (2020). Effects of teaching games on decision making and skill execution: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 17(2), 1-13. <https://doi.org/10.3390/ijerph17020505>
- Ashford, M., Burke, K., Barrell, D., Abraham, A., & Poolton, J. (2020). The impact of rule modifications on player behaviour in a talent identification and development environment: A case study of the Rugby Football Union's Wellington Academy Rugby Festival. *Journal of Sports Sciences*, 38(23), 2670-2676. <https://doi.org/10.1080/02640414.2020.1795559>
- Piggott, B., Müller, S., Chivers, P., Cripps, A., & Hoyne, G. (2019). Small-sided games can discriminate perceptual-cognitive-motor capability and predict disposal efficiency in match performance of skilled Australian footballers. *Journal of Sports Sciences*, 37(10), 1139-1145. <https://doi.org/10.1080/02640414.2018.1545522>
- Lucia, S., Bianco, V., Boccacci, L., & Di Russo, F. (2022). Effects of a Cognitive-Motor Training on Anticipatory Brain Functions and Sport Performance in Semi-Elite Basketball Players. *Brain Sciences*, 12(1). <https://doi.org/10.3390/brainsci12010068>
- Alawiah, T., Yassi, A.H., & Pammu, A. (2022). Proposed 21st Century Learning Themes in English Classrooms. *Journal of Language Teaching and Research*, 13(3), 583-589. <https://doi.org/10.17507/jltr.1303.14>
- Joynes, C., Rossignoli, S., & Amonoo-Kuofi, E.F. (2019). *21st Century Skills: evidence of issues in definition, demand and delivery for development contexts*.
- Lee, H.S., & Lee, J. (2021). Applying Artificial Intelligence in Physical Education and Future Perspectives. *Sustainability*, 13(1). <https://doi.org/10.3390/su13010351>

Ігроцентричні методи у фізичному вихованні учнів початкової школи: Систематичний огляд впровадження та результатів навчання

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 11 с., 1 табл., 3 рис., 59 джерел.

Історія питання. Ігроцентричні методи (ІЦМ) виникли як інноваційні педагогічні концепції у фізичному вихованні (ФВ), створюючи альтернативу традиційному технічно-орієнтованому навчанню. ІЦМ спрямовані на стимулювання комплексного розвитку учнів у фізичній, когнітивній, емоційній та соціальній сферах шляхом пріоритизації тактичного розуміння, адаптованого ігрового процесу та рефлексивного аналізу.

Цілі. Цей систематичний огляд мав на меті узагальнити емпіричні дані щодо впровадження та освітніх результатів в контексті використання ігроцентричних методів (ІЦМ) у фізичному вихованні початкової школи. Основна увага приділялася визначенню сфери застосування, закономірностей та педагогічного впливу різних моделей.

Матеріали та методи. Відповідно до стандартів PRISMA («Переважні елементи звітування для систематичних оглядів та метааналізів»), було проведено розширений пошук у п'яти наукометричних базах даних (Scopus, Web of Science, EBSCOHost, Google Scholar та PubMed) з метою виявлення рецензованих експериментальних статей, опублікованих у період до квітня 2025 року. У критеріях включення наголошувалося на процедурах, адаптованих для учнів початкової школи з використанням ІЦМ, які мали кількісно вимірювані результати в моторній, когнітивній, психосоціальній або афективній сферах. Було включено та проаналізовано 34 дослідження з використанням концепції якісного синтезу на основі моделі PICO.

Результати. До найбільш поширених моделей належали: навчальні ігри для тренування розуміння (Teaching Games for Understanding, TGfU) та тактична модель ігор (Tactical Games Model, TGM), інтегровані зазвичай в інвазивні ігри та організовану навчальну програму. ІЦМ показали значні переваги в покращенні основних рухових навичок, ігрової результативності, ухваленні рішень, мотивації, креативності та емоційній залученості. Гібридні моделі та соціомоторні модифікації сприяли поліпшенню застосування ІЦМ, тоді як масштабні ініціативи розширили їхній вплив на соціальний розвиток та благополуччя. Проте жодна окрема модель повноцінно не охоплювала всі чотири області навчання, що підкреслило необхідність стратегічної інтеграції моделей.

Висновки. Результати дослідження підтверджують, що ІЦМ представляють собою надійну педагогічну основу для фізичного виховання в початковій школі, забезпечуючи досягнення багатоаспектних результатів у навчанні учнів та відповідаючи освітнім цілям 21 століття. У подальших дослідженнях слід акцентувати увагу на лонгітюдних, порівняльних та контекстно-залежних методологіях, тоді як професійний розвиток викладачів має сприяти практичному, інклюзивному та сталому впровадженню зазначених моделей.

Ключові слова: ігроцентричний метод, фізичне виховання, початкова школа, тактична педагогіка, результати навчання учнів.

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Review Article

Bibliometric Analysis of Instructional Models in Physical Education: From Direct Instruction to Transformative Learning

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Abstract

Background. This study presents a comprehensive bibliometric analysis of research trends related to instructional models in physical education over the period 2015–2024.

Objectives. Utilizing the Scopus database and analyzed through Biblioshiny and VOSviewer, the study aimed to map the scientific landscape surrounding the evolving pedagogical approaches from Direct Instruction to Cooperative and Transformative Learning.

Materials and Methods. The analysis was conducted using data extracted from the Scopus database, processed with Biblioshiny and VOSviewer to examine publication trends, author productivity, collaboration networks, and keyword co-occurrence.

Results. The findings reveal a consistent annual growth rate of 25.99% in publication, with significant contributions originating from Spain, China, and the United States. Javier Fernández-Río has been identified as the most productive and highly cited author. Journals such as Physical Education and Sport Pedagogy and the International Journal of Environmental Research and Public Health have emerged as leading publication outlets. Author and country collaboration maps highlight the strong presence of research networks, particularly in Europe. Keyword co-occurrence analysis indicates the emergence of new themes, including cooperative learning, hybrid instructional models, digital technology integration, and alignment with the Sustainable Development Goals (SDGs).

Conclusions. These findings reflect a paradigm shift in physical education pedagogy from traditional methods towards more collaborative, reflective, and sustainability-oriented teaching models. The study provides insights into emerging research opportunities and offers implications for future curriculum innovation in physical education.

Keywords: physical education, instructional models, cooperative learning, direct instruction, transformative learning.

Introduction

Physical Education (PE) plays a strategic role in the holistic development of students, not only in terms of physical fitness, but also within cognitive, affective, and social domains. In the context of modern education, PE is recognized as a critical platform to promote healthy lifestyles, foster social skills, and cultivate character development

(Ramires et al., 2023). As the needs of 21st-century learners become increasingly complex, pedagogical approaches in PE have evolved, requiring innovative teaching strategies and the application of relevant instructional models.

