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ТЕОРІЯ ТА МЕТОДИКА ФІЗИЧНОГО ВИХОВАННЯ

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[Teorià ta Metodika Fizičnogo Vihovannâ]



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Determining the Impact of Adapted Yoga Training on Physical Functioning in Students with Mild Intellectual Disability

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Background. Individuals with mild intellectual disability (ID) often encounter challenges in physical functioning, impacting their overall well-being and quality of life. Traditional exercise programs may not always be accessible or effective for this population due to various barriers. Adapted yoga programs have emerged as a promising alternative, offering tailored interventions to address the unique needs of individuals with ID.

Objectives. The study aimed to close this gap by examining the effect of a structured, modified yoga programme on factors related to physical functioning.

Materials and methods. A total of 40 students with mild ID, aged between 11 and 15 years, were selected from Special Schools in Coimbatore, Tamil Nadu. A quasi-experimental design was used in this study. The participants were divided into an experimental group undergoing an 8-week adapted yoga program and a control group maintaining regular activities. Physical function parameters were assessed using standardized tests measuring cardiorespiratory endurance, muscular strength and endurance, flexibility, body composition, and balance. The adapted yoga program, conducted by qualified instructors, comprised 8 weeks of sessions, 5 days a week, each lasting 45 to 60 minutes. Statistical analyses confirmed the normal distribution of data and employed paired sample t-tests to assess pre- and post-test differences, with SPSS version 20.0 used for analysis, setting the significance level at 0.05.

Results. After undergoing 8 weeks of adapted yoga training, the results showed a significant improvement in the upper body strength ($p < 0.04$), lower body strength ($p < 0.001$), core strength ($p < 0.002$), flexibility ($p < 0.00$), and static balance ($p < 0.00$). However, there was no significant difference in body fat and cardiorespiratory endurance between adapted yoga training.

Conclusions. This study highlights the potential of adapted yoga programs as an intervention for improving physical functioning in students with mild ID. These findings indicate that the implementation of adapted yoga can be a valuable and accessible intervention for enhancing physical functioning in this population.

Keywords: intellectual disability, adapted yoga, physical functioning, muscular strength, endurance.

Introduction

Physical activity is essential for maintaining a healthy lifestyle and has several advantages for people of all ages (Donnelly et al., 2016; Gao et al., 2018). Regular exercise helps build a robust cardiovascular system, improves muscular strength and endurance, and cultivates healthy bones and

weight management (Herting & Chu, 2017; Ruegsegger & Booth, 2017; Bidzan-Bluma & Lipowska, 2018; Kohl et al., 2013). In addition, physical activity has beneficial effects on mental health by combining reduced stress, symptoms of anxiety and depression, and enhanced mood and sleep (James et al., 2023; Jacinto et al., 2023; Bouzas et al., 2018).

Persons with ID is a diverse and distinct population of restrictions in intellectual functioning and adaptive behaviours (Wang et al., 2021; Yang et al., 2022). According to the American Association on Intellectual and Developmental Disabilities (AAIDD), ID is defined by significant limitations

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in both intellectual functioning (IQ) and adaptive behaviour, which manifest during the developmental period (Rayes et al., 2022). These limitations often impact a person's ability to effectively navigate day-to-day activities, communicate, and participate in social interactions (Kharbat et al., 2020; Bouzas et al., 2018; Bartoszesky et al., 2021). While the severity of ID varies among individuals, those classified with mild ID typically demonstrate intellectual functioning within the range of approximately 50 to 70 IQ points (Rayes et al., 2022; Lynnes et al., 2009; Carter & Swank, 2014).

Physical activity interventions tailored to the needs of individuals with ID are essential for promoting their overall health and well-being (Yan et al., 2022; Jacob et al., 2023). However, traditional exercise programs may not always be suitable or accessible for individuals with mild ID due to various cognitive, sensory, and motor impairments (Bouzas et al., 2018; Lirola et al., 2020; Réadaptation, 2023). In this context, adapted yoga programs have emerged as a promising alternative for promoting physical health and functioning in this population.

Yoga is a holistic mind-body practice that incorporates physical postures, breathing exercises, and meditation techniques to promote physical, mental, and emotional well-being (Scroggins et al., 2016; Kaur & Bhat, 2019; Reina et al., 2020). Adapted yoga programmes include modified postures, visual adjustments, and specialised assistance to enhance participation and engagement for people with disabilities. Programmes are designed specifically to meet their unique needs and skills (Scroggins et al., 2016; Rayes et al., 2022).

Adapted yoga interventions have shown promise in improving various aspects of physical functioning in individuals with disabilities (Garg et al., 2013; Mohanty et al., 2016; Kaur & Bhat, 2019). Research has demonstrated the possible advantages of adapted yoga practices for people with intellectual disabilities, including improvements in flexibility, balance, muscle strength, relaxation, and overall quality of life (Pise et al., 2017; WASET, 2023; Rayes et al., 2022). However, the majority of studies in this area have focused on adults or mixed-age populations, with limited research specifically addressing the impact of adapted yoga training on physical functioning in students with mild ID.

Therefore, this study seeks to address this gap by examining the effects of adapted yoga training on physical functioning outcomes among students with mild ID. By examining the feasibility, acceptability, and efficacy of adapted yoga interventions within a school-based setting, we aim to generate empirical evidence to inform the development and implementation of effective adapted yoga programs for this population.

Materials and Methods

Participants

Purpose of this study is to find out the impact of adapted yoga on physical function of students with mild ID. For this 40 mild students with ID between the ages of 11 to 15 years were chosen from the Special Schools from Coimbatore, Tamil Nadu state. This age range was likely selected based on developmental factors and the potential for consistent participation in the study.

Table 1. Mean, Standard Deviation and t Test result of Age, Height and Weight of Experimental and Control Group

No	Variables	Mean \pm SD		Sig
		Experimental group	Control Group	
1	Age	13.4 \pm 1.04	13.65 \pm 1.22	0.412
2	Height	153.1 \pm 5.09	152.60 \pm 4.81	0.743
3	Weight	47.8 \pm 6.36	49.05 \pm 6.20	0.423

Criterion Measures

Table 2. Selected Physical Performance variables, Test and measuring unit

No	Variable	Test	Measuring Unit
1	Cardiorespiratory endurance	Treadmill Run/walk test	Distance in meters
2	Muscular Strength and endurance	Isometric puss up test	Seconds
		Sit-to-Stand test	Centimetres
3	Flexibility	Plank test	Seconds
		Sit-and-reach test	Centimetres
4	Body Composition	Body fat analyser (Omron Karada Scan Body Composition Monitor HBF-375)	Body fat percentage
5	Balance	The one-leg stance test	Seconds

Design

Quasi-experimental design was applied for this study with two groups, an experimental group and a control group. The experimental group consisted of students who participated in 8-weeks adapted yoga training program, while the control group consisted of students who did not receive any special intervention beyond their regular activities. This design allowed for comparisons to be made between the two groups, with the experimental group serving as the treatment group and the control group providing a baseline for comparison.

Testing Procedure

Cardiorespiratory endurance was assessed using treadmill run test, The students walks on a treadmill to exhaustion, at a constant walking speed while gradient/slope is increased every one or two minutes. The assistant starts the stopwatch at the beginning of the test and stops it when the subject is unable to continue.

The isometric push-up test assessed the strength and endurance of the upper body. In a straight line, participants stretched their arms under their shoulders, and testers assessed how long they held this posture.

Lower body strength and endurance were evaluated by sit-to-stand test. The task required participants to cross their arms while sitting on a chair and count how many times they could get up in 30 seconds.

The plank test addressed strength and endurance of core muscles. Participants placed themselves on their forearms and toes in a straight-bodied position. If they felt any discomfort or were unable to keep the position, they released the hold.

Flexibility in the hamstrings and lower back was assessed using the sit and reach test. The sit-and-reach box was utilised by the participants (DSI, DANESH SALAR Ltd). They slowly extended their arms as far forward as they could while sitting with their knees flat on the floor. They held this position for two seconds. Every participant made three tries, and the results showed a correct measurement.

OMRON's Fat Loss Monitor with Scale estimated body fat percentage through the Bioelectrical Impedance (BI) Method. This method relies on the fact that muscles, blood vessels, and bones, which have high water content, conduct electricity easily, whereas body fat, which has little electrical conductivity, impedes the flow of electricity.

The test of one-leg stance evaluated static balance. The participants maintained the posture for as long as possible while standing on one leg, hands on hips, and eyes open. After testing both legs, the average time was noted in seconds.