Instructional models in PE serve as systematic frameworks that guide the teaching and learning process effectively. These models reflect the approaches employed by educators in delivering content, managing classrooms, and fostering student engagement (Guzmán & Payá, 2020). One of the most widely applied models is Direct Instruction (DI), which emphasizes the teacher's active role in delivering content through explicit demonstrations, clear instructions, and reinforcement of student performance. DI has proven

effective in enhancing mastery of fundamental motor skills and ensuring the efficiency of the instructional process (Guzmán & Payá, 2020).

In line with the growing emphasis on learner-centered approaches, Cooperative Learning (CL) has also gained considerable attention. In CL, students work in small, heterogeneous groups with shared learning objectives, promoting social interaction, collective responsibility, and improved communication skills (Jiang et al., 2023; Zach et al., 2023). Studies have shown that CL in PE contributes to increased learning motivation, affective engagement, and the development of sustainable social competencies.

Alongside the demand for more contextual and participatory learning, alternative approaches grounded in games and social values have also been widely adopted in PE. The Sport Education Model (SEM), for instance, organizes learning in the format of a "sports season" in which students take on formal roles such as coach, referee, or team manager, providing an authentic and collaborative learning experience (Zhang et al., 2024). On the other hand, Transformative Learning (TL) introduces a new dimension by emphasizing critical reflection, social awareness, and changes in students' perspectives regarding their physical experiences (Casey & Kirk, 2020). TL is believed to support identity formation, empathy development, and ethical decision-making through meaningful learning processes.

The increasing volume of scholarly publications related to instructional models in PE over the past decade reflects the rapid development and dynamism of the field. Recent research has extensively explored innovative pedagogies in PE, including the integration of technology, collaborative learning, and transformative approaches (Sargent, 2017). However, to date, there is a lack of systematic bibliometric mapping that identifies major trends, author collaborations, and the intellectual impact of various instructional models in PE at the global level.

Therefore, this study aims to conduct a bibliometric analysis of global literature related to instructional models in physical education, focusing on classical models such as Direct Instruction and contemporary approaches like Cooperative Learning and Transformative Learning. This review seeks to uncover the evolution of pedagogical approaches over time, identify key contributors in the field, and highlight underexplored areas of research. The findings are expected to provide a foundation for the development of more contextual, reflective, and future-responsive PE pedagogy

Materials and Methods

Research Design

This study employed a quantitative bibliometric approach to map the global research landscape concerning instructional models in physical education. The primary aim of this approach is to identify publication trends, influential authors, patterns of scholarly collaboration, and key thematic areas within the academic literature. Bibliometric analysis is recognized as an effective method for evaluating the structure and dynamics of knowledge development in a specific field through scientific publication metadata (Aria & Cuccurullo, 2017; Donthu et al., 2021). The core objectives of this study include:

Identifying annual publication trends in the field of instructional models in physical education to map the dynamics of literature development over the past decade.

Analyzing author productivity and citation frequency to determine key contributors and assess their academic impact within the discipline.

Mapping the geographical distribution and institutional affiliations that significantly contribute to the literature, to reveal global research excellence hubs.

Examining the distribution of publications across leading journals and thematic trends among the most frequently cited articles related to instructional models in physical education.

Identifying and analyzing frequently occurring keywords (keyword co-occurrence) to capture the conceptual focus and thematic evolution of research in this domain.

Data Source and Search Strategy

The data for this study were retrieved from the Scopus database, which is widely recognized as one of the most credible and internationally indexed scientific repositories. Data collection was conducted in May 2025, using the following search strategy: TITLE-ABS-KEY ("physical education" AND ("instructional model" OR "teaching model" OR "pedagogical model").

Table 1. Document Search Criteria

Criteria	Description
Source Database	Scopus
Search within	Article title, abstract, keyword
Documents found	497
Years	2015-2024
Publication Stage	Final
Publication Language	English
Documents Final	364

Following a screening process based on the relevance of titles and abstracts, as well as initial data filtering, a total of 364 articles were identified and utilized as the primary dataset for analysis.

Data Analysis Procedure

The bibliographic data retrieved from the Scopus database were exported in .csv format and analyzed using two primary software tools: VOSviewer version 1.6.20 and Biblioshiny, the web interface of the Bibliometrix package in RStudio (Aria & Cuccurullo, 2017). Prior to analysis, the raw data underwent a data-cleaning phase using OpenRefine to ensure accuracy and consistency. This process included the normalization of author names, unification of affiliation variations, and correction of duplicate entries, common issues arising from inconsistencies in bibliographic metadata (Ahmi, 2023). This step was essential to enhance the validity of the bibliometric analysis, particularly in mapping collaborations and identifying institutional affiliations.

The analysis proceeded in several stages, beginning with the identification of annual publication trends to observe the dynamics of literature development over the past decade.

Subsequently, author productivity and citation frequency were analyzed to identify key contributors and assess their academic influence (Donthu et al., 2021). Geographic distribution and institutional affiliations were mapped to uncover centers of scholarly excellence in the field of instructional models in physical education. Keyword co-occurrence analysis was conducted to identify key terms and trace the evolution of research themes. Finally, co-authorship and co-citation network visualizations were developed to provide a comprehensive understanding of the intellectual structure and collaborative relationships within this research domain (Van Eck & Waltman, 2010).

Result

General Information

This bibliometric analysis is based on 341 documents published between 2015 and 2024, retrieved from the Scopus database. Over the past decade, the number of publications has shown an annual growth rate of 25.99%, indicating increasing interest and research intensity in this field. The average age of the documents is 3.78 years, with a mean of 13.22 citations per document, suggesting that many of the publications are relatively recent and exhibit considerable academic influence. A total of 13,423 references were cited across all documents, reflecting the broad scope of the literature base.

A total of 778 authors contributed to the publications, demonstrating a relatively high degree of collaboration, with an average of 3.16 authors per document. Nevertheless, there were also 55 single-authored papers. The proportion of international cooperation was recorded at 18.18%, indicating the presence of an active global network in research on instructional models in physical education. In terms of document types, the publications were predominantly journal articles (280 documents), followed by conference papers (40), review articles (18), and a small number of editorials and errata. A total of 932 author keywords and 1,058 Keywords Plus were identified and subsequently analyzed to map the main thematic areas in this body of research.



Fig. 1. General Information of the analysed metadata

The identification of annual publication trends in the field of instructional models in physical education was conducted to map the dynamics of literature development over the past decade.

Figure 1 illustrates the annual publication trends related to instructional models in physical education from 2015 to 2024. Overall, the data reveal a positive growth trajectory, albeit with significant fluctuations across certain years.

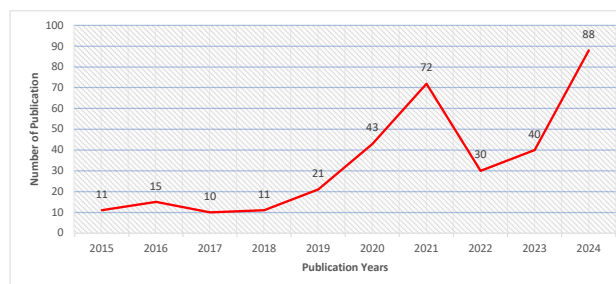


Fig. 2. Trends in Publications on Instructional Models in Physical Education (2015–2024)

During the initial period (2015–2018), the number of publications remained relatively low and stable, averaging around 11 to 15 documents per year. An upward trend began in 2019 with 21 publications, followed by a substantial increase to 43 publications in 2020. The peak was recorded in 2021, with 72 documents published, reflecting growing academic interest in this topic, likely driven by the need for pedagogical innovation during the COVID-19 pandemic.

However, this surge was followed by a sharp decline to 30 publications in 2022. The trend began to recover gradually in 2023, with 40 documents, and surged dramatically in 2024, reaching 88 publications—the highest figure within the decade. These findings indicate the sustained relevance of instructional models in physical education, particularly in addressing post-pandemic educational challenges and supporting the broader goals of sustainable development (SDGs).

Analysis of Author Productivity and Citation Frequency

To identify key contributors and evaluate their academic impact on the development of knowledge in instructional models for physical education, an analysis of author productivity and citation frequency was conducted.

The analysis of author productivity reveals that Javier Fernández-Río ranks first with a total of 25 publications, establishing himself as the most prolific contributor in this research domain. He is followed by Sixto González Villora (14 publications), David Hortigüela Alcalá and Alfonso Valero Valenzuela (10 publications each), and Stephen Harvey (9 publications). These five authors have consistently conducted and published research in the domain of physical education pedagogy, particularly focusing on cooperative learning models, values-based education, and instructional assessment. Most of them are affiliated with higher education institutions in Spain and Western European countries, reinforcing the region's status as an active and consistent hub for research in physical education pedagogy.

In terms of academic influence, measured through citation frequency, Javier Fernández-Río also holds the top position with 772 citations, indicating that his work is not only prolific but also widely referenced in scholarly literature. Other influential authors include Ashley Casey (509 citations) and Sixto González Villora (361 citations). Although Casey has published only seven documents, the high number of citations reflects the significant quality and scholarly impact of his contributions. Additionally, scholars such as Ann Macphail, Alexander Gil Arias, and Victoria A. Goodyear have also emerged as highly cited authors,

Table 2. Author Productivity and Citation Impact

Top 13 Productivity		Top 13 Most Cited Authors	
Author	Total	Author	Total
Javier Fernandez Rio	25	Javier Fernandez Rio	772
Sixto González Villora	14	Ashley Casey	509
David Hortigüela Alcalá	10	Sixto González Villora	361
Alfonso Valero Valenzuela	10	David Hortigüela Alcalá	278
Stephen Harvey	9	Stephen Harvey	278
Oscar Chiva Bartoll	8	Ann Macphail	271
Ashley Casey	7	Alexander Gil Arias	242
Alexander Gil Arias	7	Victoria A Goodyear	242
David Manzano Sánchez	7	Gustavo González Calvo	217
David Gutiérrez	6	Daniel Bores García	214
Ann Macphail	5	Oscar Chiva Bartoll	184
Carlos Evangelio	5	David Kirk	168
Alejandra Hermando Garijo	5	Alfonso Valero Valenzuela	152

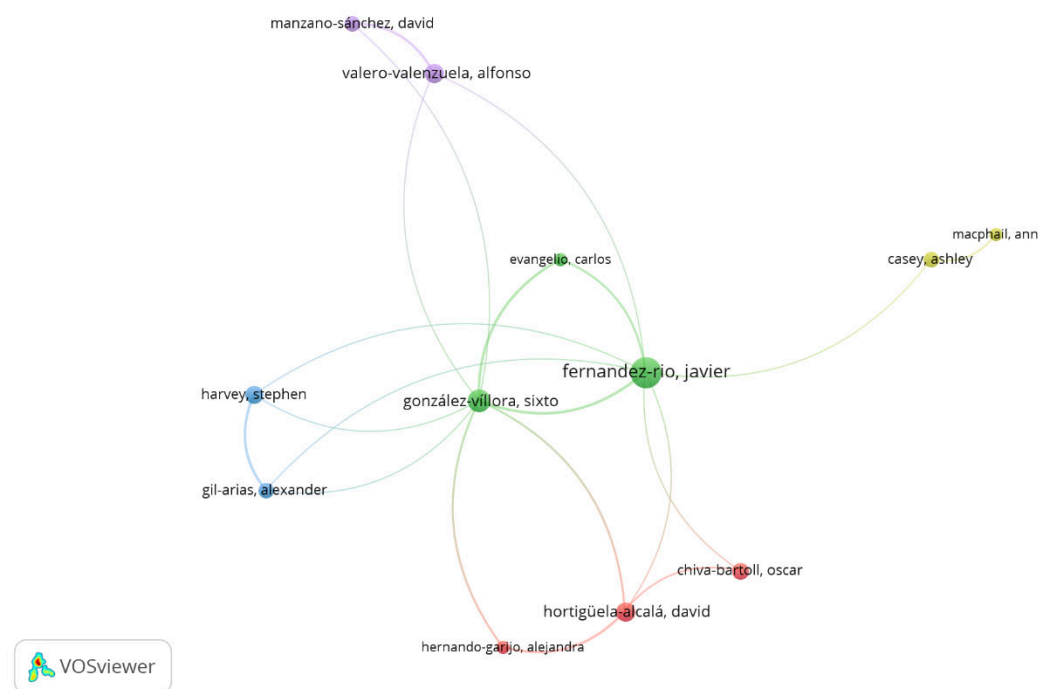


Fig. 3. Author Collaboration Network Analysis

highlighting their important roles in advancing discussions on innovative instructional models, reflective teaching, and the integration of digital technology in physical education. The combination of publication volume and citation metrics suggests that several authors act as both prolific knowledge producers and key thought leaders within the field.

The co-authorship network analysis, with a minimum threshold of five publications, reveals that collaborative structures in research on instructional models in physical education tend to be concentrated around a few prominent figures, with Javier Fernández-Río positioned as the central node. He maintains strong collaborative ties with several key

scholars, including Sixto González-Villora, David Hortigüela Alcalá, Oscar Chiva-Bartoll, and Carlos Evangelio, reflecting the formation of a cohesive research group, particularly within Spanish academic circles. These collaborations indicate not only a high frequency of joint publications but also continuity in research agendas focusing on cooperative and values-based instructional models.

Additionally, several smaller yet meaningful collaboration clusters are evident, for instance, the partnership between Stephen Harvey and Alexander Gil-Arias, who have extensively explored game-based learning and the affective domain in physical education. Meanwhile, Ashley Casey

and Ann MacPhail appear along a distinct collaboration pathway, albeit in a relatively peripheral position within the network. This suggests a specialized focus in their work and more limited interaction across the central research clusters.