Training Program

The experimental group engaged in an 8-week adapted yoga training program tailored explicitly for individuals with mild ID. Led by qualified instructors experienced in working with special needs populations, the sessions

were meticulously crafted to accommodate the unique requirements of the participants. The content and structure of the program were adapted to ensure accessibility and safety, focusing on gentle and modified yoga poses as well as breathing exercises suitable for individuals with ID. Throughout the duration of the program, attendance records and participation logs were likely maintained to track the engagement and adherence of participants, facilitating ongoing assessment and adjustment as needed to optimize the effectiveness of the training regimen.

Total weeks	- 8
Days per Week	- 5
Session per day	- 1
Duration of the session	- 45 to 60 minutes

Statistical Analysis

As the participants were randomly selected and allocated to the experimental and control groups, it was possible to justify the use of these two groups in this study using two statistical analyses. With regard to the variables, the Kolmogrov-Smirnov test revealed that the difference in scores was normally distributed. SPSS version 20.0 was used to conduct all statistical analyses.

The paired sample t test was used to statistically evaluate the pre- and post-test data in order to determine the significance of the mean differences. A significance level of 0.05 was used in order to test the hypotheses.

Table 3. Eight week of Adapted yoga training schedule for Experimental group

Weeks	Yoga	Name and Pose	Number of repetition	Duration in Minutes	Total Duration
1 & 2	Asana	Tadasana, Trikonasana, Vajrasana, Sukhasana, Bhujangasana, Salabhasana, Pawanmuktasana, Ardha Halasana	8	330	600 Minutes
	Pranayama	Anuloma villoma, kapalapathi, bhramari pranayama, bhatrika	2	180	
	Meditation	Mindfulness Meditation, Guided Imagery and Visualization, Focused Attention Meditation	1	90	
3 & 4	Asana	Vrikshasana, Utkatasana, Paschimottanasana, Marjariasana, Dhanurasana, Makarasana, Setubandhasana, arvangasana.	12	330	600 Minutes
	Pranayama	Anuloma villoma, kapalapathi, bhramari pranayama, bhatrika	2	180	
	Meditation	Mindfulness Meditation, Guided Imagery and Visualization, Focused Attention Meditation	1	90	
5 & 6	Asana	Natarajasana, Ardha Chakrasana, Gomukhasana, Ushtrasana, Astanga namaskara Chakrasana, Halasana	12	300	600 Minutes
	Pranayama	Anuloma villoma, kapalapathi, bhramari pranayama, bhatrika	3	210	
	Meditation	Mindfulness Meditation, Guided Imagery and Visualization, Focused Attention Meditation	1	90	
7 & 8	Asana	Padahastanasana, Adhomukha Shwanasana, Vakrasana, Shashakasana, Dhanurasana, Makarasana, Pawanmuktasana, Ardha Halasana	12	300	600 Minutes
	Pranayama	Anuloma villoma, kapalapathi, bhramari pranayama, bhatrika	3	210	
	Meditation	Mindfulness Meditation, Guided Imagery and Visualization, Focused Attention Meditation	1	90	

Results

Table 4. Mean, Standard Deviation and t Test result of Age, Height and Weight of Experimental and Control Group

No	Variables	Experimental group Mean ± SD			Control Group Mean ± SD		
		Pre test	Post test	Sig	Pre test	Post test	Sig
1	Cardiorespiratory endurance	21.15 ± 6.10	22.05 ± 5.34	0.070	20.10 ± 5.58	20.35 ± 5.07	0.398
2	Isometric puss up test	21.95 ± 4.93	23.15 ± 4.94	0.004	22.25 ± 5.16	22.60 ± 5.48	0.130
3	Sit-to-Stand test	13.35 ± 3.86	14.8 ± 3.50	0.001	14.00 ± 2.82	14.25 ± 2.55	0.204
4	Plank test	14.12 ± 6.31	15.04 ± 5.71	0.002	13.82 ± 4.75	14.23 ± 4.54	0.065
5	Flexibility	18.34 ± 7.06	20.46 ± 6.77	0.000	17.61 ± 7.07	18.20 ± 6.88	0.017
6	Body Composition	16.40 ± 3.54	16.65 ± 3.16	0.234	16.45 ± 2.08	16.85 ± 2.32	0.028
7	Balance	9.54 ± 3.00	11.27 ± 2.83	0.000	9.66 ± 3.33	9.97 ± 3.06	0.144

Discussion

This research sought to assess how adapted yoga affects the physical health of students with ID. The primary finding revealed that participating in eight weeks of adapted yoga notably improved physical health among the students mild ID. But there were no notable changes seen in terms of body composition or cardiorespiratory endurance. Whereas literature supports the beneficial impact of yoga on the physical fitness of the general population, there is limited evidence regarding the effects of adapted yoga specifically on the physical health of students with ID. The current investigation and these results are in agreement the Yoga-based programmes had a favourable influence on kids with ID's motor abilities, demonstrating modest to substantial increases in measured outcomes (Khalsa & Butzer, 2016; Reina et al., 2020; Hart et al., 2022).

Furthermore, after an eight-week yoga intervention, there were no significant differences in cardiorespiratory endurance. On the other hand, following exercise-based interventions, a recent study found that young individuals with ID had improved cardiovascular function (Büssing et al., 2012). Information regarding yoga's impact on cardiorespiratory endurance in students with ID, remains limited. An investigation found that prepubescent children who practiced yoga for 12 weeks had improved aerobic capacity (Veneri et al., 2018). These results may be explained by the beneficial effects of breathing exercises and yoga poses on factors including cardiac output, oxygen delivery capacity, and capillary density. The nature, duration, and intensity of physical activity play crucial roles in enhancing the cardiorespiratory system (Hawkins et al., 2012; Mishra et al., 2018; Satish et al., 2018). Marked enhancements in cardiorespiratory endurance have been noted with aerobic regimens like aquatic sports or cycling (Marandi et al., 2023). Additionally, investigations focusing on exercises targeting respiratory muscle strengthening have reported increased cardiorespiratory endurance post-yoga interventions (Pastula et al., 2012). Although our research revealed a slight rise in cardiorespiratory endurance, students with ID were unable to participate in high-intensity activities due to physical constraints. Such activities are essential for increasing aerobic capacity. Subsequent investigations may explore extended periods of yoga intervention in order to

thoroughly assess its possible impacts on cardiorespiratory endurance.

Physical well-being, which encompasses strength, endurance, power, and flexibility, plays a pivotal role in overall health (Yang et al., 2022). Students with ID typically exhibit lower levels of physical well-being compared to their peers without disabilities (Kim & Yi, 2018). Movement challenges such as poor balance and coordination can impede their participation in exercises aimed at enhancing muscle groups and overall fitness (Hsu et al., 2021). Moreover, poor muscle tone is a problem among some kids, which makes prolonged physical activity challenging. In addition to causing a propensity for solitary pursuits, cognitive and social challenges can limit possibilities for physical activity (Xu et al., 2020).

After eight weeks of adapted yoga training, the study found that there were considerable improvements in the strength and endurance of the upper, lower, and core muscles. These findings are in line with meta-analyses showing that exercise therapies increase the muscle strength and endurance of the ID population. Although outcomes have varied, yoga has been demonstrated to be effective in improving muscle fitness in those without ID. Studies on toddlers and teenagers with ID have shown improvements in leg strength and hand grip (Hawkins et al., 2012; Sun et al., 2022). Inconsistencies in findings could come from variations in methods of measuring related to ID. The effects noted in this study might be related to neuromuscular changes made possible by isometric contraction yoga postures, which improve the connections between the muscles and nerves (Folletto et al., 2016). Childhood is a critical time for neuromuscular development, and bodyweight exercise maximises muscular fitness throughout this phase (Mohanty et al., 2016).

When it comes to flexibility, people with ID usually score poorly (Serwacki & Cook-Cottone, 2012). In line with other earlier studies, our study did find that practicing yoga training increased flexibility. Yoga's combination of static and dynamic stretching exercises could extend the limbs' elastic connective tissue, improving range of motion (Gothe & McAuley, 2015; Reina et al., 2020). These positive findings highlight the potential benefits of adapted yoga training for people with ID in terms of increasing flexibility and muscle strength and endurance.

Students with ID have been shown to have motor weaknesses, balance problems, and unstable posture. Several studies have highlighted balance as a crucial aspect of motor fitness and have documented the positive benefits of exercise treatments on people with ID's ability to walk and stand balanced (Azar et al., 2023). Notably, a recent meta-analysis revealed a significant beneficial impact after yogic intervention meant to improve balance in children and adolescents with ID (Jylänki et al., 2022). Furthermore, a growing body of research indicates that yoga improves this component of motor fitness in people with ID (Reina et al., 2020).