Overall, the network structure suggests that, although the field involves contributors from diverse institutions, there is a notable dominance of central actors and an intense concentration of regional collaborations, particularly within Europe, which significantly shape the knowledge ecosystem in physical education pedagogy.

Mapping the Geographical Distribution and Institutional Affiliations

This analysis maps the geographical distribution and institutional affiliations that have significantly influenced the publication of research on instructional models in physical education. The aim is to identify global centers of research excellence and understand the regional dynamics shaping scholarly productivity in this field.

Table 3. Geographical Distribution and Countries with the Highest Academic Influence

Top 15 Geographical Distribution		Top 15 Geographical Distribution	
Country	Total	Country	Total
Spain	116	Spain	2188
China	100	United States	1001
United States	43	United Kingdom	959
United Kingdom	23	Ireland	487
Indonesia	18	China	253
Portugal	12	Australia	244
Australia	11	Sweden	197
Ireland	8	Norway	145
Norway	8	New Zealand	137
Sweden	8	Portugal	113
Norway	8	Indonesia	39
South Korea	7	Malaysia	32
Philippines	6	South Korea	23
Malaysia	6	Brazil	14
New Zealand	6	Philippines	5

Top 10 Countries with the Most Publications in Physical Education Pedagogy Research

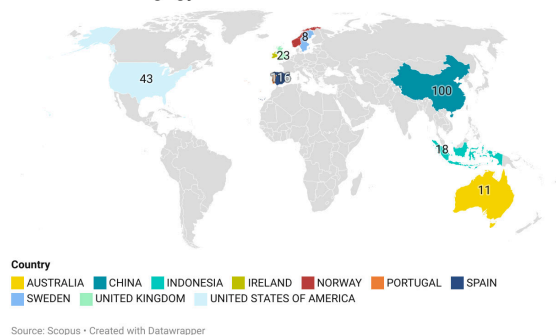


Fig. 4. Countries with the most publications in physical education pedagogy research

The geographical distribution of publications reveals that Spain holds a dominant position, contributing a total of 116 documents, followed by China (100 documents) and the United States (43 documents). Although countries such as the United Kingdom (23 documents) and Indonesia (18 documents) report comparatively fewer publications, their presence reflects active engagement from various global regions in advancing instructional models within physical education. Other contributing countries—including Portugal, Australia, Ireland, Norway, and Sweden—demonstrate that research centers are not limited to a single region but are increasingly dispersed across Asia, Europe, and Oceania.

In terms of academic impact, measured by total citation counts, Spain again leads with 2,188 citations, underscoring both its research productivity and the high academic significance of its contributions. The United States (1,001 citations) and the United Kingdom (959 citations) follow, confirming their roles as major reference points in pedagogical discourse. Notably, Ireland shows a high citation-to-publication ratio (487 citations), indicating exceptional research efficiency and influence relative to output volume. Countries such as China, Australia, and Sweden also demonstrate substantial academic contributions.

Emerging economies such as Indonesia (39 citations), Malaysia (32 citations), and the Philippines (5 citations) are beginning to increase their presence, though their global academic influence remains at an early stage. These data suggest that while the knowledge ecosystem in this field remains somewhat hierarchical, it is gradually expanding toward more inclusive global participation.

Table 4. Institutional Affiliations: Global Research Excellence Centers

Top Ten Institutional Affiliates		
Affiliate	Country	Total
Faculty of Teacher Training and Education, University of Oviedo	Spain	6
Department of Specific Didactics, Faculty of Education, University of Burgos	Spain	5
School of Sport, Exercise and Health Sciences, Loughborough University	United Kingdom	5
Department of Educational Sciences, University of Oviedo	Spain	4
Division of Kinesiology and Health, University of Wyoming	United States	4
Universitas Pendidikan Indonesia	Indonesia	4
Department of Food and Nutrition, and Sport Science, University of Gothenburg	Sweden	3
Department of Physical Education and Sport Sciences, University of Limerick	Ireland	3
School of Education, University of Strathclyde	United Kingdom	3
School of Kinesiology, Auburn University	United States	3

The analysis of institutional affiliations reveals that leading research centers in the field of instructional models in physical education are geographically dispersed, with an intense concentration in Europe and North America. Among the top ten institutions, four are based in Spain, confirming the country's position as a major producer of knowledge in this field. The Faculty of Teacher Training and Education at the University of Oviedo ranks highest, with a total of six publications. This institution has become a key hub for the development and dissemination of model-based practices, particularly through the contributions of scholars such as Javier Fernández-Río. Other notable Spanish affiliations include the University of Burgos and the Department of Educational Sciences at the University of Oviedo, reflecting a robust intra-national research network supporting pedagogical innovation.

Outside of Spain, institutions in the United Kingdom also play a significant role. The School of Sport, Exercise and Health Sciences at Loughborough University and the School of Education at the University of Strathclyde have contributed five and three publications, respectively. Loughborough, in particular, is widely recognized as a multidisciplinary center of excellence for physical education and fitness research, including the integration of technology into sport pedagogy. These contributions highlight the importance of critical, evidence-based approaches in curriculum development for physical education. The United States is also strongly represented, with the Division of Kinesiology and Health at the University of Wyoming and the School of Kinesiology at Auburn University contributing four and three publications, respectively. Research from these institutions tends to focus on evaluating the effectiveness of Direct Instruction models and the application of evidence-based pedagogy in physical education settings.

Notably, Universitas Pendidikan Indonesia (UPI) emerges as the only institution from a developing country in the top ten, with four publications. UPI's presence signifies the rising participation of Southeast Asia in global research on physical education pedagogy. This engagement presents opportunities for further development through international collaboration and the strengthening of culturally contextualized themes, such as ethnosport and indigenous-based education. Other institutions worthy of mention include the University of Gothenburg (Sweden) and the University of Limerick (Ireland). The University of Gothenburg showcases an interdisciplinary approach that integrates nutrition science with physical education, while the University of Limerick is well known for its contributions to reflective pedagogy and the teaching of physical education teachers.

An analysis of the distribution of publications in the top journals and thematic trends of popular articles that are most often cited in the study of physical education learning models

The analysis of the most productive journals publishing research on instructional models in physical education indicates that Physical Education and Sport Pedagogy is the leading outlet, with a total of 30 publications. This journal consistently serves as a primary platform for pedagogical research that emphasizes model-based approaches, critical

Table 5. Top Journals in Physical Education Learning Model Publications (2015–2024)

Top Ten Journal	
Journal Name	Document
Physical education and sport pedagogy	30
International journal of environmental research and public health	22
Applied mathematics and nonlinear sciences	21
Journal of physical education and sport	19
European physical education review	17
Journal of teaching in physical education	15
Acm international conference proceeding series	11
Sustainability (switzerland)	10
Journal of physics: conference series	9
Revista internacional de medicina y ciencias de la actividad fisica y del deporte	9

reflection, and curriculum innovation. It is followed by the International Journal of Environmental Research and Public Health (IJERPH) with 22 documents, reflecting a growing intersection between physical education, public health, and the pursuit of Sustainable Development Goals (SDGs). The prominence of these journals highlights the increasingly interdisciplinary nature of physical education, encompassing health, social, and environmental dimensions.

Interestingly, journals such as Applied Mathematics and Nonlinear Sciences, the ACM International Conference Proceedings Series, and the Journal of Physics: Conference Series also appear in the top ten. Their inclusion suggests the emergence of quantitative and technology-based approaches in assessing the effectiveness of instructional models in PE. This points toward a new trajectory in the discipline, one that integrates pedagogy with technological innovation, data science, and digital simulation. Other core journals, such as the Journal of Physical Education and Sport, European Physical Education Review, and the Journal of Teaching in Physical Education, continue to be foundational in supporting both theoretical development and instructional practices. Meanwhile, the presence of Sustainability and Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte underscores the relevance of sustainability perspectives and culturally contextualized pedagogical approaches in contemporary physical education research.

An analysis of the ten most cited articles in the field of instructional models in physical education reveals that model-based teaching approaches, particularly Cooperative Learning, Teaching Games for Understanding (TGfU), and Sport Education, have dominated the most influential literature over the past decade. The article by Casey & Goodyear (2015) "Can Cooperative Learning Achieve the Four Learning Outcomes of Physical Education?", ranks first with 211 citations, highlighting Cooperative Learning as a key topic in addressing the demands of modern PE curricula. This work reflects the importance of collaborative approaches in achieving affective, social, cognitive, and psychomotor learning dimensions.

Table 6. Trend analysis in popular articles that are regularly cited

No	Author's name	Article Title	Total of Citation
1	Ashley Casey & Victoria A. Goodyear	Can Cooperative Learning Achieve the Four Learning Outcomes of Physical Education? A Review of Literature (Casey & Goodyear, 2015).	211
2	Ashley Casey & Ann MacPhail	Adopting a models-based approach to teaching physical education (Casey & MacPhail, 2018).	173
3	Javier Fernandez-Rioences, Naira Sanz, Judith Fernandez-Cando & Luis Santos	Impact of a sustained Cooperative Learning intervention on student motivation (Fernandez-Rio et al., 2017)	115
4	Kimberly L. Oliver & David Kirk	Towards an activist approach to research and advocacy for girls and physical education (Oliver & Kirk, 2016)	114
5	Sixto González-Víllora, Carlos Evangelio, Jacob Sierra-Díaz & Javier Fernández-Río	Hybridizing pedagogical models: A systematic review (González-Víllora et al., 2019)	99
6	Méndez-Giménez, Fernández-Río, J. & Méndez-Alonso,	Sport education model versus traditional model: Effects on motivation and sportsmanship; [Modelo de educación deportiva versus modelo tradicional: Efectos en la motivación y deportividad] (Méndez-Giménez et al., 2015)	87
7	Daniel Bores-García, David Hortigüela-Alcalá, Francisco Javier Fernandez-Río, Gustavo González-Calvo & Raúl Barba-Martín.	Research on Cooperative Learning in Physical Education: Systematic Review of the Last Five Years (Bores-García et al., 2021) 15 articles were fully assessed based on eight criteria: (1	86
8	Peter Iserbyt, Phillip Ward & Weidong Li	Effects of improved content knowledge on pedagogical content knowledge and student performance in physical education (Iserbyt et al., 2017)	82
9	Luis García-Rico, L. Fernando Martínez-Muñoz, María Luisa Santos-Pastor & Oscar Chiva-Bartoll	Service-learning in physical education teacher education: a pedagogical model towards sustainable development goals (García-Rico et al., 2021)	82
10	Raúl A. Barba-Martín, Daniel Bores-García, David Hortigüela-Alcalá, & Gustavo González-Calvo	The application of the teaching games for understanding in physical education. Systematic review of the last six years (Barba-Martín et al., 2020) updating and expanding with new categories the last published review by Harvey and Jarret in 2014. Four databases were used to select those articles that included information on the implementation of Teaching Games for Understanding in different educational stages. According to PRISMA guidelines and including the PICO strategy after the exclusion criteria, 12 articles were fully assessed based on eight criteria: (1	81

In parallel, there is a consistent trend toward hybridized instructional models, as exemplified by González-Víllora et al. (2019) and Barba-Martín et al. (2020) updating and expanding with new categories the last published review by Harvey and Jarret in 2014. Four databases were used to select those articles that included information on the implementation of Teaching Games for Understanding in different educational stages. According to PRISMA guidelines and including the PICO strategy after the exclusion criteria, 12 articles were fully assessed based on eight criteria: (1, which explore integrated approaches such as TGfU combined with affective taxonomies. Articles by Fernandez-Río et al. (2017) and Bores-García et al. (2021) 15 articles were fully assessed based on eight criteria: (1 further highlight the sustained impact of Cooperative Learning on student motivation and social development. Meanwhile, Oliver & Kirk, (2016) introduce a critical pedagogical perspective by advocating for pedagogical activism and gender equity in PE, marking a broadening of thematic focus in the most cited works. Equally significant are publications that connect service-learning strategies to the achievement

of the Sustainable Development Goals (SDGs), as seen in García-Rico et al. (2021), which expand the scope of physical education into the domain of sustainable development and community engagement. Collectively, these highly cited articles exemplify not only methodological rigor and thematic originality but also reflect a growing academic concern for social values, sustainability, and pedagogical justice in PE instructional design. The systematic presence of scholars such as Ashley Casey, Javier Fernández-Río, and David Hortigüela-Alcalá among the most cited authors underscores their role as thought leaders in shaping the global discourse on physical education pedagogy.

To capture the conceptual focus and thematic evolution within the literature on instructional models in physical education, a keyword co-occurrence analysis was conducted

The keyword co-occurrence map reveals a thematic structure divided into several major clusters, each representing distinct conceptual focuses within the physical education

Table 7. Presents the top 15 most frequently used keywords, extracted from author keywords and Keywords Plus, which reflect the dominant research themes and their interrelations

Key Word	Occurrences	Total Link Strength
physical education	212	1330
students	90	831
pedagogical models	81	464
teaching	74	725
sports	73	694
humans	59	885
education computing	53	306
human experiment	47	748
article	47	730
motivation	41	477
female	37	610
teaching models	36	180
male	34	561
learning	34	494
physical activity	33	406