In a comparable manner, our research on students with ID showed significant improvements in static balance after receiving adapted yoga instruction. On the other hand, after a creative yoga intervention, a research found no difference in balance, which it attributed to differences in the yoga programme and the balance subtest performed (Jeter et al., 2014). Adapted yoga has been shown to improve balance by stimulating the proprioceptive, vestibular, and visual systems, all of which support sensory integration (Kaur et al., 2021). Additionally, better posture control and balance are probably influenced by the enhanced muscle fitness that comes with yoga. Attention-focused yoga poses have the potential to improve postural control (Kaur & Bhat, 2019). Ultimately, students with ID benefit from adapted yoga training as an effective intervention for improving their balance, which may also improve their motor fitness and general physical well-being.

Conclusions

This study highlights the potential of adapted yoga programs as an intervention for improving physical functioning in students with mild intellectual disability. These findings suggest that adapted yoga can be a valuable and accessible intervention to enhance physical functioning in this population.

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Conflict of interest

There are no conflicts of interest, the authors assure.

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Визначення впливу адаптованого тренування з йоги на фізичне функціонування учнів з порушенням інтелектуального розвитку помірного ступеня

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

Реферат. Стаття: 8 с., 4 табл., 47 джерел.

Історія питання. Особи з порушенням інтелектуального розвитку (ПІР) помірного ступеня часто зазнають труднощів у фізичному функціонуванні, що впливає на їхнє загальне самопочуття та якість життя. Традиційні програми фізичних вправ не завжди можуть бути доступним або ефективним засобом для цієї категорії осіб через різні обмеження. Адаптовані програми з занять йогою розглядаються як перспективна альтернатива, що пропонує індивідуальні інтервенції, спрямовані на забезпечення особливих потреб осіб з порушенням інтелектуального розвитку.

Мета дослідження. Метою дослідження було подолання вказаної проблеми шляхом вивчення впливу структурованої, модифікованої програми з йоги на фактори, пов'язані з фізичним функціонуванням.

Матеріали та методи. Загалом було відібрано 40 учнів з порушеннями інтелектуального розвитку помірного ступеня у віці від 11 до 15 років зі спеціальних шкіл у місті Коїмбатор, штат Таміл-Наду. Дослідження проводилося за квазі-експериментальною схемою. Учасники дослідження були розділені на експериментальну групу, яка проходила 8-тижневу адаптовану програму з занять йогою, і контрольну групу, яка дотримувалася звичайного режиму занять. Параметри фізичної функції оцінювали шляхом проведення стандартизованих тестів, що вимірюють кардіореспіраторну витривалість, м'язову силу та витривалість, гнучкість, композицію тіла та рівновагу. Адаптована програма з йоги, яку проводили кваліфіковані інструктори, складалася з 8 тижнів занять по 5 днів на тиждень, кожне з яких тривало від 45 до 60 хвилин. За допомогою статистичних методів аналізу було підтверджено нормальний розподіл даних і застосовано t-критерії парних вибірок для оцінки відмінностей до і після проведення дослідження з використанням програмного забезпечення SPSS версії 20.0 із встановленим рівнем значущості 0,05.

Результати. Після 8 тижнів проходження адаптованих тренувань з йоги спостерігалось значне покращення показників сили верхньої частини тіла ($p < 0,04$), нижньої частини тіла ($p < 0,001$), зміцнення м'язів кору ($p < 0,002$), гнучкості

($p < 0,001$) та статичної рівноваги ($p < 0,00$). Однак не було зафіксовано достовірної різниці у показниках вмісту жиру в організмі та кардіореспіраторної витривалості між адаптованими тренуваннями з йоги.

Висновки. У цьому дослідженні висвітлено потенціал адаптованих програм занять з йоги як інтервенції для покращення фізичного функціонування учнів з ППР помірною ступеня. Отримані результати вказують на важливість та доступність впровадження занять з адаптованої йоги з метою поліпшення фізичного функціонування даної категорії осіб.

Ключові слова: порушення інтелектуального розвитку, адаптована йога, фізичне функціонування, м'язова сила, витривалість.

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Analyzing Lived Experiences of Athlete and Coach Relationships in Sports

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Abstract

Objectives. The two main stressors affecting athletes' wellbeing are relationships between coaches and athletes and social support. This study aims to investigate the connections between athletes' psychological health, social support, and coach-athlete interactions. Relationships between coaches and athletes have a favorable impact on future coaching techniques and support systems, which in turn improves athlete wellbeing.

Materials and methods. This study employed a quantitative approach using survey methods. The study involved 323 respondents consisting of 231 males (71.52%) and 92 females (28.48%). The instrument used in this study was the Instructor-Student Rapport Scale, comprising 2 dimensions (pleasant interactions and personal relationships). The study results were analyzed using the t-test to determine the significance of differences in athletes' life experiences based on their relationship with the coach. The findings of the study explain that the experiences of athletes' gender have differences regarding the relationship with the coach.

Results. This result has also been proven by the results of the t test calculation of <0.001 . Meanwhile, the results of t test calculations related to the type of sport (individual and group) obtained results >0.001 , which states that there is no difference in life experience between athletes and coaches.

Conclusions. These findings lead to the conclusion that the most crucial factor in facilitating and enabling meaningful life experiences between coaches and athletes is the coach's proximity to the athletes.

Keywords: life experience, athlete, coach, relationships, sport.

Introduction

Around 70% of young athletes quit sports at the age of 13, which is due to the role of coaches influencing athletes' motivation and behavior to continue to be competent in sports activities (Wekesser et al., 2021). From an ecological point of view, it is expected that competent behavior in areas such as academics and sports performance will mold useful connections between people and their surroundings. Over time, everyday behavior, attitudes, and conventions (sociocultural practices) in sport organizations affect the strength of this functional relationship (Rothwell et al., 2022). The coach's unique considerations, the athletes' intellectual stimulation, and the presence of suitable role models all

influence the quality of the interaction between the coach and the athlete (López de Subijana et al., 2021). Coach leadership behavior predicts positive and negative affect for athletes, this is because coach social support significantly controls negative affect both pre-competitive and during competition (González-García et al., 2021; Sakalidis et al., 2023; Trninić et al., 2009). Based on the explanation above, it can be seen that the relationship between coach and athlete is the main foundation in fostering the continuity of athlete performance. The coach's role is not only as a leader in a sports club, but more than that, the coach also plays a role as the main contributor for athletes to continue to show their best performance both in training and in competition.

Research indicates a strong positive correlation between players' mental health and their relationship with their coach (Powers et al., 2020). The coach's knowledge about the long-term effects of the coach-athlete relationship can help the athlete to understand himself to become an outstanding

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athlete (Kuhlin et al., 2020). Other results also show that the lack of attention given to athletes is the main topic that influences athletes' performance during competition and training (J. A. Graham & Smith, 2022). Relationships with coaches deteriorate for athletes whose coaches are untrained, building positive coach-athlete relationships as a tool to encourage athlete personal growth and development (Falcão et al., 2020). The role of the coach in supporting athletes who experience psychological distress is divided into three, namely, (1) the coach's role is to provide an environment that facilitates the expression of distress, (2) the coach has the responsibility to connect athletes with appropriate resources, (3) the coach's job is to support athletes in help-seeking behavior (a period where athletes experience difficulties) (Bissett & Tamminen, 2022). Discussions between athletes and coaches are a way to build a relationship that involves sharing experiences between coaches and athletes, where this activity functions as a way for coaches to evaluate athletes, especially with regard to their psychological well-being (Allan et al., 2018; MacDonald et al., 2020).

The setting in which athletes interact with their coaches is provided by strong coach-athlete interactions. Relationships are crucial to fostering an effective coaching environment since it is likely that athletes who have good relationships with their coaches would receive better coaching help (Sophia Jowett, Nicolas, et al., 2017). The more cooperative and effective interactions that result from alignment produce a level of connection to athlete success (Purnomo et al., 2021; SA et al., 2022). The relationship between athletes and their coaches has important implications for psychological health. Further research explains that identifying aspects of the coach-athlete relationship can suppress fatigue factors and improve athletes' mental well-being (McGee, 2016). Therefore, as a coach you are required to reflect on your own behavior and understand the motivation behind your athlete's behavior (Moen, 2014; Westfall et al., 2018). Considering the fact that coaches and athletes are 2 important components in the success of a sports club (Jackson & Beauchamp, 2010).