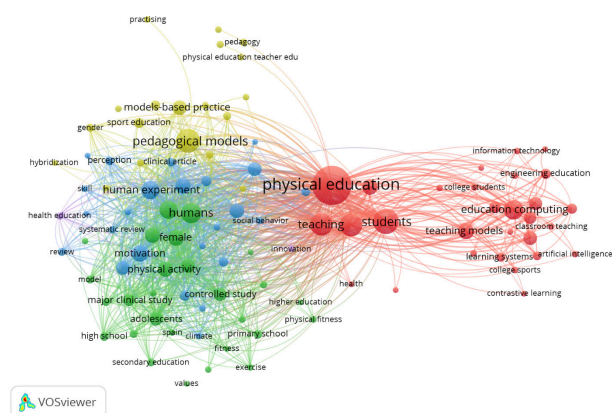


Fig. 5. Keyword Co-Occurrence Analysis: Conceptual Structure and Theme Evolution

literature. The keyword “physical education” appears as the central node, the largest and most connected highlighting its role as the core domain to which all other research themes are linked. The red cluster, located on the right side of the map, comprises keywords such as students, teaching, teaching models, education computing, engineering education, and learning systems. This cluster indicates a thematic focus on integrating technology into physical education, including

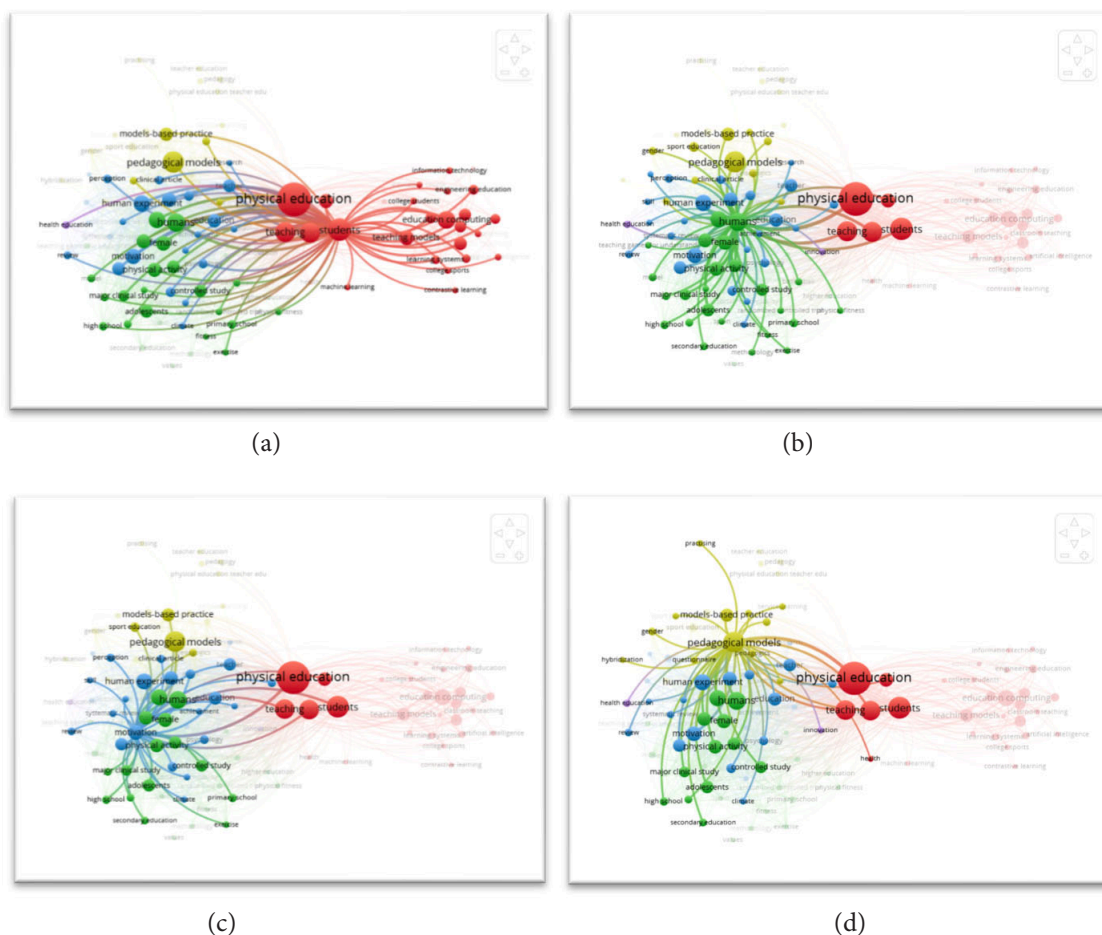


Fig. 6. Some examples of specific keywords: a) education computing, b) humans, c) motivation, d) pedagogical models

terms such as artificial intelligence, contrastive learning, and information technology. It reflects a contemporary trend toward merging pedagogical strategies with digital systems and educational technology (edtech), particularly within higher and vocational education contexts.

Conversely, the green and blue clusters on the left side of the map feature keywords such as motivation, physical activity, female, human experiment, adolescents, and controlled study. These clusters represent themes focused on student participation, physical health, and empirical research assessing the effectiveness of instructional models based on psychological and physiological variables. The presence of keywords such as “systematic review” and “review” further indicates a growing body of meta-analyses and literature reviews over the last decade.

The yellow cluster includes keywords such as pedagogical models, models-based practice, sport education, and hybridization. This reflects a strong emphasis on the development and evaluation of value-based instructional models, including Cooperative Learning, the Sport Education Model, and hybrid strategies that combine multiple models to achieve more holistic learning outcomes. Overall, the map demonstrates that contemporary literature in physical education extends beyond skill acquisition. It increasingly incorporates social-emotional learning, educational technology, health promotion, and sustainability. This thematic evolution reflects the urgent need for physical education to adapt to modern educational demands emphasizing digital contexts, social justice, and curricular relevance in the 21st century.

Discussion

The publication trends in the study of instructional models in physical education have shown a significant increase over the past decade. Following a relatively stable period from 2015 to 2018, a sharp increase in publication output began in 2019, culminating in the highest peak in 2024. This increase reflects growing academic attention to pedagogical innovation within physical education. One of the key drivers was the need to adapt physical education to the constraints imposed by the COVID-19 pandemic. Restrictions on physical activity within school environments have prompted educators to explore new approaches, including the integration of digital technologies and more flexible instructional models (Howley, 2021). In particular, the integration of digital technology into physical education has become a central focus. A study by Casey et al. (2016) emphasized the use of technology to enhance student learning through pedagogically driven case-based approaches that foster critical reflection and collaboration between educators and researchers. The rise in publications also aligns with global efforts to achieve the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-Being) and SDG 4 (Quality Education) (UNESCO, 2020). Thus, the surge in scholarly output reflects an ongoing transformation in physical education toward more adaptive, tech-informed, and holistically student-centered approaches.

The bibliometric findings further demonstrate a substantial thematic shift in the literature on instructional models in physical education over the last decade. This evolution is characterized by a movement away

from traditional, teacher-centered instruction toward participatory, reflective, and globally responsive models. A key finding is the increased focus on cooperative learning as a pedagogical approach that not only enhances student engagement but also significantly contributes to the development of social-emotional competencies (Dyson et al., 2021; Zhou et al., 2023). Recent literature highlights the importance of collaborative strategies in fostering inclusive, emotionally supportive, and value-oriented learning environments (Zach et al., 2023).