The research results revealed that coaches have a strong and often excessive role in the lives of athletes, especially high-achieving female athletes, but a more democratic, personal and positive coach-athlete relationship has proven to play an important role in improving the athlete's experience. female athletes in sports competitions (Norman & French, 2013; Serpell et al., 2023). An athlete's growth as a player and a person is significantly influenced by the quality of their relationship with their coach. Programs for coach education offer knowledge to assist coaches in building strong bonds with their athletes (S. Jowett & Cockerill, 2003; Mohammad Fazilah et al., 2023; Shuai et al., 2024). In terms of gender, female athletes typically train under male coaches, whereas male athletes place more value on coach expertise than gender. According to the study's findings, athletes are more perceptive in relationships with coaches of a different gender than they are in relationships with coaches of the same gender the same (Li et al., 2015). A description of the relationship between coaches and athletes by gender reports that the gender of the coach influences the success of athletes in achieving achievements. It is assumed that the gender of the coach is a guideline when leading a sports club and describes the relationship between the coach and the athletes.

Materials and Methods

Design

The study intends to investigate the life experiences of coaches and athletes in the realm of sports, with a focus on the dynamics of their relationships. Using a quantitative approach using survey methods will provide a structured and systematic way to collect data on this topic. This approach will enable the collection of large amounts of data from a diverse range of athletes and coaches, thereby enabling a comprehensive analysis of their perspectives and experiences in a sporting context. This will involve identifying specific aspects of the relationship between the athlete and coach that wish to be explored, such as communication dynamics, leadership styles, and the impact of the relationship on the athlete's performance. This survey was designed to collect quantitative data regarding various aspects of the relationship between athletes and coaches. Inquiries about communication styles, training techniques satisfaction, coach support perception, and the overall effect of the coach-athlete relationship on performance and well-being will all be covered.

Respondent

There were 323 participants in the study, 231 of whom (71.52%) were men and 92 of whom (28.48%) were women. Snowball sampling was the sample method utilized in this investigation, with the aim of collecting as many samples as possible to enhance the study's conclusions. The respondents' average age was 21.1 years. In specifics, the average age of female respondents was 20.6 years, compared to 21.4 years for male respondents. Athletes who had trained for at least two years in both team and individual sports made up the study's respondents. It was requested of each respondent to take part in this research.

Instrument

In this research, the instructor-student rapport scale instrument was used (Frisby & Myers, 2008). The aim of research using the instructor-student rapport scale instrument is to measure the level of positive relationships and interactions between instructors (coaches) and students (athletes) in a sports context. This instrument is specifically designed to evaluate the quality of interpersonal relationships between instructors and students in the context of education or training. This instrument has been reviewed and used several times. In the second study, it was found that each of the dimensions: pleasant interactions ($\alpha = 0.91$) and personal relationships ($\alpha = 0.90$) (Frisby & Martin, 2010). Later studies reported adequate reliability for dimensions: pleasant interactions ($\alpha = 0.93$) and personal connections ($\alpha = 0.93$) (Young et al., 2013; Graham & Mazer, 2020). Based on the 2 studies above, this means that the instrument has a very good level of validity and reliability and can be used in this research.

Data Analysis

The Sample t-Test will be used to test the research hypothesis. The results of the analysis using the t-test will

determine that the average level of satisfaction of athletes who receive high coach support is significantly different from athletes who receive low coach support. After applying the t-test, the results will be interpreted to determine the significance of differences in athletes' life experiences based on their relationship with the coach. This analysis will provide insight into the impact of the coach-athlete relationship on various aspects such as performance, motivation and overall well-being. Analysis with sample t-tests in the data analysis process will allow the identification of specific areas where the coach-athlete relationship has a significant influence.

Results

The athlete's life experience in relation to the coach in the sports context is an important aspect that can influence the athlete's achievement, psychology and personal development (Davis et al., 2019; Lisinskiene, 2018; Owiti & Hauw, 2021; Raunig & Coggins, 2018). Positive relationships between athletes and coaches have long been recognized as a key factor in creating a supportive environment for successful sports coaching (Davis et al., 2019; Zhao & Jowett, 2023). This research seeks to investigate and analyze the lived experiences of athletes in their relationships with coaches, with a focus on the dynamics, quality and implications of these interactions in sport.

Before carrying out the t-test, it would be good to carry out a prerequisite test consisting of normality and homogeneity tests. This is the main requirement so that it can be analyzed at the next stage. To ascertain if the data is regularly distributed or not, a normality test is utilized. According to the normalcy test, if the data's Sig. (significant) value is less than 0.05, it is deemed anomalous; on the other hand, if it is greater than 0.05, the distribution of the data is deemed normal. The analysis's findings are shown in Table 1 below.

Table 1. Normality Test (Shapiro-Wilk)

Indicator	W	p
ISRS	0.972	0.061

The results of the study demonstrate that the data can be regarded as regularly distributed since $p > 0.05$, which is consistent with the normality test findings shown in Table 1. In the meantime, Table 2 below displays the results of the research data's homogeneity test.

Table 2. Homogeneity of Variances Test (Levene's)

Indicator	F	df1	df2	p
ISRS	0.0155	1	321	0.901

A p value > 0.05 was found based on the homogeneity test findings shown in Table 2. These findings support the hypothesis that the data exhibit uniform variance.

Taking into account that the two prerequisite analyzes in this study are normally distributed and homogeneous, further analysis can be carried out. In this t-test analysis, researchers divided the results based on gender (men and women) and also the type of sport (individual and team).

Instructor–Student Rapport Scale in Terms of Gender

Based on the t-test relating the instructor–student rapport scale to gender, the following data was obtained:

Table 3. Independent Samples T-Test

Indicator	t	df	p
Instructor–Student Rapport Scale	3.35	321	0.001

Note. $H_a \mu_{Male} \neq \mu_{Female}$

Based on the test results in the table above using the independent samples t-test, the p value < 0.001 , the hypothesis H1 is accepted, which means there is a difference in the influence between gender and the Instructor-Student Rapport Scale. This proves that the responses between coaches and athletes are different from each other. Which also means that the treatment of relationships between men and women is different. Therefore, a trainer must also be able to explain in more detail the approach that will be taken.

It is important to acknowledge the unique dynamics that exist in the athlete-coach relationship, especially when comparing the experiences of male and female athletes (Aydinlar et al., 2024; Munikrishnan et al., 2024; Zhao & Jowett, 2023). Research shows that gender can play an important role in interactions between athletes and their coaches. For example, female athletes may face different expectations, communication styles, and support systems compared to male athletes (Mire et al., 2021; Swim et al., 2022; Zhao & Jowett, 2023). These differences can impact the overall coaching experience and can impact an athlete's performance, motivation, and well-being. When exploring differences in lived experiences regarding relationships between athletes and coaches, it is important to consider the broader social and cultural context. Gender norms, stereotypes, and power dynamics may all contribute to shaping these relationships in different ways for male and female athletes (Mire et al., 2021; Swim et al., 2022). Additionally, examining the impact of mentoring, feedback, and leadership in these relationships can provide valuable insight into how athletes navigate their sporting journey.

Instructor–Student Rapport Scale Viewed from the Sport Category

Based on the t-test relating to the instructor-student rapport scale with the sport category, the following data was obtained:

Table 4. Independent Samples T-Test

Indicator	t	df	p
Instructor–Student Rapport Scale	-1.15	321	0.251

Note. $H_a \mu_{Team} \neq \mu_{Individual}$

Based on the test results in the table above using the independent samples t-test, the p value (0.251) > 0.001 means the hypothesis is rejected, which means there is no difference in influence between the sport categories (individual and group) and instructor-student rapport scale. This proves that there is no difference between the sports categories

between coaches and athletes. Which means that individual and team sports have the same level of life experience. The results of the independent samples t-test with a p value of 0.251 showed that there was no significant difference in the Instructor-Student Rapport Scale scores between two groups of athletes from different sport categories (individual and group). A p value greater than the 0.001 significance level indicates that there is not enough statistical evidence to reject the hypothesis. In this context, a p value greater than 0.001 indicates that the observed difference in instructor-student rapport scores between the two groups of athletes cannot be considered a statistically significant result. This means that the relationship between athletes and coaches, as reflected in instructor-student rapport scores, does not appear to be significantly influenced by sport category. In other words, there is no significant difference in the quality of the relationship between athletes and coaches between different sports.

It appears that the athlete-coach relationship has a similar impact on individual and group sports. The bond between an athlete and their coach is critical to their success, no matter what type of sport they participate in (Lisinskiene, 2018; Munikrishnan et al., 2024). These findings suggest that the quality of the athlete-coach relationship is universally important in the world of sport. Research has shown that a positive athlete-coach relationship can result in better performance, increased motivation, and overall athlete satisfaction. In individual sports, coaches play a more personal role in guiding and supporting athletes, whereas in team sports, coaches foster teamwork and unity among athletes (Lisinskiene, 2018; Mire et al., 2021; Sandström et al., 2016). Despite differences in their specific roles, the impact of athlete-coach relationships on athletes' experiences and performance remains consistent in both individual and group sports. It is clear that the bond between an athlete and his or her coach has a significant impact on the athlete's overall experience and performance, regardless of whether they participate in an individual or group sport (Davis et al., 2018; Karapanos et al., 2016). This underlines the importance of fostering positive athlete-coach relationships in the world of sport. The role of the coach may vary in individual and team sports, with a focus on personalized guidance and support in individual sports and fostering teamwork and unity in team sports, but the overall impact on the athlete's experience and performance remains consistent (Jackson et al., 2009; Jowett & Cockerill, 2003). This highlights the important role the athlete-coach relationship plays in the success and well-being of athletes across a wide range of sports.

Discussion

Athletes, coaches, managers, and sponsors are all involved in their performance and success. However, the relationship between coaches and athletes is thought to be a fundamental vector in the context of sport, with several factors contributing to it, including the coach's leadership and personality, motivational factors, communication, cohesion, and The setting of sports coaching introduces emotions as a psychosocial component (Bennie & O'Connor, 2012; Vigário et al., 2020). Athlete well-being is favorably connected with relationships between coaches and athletes as well as with social support among athletes (Miller et al.,

2007; Simons & Bird, 2022). The development of positive experiences in an effort to increase the strength, potential and competence of adolescents is described as the result of the social environment of adolescents including school, family and community which directs them to become useful individuals (MacDonald et al., 2020). The research results show that athlete performance sometimes depends on positive and negative interpersonal relationships between coaches, athletes and parents (Lisinskiene & Lochbaum, 2022; Roşca, 2010). The study results stated that the athlete's attachment to the coach was significantly related to the athlete's psychological development in facilitating the athlete's success in achieving peak performance (Cushion et al., 2012; Davis et al., 2021).

Athletes' self-esteem and level of life satisfaction might increase when positive relationships are developed between them and their coaches (Baker et al., 2000; Gencer, 2021). This shows that actions in sports coaching are oriented towards supporting athletes as one way of creating a healthy environment in shaping athlete behavior which functions to improve athlete perception. Some positive coaching behaviors aimed at increasing an athlete's perception of competence may include providing positive and informative feedback, using positive reinforcement, and creating opportunities for the athlete to increase success in athletic competition (Wekesser et al., 2021). Coach education programs and training can be utilized to increase awareness of the importance of coaching practices as techniques and strategies that help foster positive coach behavior (e.g., supporting competence) in their athletes.

The findings show a substantial correlation between the variables of trust and confidence as well as between confidence and commitment to maximize the ability of competent coaches to provide encouragement to athletes and foster feelings of self-confidence and trust (Fikri et al., 2024). Trainers must establish an environment that supports participants' autonomy and satisfies their three fundamental psychological requirements (Cronin et al., 2022). A study relating to the implications for the development and evaluation of mental skills training programs in the case of elite team sports athletes categorizes the psychological qualities of coaches, such as comfort in coaching, responsibility, adaptability, enthusiasm, self-aware learner, determination, self-confidence, performance conditions optimal performance, harmonious play, focused attention, and mental toughness (Erickson et al., 2011; Holland et al., 2010; Smith et al., 2023). A coach's training ability is an important foundation for the success of an athlete or a sports team. In this case, coaches are an important key in improving athlete competence in every training performance and match performance. In young athletes, the closeness of the athlete and coach has the effect of building the athlete's self-confidence in maximizing performance towards peak performance (Pandini & Widodo, 2021; Purnomo et al., 2020).

The close friendships and romantic relationships between coaches and athletes represent an area where mutual autonomy support is essential, where each party provides autonomy support to the other party, as well as receiving it from the other party (Deci & Ryan, 2008; Myer et al., 2016). According to research on career and talent development, which looks at young athletes' growth from an ecological

standpoint, future athletes' development can be understood as a slow, reciprocal adjustment that takes place between them and their surroundings, including the coach's role (Stambulova et al., 2021). The literature on the relationship between athletes and coaches states that the dimensions of communication, trust and mutuality are important parts in improving an athlete's performance (LaVoi, 2007; Santos et al., 2018). The closeness of athletes and coaches is an important part in developing athlete potential. Coach communication is the main door to evaluating athlete development, athletes feel safe if the coach cares and is able to motivate themselves. The feeling of belonging felt by athletes is often related to mental well-being for an athlete.

The results of semi-structured interviews conducted on international level coach-athlete relationships are the reason for increasing athletes' "efficacy beliefs" (Lent & Lopez, 2002). The findings are discussed in light of how successful relationships between coaches and athletes can be created and maintained at the highest level (Jackson et al., 2009). Additional analyses also discovered a significant correlation between players' self-esteem and their assessments of their connections with coaches, particularly for those athletes who had positive associations (Sophia Jowett, 2008). The study's findings expand our understanding of athletes' physical self-concept in the relational context of the coach-athlete relationship by demonstrating that an athlete's perceived quality of relationship with the coach is correlated with their level of fatigue, suggesting that athlete-coach similarity is an important mediator of the athlete-coach relationship (Isoard-Gauthier et al., 2016). The findings further bolster the self-determination theory's universal applicability and the importance of interpersonal ties in fostering well-being (Sophia Jowett, Adie, et al., 2017; McGee, 2016; Westfall et al., 2018). When competing against more seasoned athletes or older athletes who are superior to them, young athletes, or junior athletes, are more likely to develop stage fright or extreme anxiety, which can negatively impact their mental health (Marheni et al., 2019). Mental strengthening of athletes through the relationship between coaches and athletes strengthens social values which are used as a way to respect themselves and others around them (Sari et al., 2024).

Conclusions

An athlete is always faced with psychological problems that can interfere with his mental ability to train or compete. Coaches are required to understand the triggers of psychological problems faced by their athletes. A good relationship between coach-athlete has a positive impact on the psychological well-being of athletes. The coach's communication skills are the main key in building closeness between athletes and coaches. The coach's communication becomes a reflection that the athlete responds to which then becomes the athlete's reference in undergoing the training process. A coach's training ability is characterized by the ability to understand every aspect of an athlete. Coaches don't just provide training material, more than that, coaches act as main facilitators in assisting athletes in improving maximum performance. Maximum performance produced by athletes is a combination of training and the relationship with their coach. Athlete-coach harmony fosters a relational

context for the connection between the two, which lowers the amount of athlete tiredness during both the training and competition phases.

Conflict of interest

The authors state that no commercial or financial ties that might be considered a possible conflict of interest existed during the conduct of the study.

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Аналіз життєвого досвіду взаємовідносин між спортсменом і тренером у спорті

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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., 71 джерело.

Мета дослідження. Двома основними стресовими факторами, що впливають на благополуччя спортсменів, є відносини між тренерами і спортсменами та соціальна підтримка. Метою цього дослідження є вивчення зв'язку між психологічним здоров'ям спортсменів, соціальною підтримкою та взаємодією між тренером і спортсменом. Відносини між тренерами та спортсменами мають сприятливий вплив на майбутні тренерські методики та системи підтримки, що, в свою чергу, сприяє покращенню показників благополуччя спортсменів.

Матеріали та методи. У дослідженні застосовано кількісний підхід з використанням методів опитування. У дослідженні взяли участь 323 респонденти, серед яких 231 осіб чоловічої статі (71,52%) та 92 — жіночої (28,48%). У якості інструменту дослідження була використана Шкала оцінки взаємовідносин між викладачем і студентом, що складалася з 2 вимірів (сприятливі взаємодії та особисті відносини). Результати дослідження проаналізовано за допомогою t-критерію для визначення значущості відмінностей у життєвому досвіді спортсменів залежно від їхніх взаємовідносин з тренером. Результати дослідження свідчать про наявність відмінностей у життєвому досвіді спортсменів залежно від статі в контексті відносин з тренером.

Результати. Підтвердженням цього результату є також розрахунки t-критерію <0,001. Водночас, результати розрахунків t-критерію, пов'язані з видом спорту (індивідуальний та груповий), показали значення > 0,001, що свідчить про відсутність різниці в життєвому досвіді між спортсменами та тренерами.

Висновки. Отримані дані дозволяють зробити висновок, що найбільш важливим фактором, який сприяє та уможливає забезпечення значущого життєвого досвіду між тренерами та спортсменами, є близькість тренера до спортсменів.

Ключові слова: життєвий досвід, спортсмен, тренер, взаємовідносини, спорт.

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Enhancing Self-Esteem, Satisfaction, and Motor Skills through Gamification in Elementary Physical Education

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. This study aimed to investigate the impact of gamification in physical education on enhancing the self-esteem, satisfaction, and motor skills of 7-9-year-old elementary school students.