Moreover, there is a notable rise in the integration of technology in physical education, evidenced by growing research on digital tools, artificial intelligence, and online learning platforms. Emerging studies show that technology is increasingly employed not only as a visual or evaluative aid but as a core component of adaptive, data-driven instructional design (Sargent & Calderón, 2021; Y. Wang & Wang, 2024). This is supported by systematic reviews exploring teachers' readiness and challenges in adopting digital technologies in physical education settings (Saiz-González et al., 2024). Another strategic direction in the literature is the alignment of instructional models in physical education with the Sustainable Development Goals (SDGs). Research by (Baena-Morales et al., 2021, 2023, 2024). Illustrates how value-based and service-learning approaches are being integrated to foster environmental awareness, social collaboration, and character development. These studies reinforce the notion that physical education not only contributes to physical well-being but also serves as a vital educational tool for building a healthy and sustainable society.

Additionally, hybrid or blended learning models have begun to gain traction in the design of physical education curricula, particularly in higher education. Studies by C. Wang et al. (2023, 2024) reveal that these blended approaches not only improve students' motor skills but also positively influence their attitudes toward sport and physical activity. This thematic evolution reflects a knowledge ecosystem in physical education that is increasingly complex, interdisciplinary, and responsive to the demands of 21st-century education

Conclusion

This study examined the evolving landscape of research on instructional models in physical education using a bibliometric approach covering the period 2015–2024. The analysis revealed steady growth in the field, marked by increasing publication output, broader author participation, and expanding institutional and geographic diversity. Scholars from Spain emerged as dominant contributors in both productivity and citation impact, highlighting the presence of strong research hubs in the European region. Leading journals such as *Physical Education and Sport Pedagogy* and the *International Journal of Environmental Research and Public Health* played pivotal roles in disseminating knowledge and shaping discourse in this domain. The thematic evolution of the literature indicates a shift away from traditional instructional models toward more reflective, collaborative, and contextual pedagogical approaches. Keywords such as cooperative learning, hybrid learning, digital technology, and Sustainable Development

Goals (SDGs) serve as critical indicators of this emerging research orientation. These findings underscore that physical education is no longer perceived merely as a vehicle for physical activity but increasingly as a strategic space for promoting social values, fostering 21st-century competencies, and contributing to the global sustainability agenda. Accordingly, this study offers valuable insights into current research trajectories and provides strategic direction for curriculum development, instructional practice, and future research agendas. Moving forward, strengthening cross-national collaborations and further exploring the integration of digital innovation and sustainability values into physical education represent promising areas for continued scholarly inquiry.

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Conflict of Interest

The authors declare no conflicts of interest.

References

- Ramires, V.V., Dos Santos, P.C., Barbosa Filho, V.C., Bandeira, A.D. S., Marinho Tenório, M.C., De Camargo, E.M., Ravagnani, F.C. D.P., Sandreschi, P., De Oliveira, V.J. M., Hallal, P.C., & Silva, K.S. (2023). Physical Education for Health Among School-Aged Children and Adolescents: A Scoping Review of Reviews. *Journal of Physical Activity and Health*, 20(7), 586-599. <https://doi.org/10.1123/jpah.2022-0395>
- Guzmán, J.F., & Payá, E. (2020). Direct Instruction vs. Cooperative Learning in Physical Education: Effects on Student Learning, Behaviors, and Subjective Experience. *Sustainability*, 12(12), 4893. <https://doi.org/10.3390/su12124893>
- Jiang, M., Yu, H., He, J., Qian, G., & Bialas, M. (2023). Effectiveness of Cooperative Learning Instructional Models in Training In-Service Physical Education Teachers in Southwest China. *Sustainability*, 15(13), 9993. <https://doi.org/10.3390/su15139993>
- Zach, S., Shoval, E., & Shulruf, B. (2023). Cooperative learning in physical education lessons-Literature review. *Frontiers in Education*, 8, 1273423. <https://doi.org/10.3389/feduc.2023.1273423>
- Zhang, J., Xiao, W., Soh, K.G., Yao, G., Anuar, M.A. B.M., Bai, X., & Bao, L. (2024). The effect of the Sport Education Model in physical education on student learning attitude: A systematic review. *BMC Public Health*, 24(1), 949. <https://doi.org/10.1186/s12889-024-18243-0>
- Casey, A., & Kirk, D. (2020). *Models-based Practice in Physical Education* (1st ed.). Routledge. <https://doi.org/10.4324/9780429319259>
- Sargent, J. (2017). Digital technologies and learning in physical education: Pedagogical cases. *Sport, Education and Society*, 23(1), 108-110. <https://doi.org/10.1080/13573322.2017.1394836>
- Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959-975. <https://doi.org/10.1016/j.joi.2017.08.007>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W.M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285-296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Ahmi, A. (2023). *OpenRefine: An approachable tool for cleaning and harmonizing bibliographical data*. 030006. <https://doi.org/10.1063/5.0164724>
- Van Eck, N.J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523-538. <https://doi.org/10.1007/s11192-009-0146-3>
- Casey, A., & Goodyear, V. A. (2015). Can Cooperative Learning Achieve the Four Learning Outcomes of Physical Education? A Review of Literature. *Quest*, 67(1), 56-72. <https://doi.org/10.1080/00336297.2014.984733>
- Casey, A., & MacPhail, A. (2018). Adopting a models-based approach to teaching physical education. *Physical Education and Sport Pedagogy*, 23(3), 294-310. <https://doi.org/10.1080/17408989.2018.1429588>
- Fernandez-Rio, J., Sanz, N., Fernandez-Cando, J., & Santos, L. (2017). Impact of a sustained Cooperative Learning intervention on student motivation. *Physical Education and Sport Pedagogy*, 22(1), 89-105. <https://doi.org/10.1080/17408989.2015.1123238>
- Oliver, K. L., & Kirk, D. (2016). Towards an activist approach to research and advocacy for girls and physical education. *Physical Education and Sport Pedagogy*, 21(3), 313-327. <https://doi.org/10.1080/17408989.2014.895803>
- González-Víllora, S., Evangelio, C., Sierra-Díaz, J., & Fernández-Río, J. (2019). Hybridizing pedagogical models: A systematic review. *European Physical Education Review*, 25(4), 1056-1074. <https://doi.org/10.1177/1356336X18797363>
- Méndez-Giménez, A., Fernández-Río, J., & Méndez-Alonso, D. (2015). Modelo de educación deportiva versus modelo tradicional: Efectos en la motivación y deportividad / Sport Education Model Versus Traditional Model: Motivational and Sportsmanship Effects pp. 449-466. *RIMCAFD*, 59(2015), 449-466. <https://doi.org/10.15366/rimcafd2015.59.004>
- Bores-García, D., Hortigüela-Alcalá, D., Fernandez-Rio, F.J., González-Calvo, G., & Barba-Martín, R. (2021). Research on Cooperative Learning in Physical Education: Systematic Review of the Last Five Years. *Research Quarterly for Exercise and Sport*, 92(1), 146-155. <https://doi.org/10.1080/02701367.2020.1719276>
- Iserbyt, P., Ward, P., & Li, W. (2017). Effects of improved content knowledge on pedagogical content knowledge and student performance in physical education. *Physical Education and Sport Pedagogy*, 22(1), 71-88. <https://doi.org/10.1080/17408989.2015.1095868>
- García-Rico, L., Martínez-Muñoz, L.F., Santos-Pastor, M.L., & Chiva- Bartoll, O. (2021). Service-learning in physical