Materials and methods. This study employed a pre-experimental method using a one-group pretest-posttest design without a control group. The participants were 90 elementary school students aged 7-9 years in Salatiga City (Indonesia), selected through purposive sampling. The research instruments included self-esteem, sports satisfaction, and motor skills assessment tools that have been validated and tested for reliability. The gamified intervention was implemented in physical education instruction over eight weeks. The statistical analysis was conducted using descriptive statistics, prerequisite tests, analysis of variance (ANOVA), and paired samples t-tests.

Results. The study's findings indicate significant changes in the observed variables following the intervention, with a significance value (Sig) of $0.000 < 0.05$. The calculated t-values for all three variables were more significant than the critical t-value of 1.990, with a significance level (Sig. 2-tailed) < 0.05 . Therefore, this implies that gamification in elementary physical education instruction has a statistically significant positive impact on students' self-esteem, satisfaction, and motor skills.

Conclusions. The findings elucidate that the implementation of a gamification intervention has proven effective in enhancing students' self-esteem, satisfaction with learning, and motor skills abilities. The practical implications of these findings underscore the importance of considering the integration of gamified process into instructional design as a strategy to enhance the quality of physical education learning in elementary schools.

Keywords: self-esteem, satisfaction, motor skills, gamification, physical education.

Introduction

Physical education plays a crucial role in shaping students' physical and psychosocial well-being worldwide. With the advancements of the modern world, the challenges faced in physical education are becoming increasingly diverse, particularly at the elementary school level. One primary challenge is enhancing students' self-esteem, satisfaction, and motor skills, which are critical in fostering healthy and holistically developing individuals (Invernizzi et al., 2019). Although physical education has long been recognized as an integral part of the elementary school curriculum, innovative and practical approaches to achieving desired learning outcomes remain the research focus. In this context,

gamification emerges as a promising approach to enhance student motivation and engagement in learning through the integration of games, with the potential to improve their psychosocial well-being. However, research specifically investigating the influence of gamification in physical education among elementary school students still needs to be completed. Therefore, this study aims to fill this gap by investigating the impact of gamification implementation in physical education on elementary school students' self-esteem, satisfaction, and motor skills. By expanding the understanding of gamification potential in the context of physical education, this research is expected to provide valuable insights and significantly contribute to developing more effective and inclusive educational practices at the elementary school level.

Although physical education is widely recognized as an essential part of the elementary school curriculum, significant challenges persist in achieving desired learning

outcomes, particularly concerning students' psychosocial and motor aspects. One of the primary issues is low self-esteem, satisfaction, and motor skills among some students (Chen et al., 2017; Xue-Yan et al., 2016). Low self-esteem can negatively impact learning motivation, social interaction, and students' emotional well-being (Nguyen et al., 2019; Scherrer & Preckel, 2019). Additionally, students' satisfaction with learning also plays a crucial role in influencing participation rates and academic performance (Griebler et al., 2017). Meanwhile, underdeveloped motor skills can restrict elementary school students' participation in physical activities and sports, essential components of their daily lives (Eddy et al., 2019; Lee et al., 2020). Despite efforts to enhance these aspects through various teaching approaches, more innovative and effective strategies are still needed. Therefore, this research explores the potential use of gamification in physical education to improve elementary school students' self-esteem, satisfaction, and motor skills.

While research in physical education continues to evolve, there remains a significant gap in the literature regarding the influence of gamification in enhancing elementary school students' self-esteem, satisfaction, and motor skills. Studies specifically investigating the use of gamification in the context of physical education at the elementary school level are limited, with the majority of research focused on higher education and middle school levels (Arufe-Giráldez et al., 2022; Fernandez-Rio et al., 2022). Furthermore, research tends to be limited in geographical scope, with most studies conducted in developed countries. This limitation hinders the generalizability of research findings to elementary school student populations in various cultural and social contexts. Additionally, within the existing literature, there is a lack of comprehensive research examining the influence of gamification on motor skills, with more focus on cognitive and motivational aspects. Therefore, there is an urgent need to address this gap by conducting more in-depth and holistic research on the impact of gamification in physical education on elementary school students.

This research reflects a new and significant contribution to physical education, particularly in using gamification to enhance elementary school students' self-esteem, satisfaction, and motor skills. Although gamification has gained attention in various fields, including education, its application in physical education is relatively new and has yet to be fully explored. Focusing on the age group of 7-9-year-olds at the elementary school level, this study expands the understanding of the potential use of gamification in achieving learning objectives related to students' physical and psychosocial well-being. The uniqueness of this research lies in its holistic approach, which explores the impact of gamification on students' psychological aspects and their motor skills, which are vital components of physical development. By highlighting the novelty and importance of this research, it is hoped that the findings will contribute to developing more inclusive, innovative, and effective physical education practices at the elementary school level and inspire further research in this field.

Materials and Methods

Study Participants

The participants in this research are elementary school students in Salatiga. The research sample consists of 7-9-year-

old elementary school students selected randomly from elementary schools in Salatiga city using purposive sampling, resulting in a total sample size of 90 elementary school students.

Study Organization

This study adopts a pre-experimental method with a one-group pretest-posttest design. No control group is included in this design. Subject placement involves all elementary school students aged 7 to 9 in Salatiga who meet the age criteria. First, the students will be informed about the research objectives and procedures after obtaining permission from the schools and parents. Then, they will be asked to fill out self-esteem and satisfaction questionnaires tailored to the characteristics of elementary school students. Additionally, the researcher will conduct motor skills assessments. Subsequently, gamification intervention will be implemented in physical education instruction for eight weeks. After the intervention period, all measurement instruments will be repeated to compare changes before and after the intervention.

The research instruments consist of a self-esteem questionnaire tailored to the characteristics of 7-9-year-old elementary school students, with validity test results of 0.82 and a Cronbach's alpha reliability of 0.71. To measure satisfaction, the Sports Satisfaction Inventory (SSI) (Duda & Nicholls, 1992), adapted to physical education classes in schools (Antonio Baena-Extremera et al., 2012), and also used in previous research (Morales-Sánchez et al., 2021) to assess student satisfaction with physical education instruction. In practice, the SSI instrument underwent validity and reliability testing adjusted to the characteristics of 7-9-year-old students with more straightforward language and easier comprehension. Meanwhile, to assess students' motor skills, a performance-based motor skills assessment instrument is used with item validity of 1, validity criteria of $0.000 < 0.05$, and reliability based on Cronbach's alpha of 0.72 (Wibowo et al., 2024).

Table 1. Self-esteem instrument

Description
1. I am happy with myself.
2. I am proud of what I do.
3. I feel confident.
4. I feel valuable and important.
5. I feel comfortable with my appearance.
6. I have many friends who care about me.
7. I am happy being myself.

Table 2. SSI Instruments

Description
1. I enjoy participating in physical education classes.
2. During Physical Education class, I sometimes daydream and lose focus on what I should be doing.
3. I feel bored during physical education classes.
4. In Physical Education class, I often wish the class would end quickly.
5. Physical Education lessons are engaging.
6. When I am in Physical Education class, time flies by quickly.
7. I am active during physical education classes.
8. I enjoy physical education classes.

Table 3. Statistical Description

Variabel	N	Mean	Std. Deviation	Min	Max	Sum
Self-esteem	90	24.31	3.514	17	33	2188
Satisfaction	90	21.64	3.974	11	31	1947
Motor Skills	90	26	2.962	19	33	2340

Statistical Analysis

The statistical analysis in this research involves several approaches, namely descriptive statistical analysis, prerequisite testing, analysis of variance (ANOVA), and hypothesis testing using paired sample t-tests. Descriptive statistical analysis refers to summarizing and describing the observed data using statistics such as mean and standard deviation to provide a general overview of the data characteristics. Prerequisite testing refers to tests or analyses conducted before the primary analysis to ensure that statistical assumptions are met. This includes checking assumptions such as normality and homogeneity. Analysis of variance (ANOVA) is a statistical technique used to compare means across three or more variable groups to see if significant differences exist among the variables. Hypothesis testing using paired sample t-tests indicates that the research employs paired t-tests to test the difference between before and after treatment or intervention (pretest-posttest).

Results

The results section of this research presents the main findings emerging from data analysis related to the use of gamification in physical education learning in elementary schools. These findings provide an in-depth picture of the impact of using gamification on students' self-esteem, satisfaction, and motor skills, as well as its relevance to the research objective of improving students' holistic learning experience.

In this study, an analysis was conducted on three relevant variables, self-esteem, satisfaction, and motor skills, among a sample of 90 participants. The analysis results indicate that the observed average self-esteem is 24.31, with a standard deviation of 3.514 and a range of values between 17 and 33. Similarly, for the satisfaction variable, the recorded average is 21.64 with a standard deviation of 3.974, with a range of values between 11 and 31. Furthermore, regarding motor skills, the observed average is 26, with a standard deviation of 2.962, and it has a range of values ranging between 19 and 33. This data provides an overview of the characteristics of the variables examined within the observed sample population, which can offer valuable insights for further studies.

Table 4. Test prerequisites

Kolmogorov-Smirnov	Homogeneity
0.200	0.116

In the context of this research, the Kolmogorov-Smirnov test was used to test the normality of the data distribution, yielding a result of $0.200 > 0.05$, indicating that the data is usually distributed. Subsequently, the homogeneity test was employed to evaluate the homogeneity of variance among

the compared groups, yielding a test result of 0.116. This data provides an overview of the validity of the statistical assumptions considered in the data analysis, which is crucial in interpreting the research findings and drawing conclusions.

Table 5. Anova analysis of self-esteem, satisfaction and motor skills

	Sum of square	df	Mean Square	F	Sig.
Between groups	932.682	2	466.341	36.117	0.000
Within Groups	3447.451	267	12.912		
Total	4380.133	269			

Analysis of variance (ANOVA) tests the differences in means among two or more groups. In the context of this research, the ANOVA results indicate a significant difference in means among the compared groups, with a significance value (Sig.) of 0.000, which is smaller than the commonly established significance level (0.05). This result suggests a significant difference between the two groups.

Table 6. Paired sample statistics

Variabel		N	Mean	Std. Deviation
Self-esteem	Pretest	90	24.31	3.541
	Posttest	90	31.32	2.628
Satisfaction	Pretest	90	20.39	4.463
	Posttest	90	32.67	3.597
Motor Skills	Pretest	90	26.12	3.605
	Posttest	90	35.45	3.287

The data in Table 6 includes the pretest and posttest results of three observed variables: self-esteem, satisfaction level, and motor skills. For self-esteem, the pretest mean score is 24.31 with a standard deviation of 3.541, while the posttest mean score is 31.32 with a standard deviation of 2.628. Similarly, for satisfaction level, the pretest mean score is 20.39 with a standard deviation of 4.463, while the posttest mean score is 32.67 with a standard deviation 3.597. Lastly, the pretest mean score for motor skills is 26.12 with a standard deviation of 3.605, and the posttest mean score is 35.45 with a standard deviation of 3.287. This data provides a clear overview of the observed changes from pretest to posttest in each variable, which can offer valuable insights in evaluating the effectiveness of the given intervention or treatment.

The analysis of the difference between pretest and posttest scores for the three observed variables, namely self-esteem, satisfaction level, and motor skills, indicates

Table 7. Paired Samples test

Variabel	Mean	Std. Deviation	95% confidence interval of diffence		t	df	Sig. (2 tailed)
			lower	Upper			
Self-esteem pretest-posttest	-7.012	4.562	-7.968	-6.057	-14.593	89	0.000
Satisfaction pretest-posttest	-12.280	5.490	-13.430	-11.130	-21.221	89	0.000
Motor skills pretest-posttest	-9.338	4.855	-10.355	-8.321	-18.246	89	0.000

statistically significant differences. The average difference score between pretest and posttest for self-esteem is -7.012, with a 95% confidence interval ranging from -7.968 to -6.057. Similarly, the average difference score for satisfaction level is -12.280, with a 95% confidence interval ranging from -13.430 to -11.130. Lastly, the average difference score for motor skills is -9.338, with a 95% confidence interval ranging from -10.355 to -8.321. These results indicate significant changes in these variables after the intervention or treatment, with significance values (Sig.) smaller than the established significance level (0.05). This analysis provides crucial insights into evaluating the effectiveness of the intervention or treatment.

The data analysis indicates that the t-test values for self-esteem, satisfaction, and motor skills variables are harmful, namely -14.593, -21.221, and -18.246, respectively. This harmful condition arises from comparing the lower average pretest results and the higher average posttest results. However, in this context, negative t-test values can be interpreted positively. This is because the difference between the average posttest and pretest results indicates an improvement from the initial condition.

Furthermore, since the t-test values for all three variables exceed the critical t-value of 1.990, and the significance (Sig. 2-tailed) is less than 0.05, the null hypothesis (H₀) is rejected, and the alternative hypothesis (H_a) is accepted. Thus, there is a significant difference between the pretest and posttest results, indicating the positive influence of gamification in physical education learning on elementary school students' self-esteem, satisfaction, and motor skills.

Discussion

The implementation of gamification in elementary school physical education has been proven to have a positive impact on students' self-esteem. The analysis indicates a significant improvement in self-esteem following teaching methods involving gaming elements and competition. These findings affirm that gamification interventions can enhance students' self-esteem within the context of learning processes and participation in physical activities (Navarro-Mateos et al., 2024). The improvement in self-esteem holds important implications for building the confidence of elementary school students, motivating them to learn, and enhancing their abilities to achieve academic and social goals (Acosta-Gonzaga, 2023; Kärchner et al., 2021; Yang et al., 2019). Therefore, gamification can be considered a practical approach to strengthening elementary school students' psychological and emotional aspects.

The use of gamification in elementary school physical education has also been proven to impact students' satisfaction levels with the learning process positively. These

findings are consistent with previous research indicating that teaching methods involving gaming elements can enhance students' satisfaction with learning (Videnovik et al., 2020). The research results indicate that elementary school students are more satisfied with their learning experiences when teaching is fun and interactive (Bukit et al., 2023; Irwansyah et al., 2019). Similarly, other research findings suggest that elementary school students' satisfaction and academic performance in physical education learning can be improved through the use of technology and gaming elements in the learning process (Andrade et al., 2020; Cojocaru et al., 2022). Factors such as higher levels of engagement, enjoyment, and the challenges faced by students when learning through gamification have also been recognized by previous studies as contributing factors to increased student satisfaction with learning (Ahmad et al., 2020; Nguyen-Viet & Nguyen-Viet, 2023; Rivera & Garden, 2021). Therefore, the use of gamification in elementary school physical education not only benefits academic achievement but also enhances students' satisfaction with the overall learning process (Segura-Robles et al., 2020).

Implementing gamification in elementary school physical education has been proven to impact the improvement of students' motor skills positively. This research found that students significantly improved motor skills after being exposed to teaching methods involving gaming elements and competition. These findings are consistent with previous research indicating that fun and interactive learning approaches can effectively facilitate the development of motor skills in elementary school students (Rizqi & Sutapa, 2019). The study found that using games and physical activities in learning can enhance children's gross motor skills (Aliriad et al., 2024; Nur et al., 2020; Sutapa & Suharjana, 2019). Similarly, research results have shown that integrating gaming elements into learning can improve coordination and motor control in elementary school students (Mujriah et al., 2022; Saputra et al., 2021; Suryadi et al., 2023). Therefore, these findings affirm that gamification in physical education not only enhances students' interest and participation but is also effective in improving their motor skills.

The improvement in elementary school students' self-esteem, satisfaction, and motor skills after implementing gamification in physical education has significant implications for learning practices in elementary schools. These findings indicate that the use of gaming elements and competition facilitates academic achievement and significantly contributes to the psychological and emotional aspects of students and their motor skills and well-being. Therefore, physical education teachers are encouraged to consider integrating gamification into their lesson designs to enhance elementary school students' learning experience

and stimulate their holistic development. By adopting this approach, physical education teachers can create a more engaging, motivating, and enjoyable learning environment, which, in turn, will increase student participation and create a sustainable positive impact on academic development.

In the context of research limitations, it is essential to acknowledge that this study also has several constraints that must be considered in interpreting its results. Firstly, the research sample is limited to elementary school students in specific locations and age groups; thus, generalizing the findings to a broader population must be done cautiously. Additionally, the relatively short duration of the intervention in this study may reflect something other than the long-term effects of using gamification in physical education learning. Furthermore, measuring self-esteem, satisfaction, and motor skills was only conducted using specific instruments, which may not cover other relevant aspects important in physical education learning.

For future research, it is recommended to expand the sample coverage, both in terms of location and the age range of students, to obtain a broader generalization of the findings. Additionally, conducting long-term studies involving more intensive gamification interventions is suggested to understand their long-term effects on students' self-esteem, satisfaction, and motor skills. Furthermore, future research could also consider using various comprehensive measurement methods to gain a more holistic understanding of the impact of gamification in physical education learning. Future research is expected to provide more profound and relevant insights for developing more effective and sustainable learning practices by addressing these limitations.