- education teacher education: A pedagogical model towards sustainable development goals. *International Journal of Sustainability in Higher Education*, 22(4), 747-765. <https://doi.org/10.1108/IJSHE-09-2020-0325>
- Barba-Martín, R.A., Bores-García, D., Hortigüela-Alcalá, D., & González-Calvo, G. (2020). The Application of the Teaching Games for Understanding in Physical Education. Systematic Review of the Last Six Years. *International Journal of Environmental Research and Public Health*, 17(9), 3330. <https://doi.org/10.3390/ijerph17093330>
- Howley, D. (2021). Experiences of teaching and learning in K-12 physical education during COVID-19: An international comparative case study. *Physical Education and Sport Pedagogy*, 27(6), 608-625. <https://doi.org/10.1080/17408989.2021.1922658>
- Casey, A., Goodyear, V.A., & Armour, K.M. (Eds.). (2016). *Digital Technologies and Learning in Physical Education: Pedagogical cases* (1st ed.). Routledge. <https://doi.org/10.4324/9781315670164>
- Dyson, B., Howley, D., & Shen, Y. (2021). 'Being a team, working together, and being kind': Primary students' perspectives of cooperative learning's contribution to their social and emotional learning. *Physical Education and Sport Pedagogy*, 26(2), 137-154. <https://doi.org/10.1080/17408989.2020.1779683>
- Zhou, T., Wang, H., & Li, D. (2023). Focusing on the value of cooperative learning in physical education: A bibliometric analysis. *Frontiers in Psychology*, 14, 1300986. <https://doi.org/10.3389/fpsyg.2023.1300986>
- Sargent, J., & Calderón, A. (2021). Technology-Enhanced Learning Physical Education? A Critical Review of the Literature. *Journal of Teaching in Physical Education*, 41(4), 689-709. <https://doi.org/10.1123/jtpe.2021-0136>
- Wang, C., Yuan, Y., & Ji, X. (2024). Effects of blended learning in physical education on university students' exercise attitudes and basketball skills: A cluster randomized controlled trial. *BMC Public Health*, 24(1), 3170. <https://doi.org/10.1186/s12889-024-20469-x>
- Saiz-González, P., Sierra-Díaz, J., Iglesias, D., & Fernandez-Rio, J. (2024). Exploring physical education teachers' willingness and barriers to integrating digital technology in their lessons. *Education and Information Technologies*, 30(5), 5965-5987. <https://doi.org/10.1007/s10639-024-13060-9>
- Baena-Morales, S., Jerez-Mayorga, D., Delgado-Floody, P., & J. Martínez-Martínez. (2021). Sustainable development goals and physical education. A proposal for practice-based models. *International Journal of Environmental Research and Public Health*, 18(4), 1-18. Scopus. <https://doi.org/10.3390/ijerph18042129>
- Baena-Morales, S., Merma-Molina, G., & Ferriz-Valero, A. (2023). Integrating education for sustainable development in physical education: Fostering critical and systemic thinking. *International Journal of Sustainability in Higher Education*, 24(8), 1915-1931. <https://doi.org/10.1108/IJSHE-10-2022-0343>
- Baena-Morales, S., Prieto-Ayuso, A., Merma-Molina, G., & González-Villora, S. (2024). Exploring physical education teachers' perceptions of sustainable development goals and education for sustainable development. *Sport, Education and Society*, 29(2), 162-179. <https://doi.org/10.1080/13573322.2022.2121275>
- Wang, C., Omar Dev, R. D., Soh, K. G., Mohd Nasiruddin, N. J., Yuan, Y., & Ji, X. (2023). Blended learning in physical education: A systematic review. *Frontiers in Public Health*, 11, 1073423. <https://doi.org/10.3389/fpubh.2023.1073423>

Бібліометричний аналіз інструктивних моделей у фізичному вихованні: Перехід від методу прямої інструкції до трансформативного навчання

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 7 табл., 6 рис., 32 джерела.

Історія питання. У цьому дослідженні представлено комплексний бібліометричний аналіз дослідницьких тенденцій щодо інструктивних (освітніх) моделей у фізичному вихованні за період 2015–2024 років.

Мета дослідження. Мета дослідження полягала у мапуванні наукового ландшафту, пов'язаного з еволюцією педагогічних підходів від методу прямої інструкції до кооперативного та трансформативного навчання, використовуючи наукометричну базу даних Scopus та здійснюючи аналіз за допомогою програмного забезпечення Biblioshiny та VOSviewer.

Матеріали та методи. Аналіз проводився із використанням отриманої інформації з бази даних Scopus, обробленої за допомогою Biblioshiny та VOSviewer для вивчення публікаційних тенденцій, авторської продуктивності, мереж співпраці та сполучуваності ключових слів.

Результати. Результати дослідження показують стабільне щорічне зростання кількості публікацій на 25.99% за рахунок значного внеску науковців з Іспанії, Китаю та США. Хав'єра Фернандеса-Ріо визнано найпродуктивнішим і найцитованішим автором. Провідними публікаційними виданнями стали такі журнали, як «Фізичне виховання та педагогіка спорту» й «Міжнародний журнал екологічних досліджень та громадського здоров'я». Мапи співпраці авторів та країн підкреслюють сильну присутність дослідницьких мереж, особливо в Європі. Аналіз сполучуваності ключових слів вказує на появу нових тематик, зокрема кооперативного навчання, гібридних освітніх моделей, інтеграції цифрових технологій та узгодження з Цілями Сталого Розвитку (ЦСР).

Висновки. Отримані результати відображають зміну парадигми в педагогіці фізичного виховання від традиційних методів до більш колаборативних, рефлексивних та орієнтованих на сталий розвиток моделей навчання. Проведене дослідження забезпечує розуміння нових науково-дослідних можливостей та має значення для розвитку подальших інновацій у навчальній програмі з фізичного виховання.

Ключові слова: фізичне виховання, освітні моделі, кооперативне навчання, метод прямої інструкції, трансформативне навчання.

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