Conclusions

The conclusion of this study elucidates that the utilization of gamification in physical education learning at elementary schools significantly impacts students' self-esteem, satisfaction, and motor skills. These findings align with the research objective of exploring gamification's effects in enhancing student's learning experiences and promoting their holistic development. The results of the analysis indicate that gamification interventions effectively improve students' self-esteem, satisfaction with learning, and motor skills. The practical implications of these findings underscore the importance of considering gamification integration in learning design as a strategy to enhance the quality of education at the elementary school level.

However, it is essential to acknowledge the limitations of this research in interpreting its findings. The limited research sample and short intervention duration constrain the extensive generalization of the findings. Therefore, for future research, it is recommended that the sample coverage be broadened and long-term studies conducted to understand the long-term impacts of gamification be conducted. Additionally, more comprehensive measurement methods are warranted to gain a more holistic understanding of the effects of gamification in physical education learning.

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Conflict of Interest

The authors have no conflicts of interest.

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Підвищення рівня самооцінки, задоволеності та рухових навичок шляхом гейміфікації на заняттях з фізичного виховання у початковій школі

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

Реферат. Стаття: 7 с., 7 табл., 34 джерел.

Мета дослідження. Метою цього дослідження було вивчення впливу гейміфікації занять з фізичного виховання на підвищення рівня самооцінки, задоволеності та рухових навичок учнів початкових класів 7-9 років.

Матеріали та методи. У дослідженні застосовано передекспериментальний метод з використанням моделі одно-групового перед- і післятестового спостереження без залучення контрольної групи. У дослідженні взяли участь 90 учнів початкових класів у віці 7-9 років з міста Салатіга (Індонезія), відібраних шляхом цілеспрямованої вибірки. У ході дослідження використано інструменти для визначення рівня самооцінки, задоволеності спортом та оцінки рухових навичок, які були валідовані та протестовані на достовірність. Гейміфікована інтервенція була впроваджена в навчальний процес з фізичного виховання протягом восьми тижнів. Статистичний аналіз проведено з використанням описової статистики, тестів на відповідність умовам дослідження, дисперсійного аналізу (ANOVA) та t-критеріїв для парних вибірок.

Результати. Представлені результати свідчать про значні відмінності у спостережуваних змінних після проведення інтервенції з рівнем значущості (Sig) $0,000 < 0,05$. Розрахункові значення t-критерію для всіх трьох змінних показали більшу значущість, ніж критичне значення t-критерію 1,990, з рівнем двосторонньої значущості (Sig. 2-tailed) $< 0,05$. Отже, це означає, що гейміфікація на заняттях з фізичного виховання в початковій школі має статистично значущий позитивний вплив на показники самооцінки, задоволеності та рухових навичок учнів.

Висновки. Результати дослідження доводять ефективність впровадження гейміфікованих інтервенцій у підвищенні рівня самооцінки учнів, їхньої задоволеності навчанням та поліпшенні розвитку рухових навичок та здібностей. Практичне значення цих результатів підкреслює важливість врахування інтеграції гейміфікованого процесу у навчальний дизайн як стратегії підвищення якості навчання фізичного виховання в початкових школах.

Ключові слова: самооцінка, задоволеність, рухові навички, гейміфікація, фізичне виховання.

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Evaluating the Benefits of a Tele-Exercise Program on Quality of Life and Body Composition Among Female Older Adults

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. This study aimed to assess the impact of an 8-week tele-exercise program on the quality of life (QoL) and body composition among female older adults.

Materials and methods. This study involved female participants aged 60 and older, using a quasi-experimental research design. The tele-exercise regimen comprised a multimodal approach, with sessions lasting 30 minutes, conducted three times a week over an 8-week period. The program included breathing exercises, cognitive training, balance exercises, strength training, stretching, aerobic dance and karaoke singing. The sessions were conducted via streaming studio facilities at the Computer Center of Ubon Ratchathani Rajabhat University (Thailand). The tele-exercise equipment was represented by the following technical means: a 50-inch LED TV, OBS (Open Broadcaster Software) version 30.1.2 for live broadcasting and video recording, Google Meet for virtual interaction, wireless portable microphones, a desktop computer, and two 19-inch computer monitors. Pre- and post-intervention data were collected, including assessments of QoL using the Thai abbreviated version of the World Health Organization QoL questionnaire and body composition measurements (waist circumference and bioelectrical impedance analysis; BIA).

Results. Statistically significant improvements were observed in both QoL and body composition following the tele-exercise intervention. QoL scores demonstrated significant enhancements in overall QoL ($p = 0.004$), as well as in the social relationship ($p = 0.002$) and environmental ($p = 0.001$) domains. Regarding body composition, reductions in waist circumference and visceral adipose tissue were statistically significant ($p < 0.05$), while muscle mass and body fat mass showed trends toward improvement, though not statistically significant.

Conclusions. The findings suggest that tele-exercise training holds promise for enhancing QoL and positively influencing body composition among female older adults. This underscores the potential of tele-exercise as a viable option for older adults, offering cost and time-saving benefits, particularly in situations where transportation may pose challenges.

Keywords: body composition, older adults, quality of life, tele-exercise.

Introduction

Individuals at any stage of life are now required to be proficient in digital technologies. This topic has garnered significant attention from researchers (Oh et al., 2021). Particularly in countries like Japan, South Korea, Singapore, and Thailand, the importance of digital technology for

maintaining the health of older adults is increasingly recognized (Aung et al., 2022). Additionally, the concept of digital literacy has expanded to include eHealth literacy, which refers to the ability to effectively locate, understand, and evaluate health-related information from electronic sources and apply it to address health concerns (Norman & Skinner, 2006). This comprehensive understanding of digital literacy highlights the necessity for older adults to adeptly navigate digital platforms to access vital health information (Chanyawudhiwan & Mingsiritham, 2022).

Recent years have seen a notable surge in the development of technological innovations tailored to

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meet the specific needs of older adult populations. These innovations encompass a wide range of systems designed to provide assistance across various contexts (Liu et al., 2023), especially in addressing challenges exacerbated by the COVID-19 pandemic (Haase et al., 2021).

Home tele-exercise offers numerous advantages, including a reduced risk of infection transmission due to decreased interpersonal contact. Empirical evidence suggests that it fosters increased independence among older adults and yields positive outcomes for their physical and mental well-being (Ghram et al., 2021). Moreover, the convenience of home tele-exercise is enhanced by eliminating the need for travel, resulting in both time and cost savings in healthcare expenditures (Noel et al., 2004).

From a healthcare perspective, telemedicine emerges as a viable solution for managing healthcare during the COVID-19 pandemic (Latifi & Doarn, 2020). Despite experiencing a decline in quality of life compared to previous years, over 80% of older adults utilized technology to maintain social connections, thereby mitigating the impact of social distancing measures on their social networks (Siette et al., 2021). Previous systematic reviews have reported small improvements in balance and moderate improvements in mobility and strength among older adults with frailty (Dawson et al., 2024), while older adults with sarcopenia have shown improved functional fitness and body composition (Hong et al., 2017). In dementia patients, telemedicine has proven valuable for assessment and intervention approaches during periods of social distancing (Elbaz et al., 2021; Sari et al., 2023). Furthermore, prior research on tele-exercise has demonstrated enhancements in both physical and mental health outcomes (Sangprapai et al., 2023). Consequently, the aim of this study was to investigate the quality of life (QoL) and body composition of healthy older adults.

Materials and Methods

Study Participants

Older adults affiliated with the senior club of the Ubon Ratchathani Provincial Administrative Organization were recruited during the social distancing period in September and October 2021. The sample size was determined using the G*power 3.1.4.9 program, with an effect size of 0.95, a significance level (α) of 0.05, and a statistical power ($1-\beta$) of 0.95, resulting in a total sample size of 15 participants. The inclusion and exclusion criteria are outlined in Table 1.

Human Research Ethics

The study was approved by the Ubon Ratchathani Rajabhat University Ethics Committee for Human

Research (Approval No.641008), ensuring adherence to ethical standards. The research protocol was conducted in accordance with the principles outlined in the Declaration of Helsinki. Additionally, the study was registered in the Thai Clinical Trials Database (TCTR 20221103001).

Experimental Design

During the period of COVID-19 social distancing measures, participants were offered an eight-week tele-exercise training program comprising sessions lasting 30 minutes, conducted three times weekly. Prior to the pre-test day, participants received a handbook detailing the training program. The study methodology adhered to the approach outlined in a previous study (Sangprapai et al., 2023). Assessments at the pre- and post-intervention stages were conducted at the UBRU Fitness Center, Ubon Ratchathani Rajabhat University.

The exercise program, conducted in the Streaming Studio room at the Computer Center, Ubon Ratchathani Rajabhat University (see Fig. 1), included a variety of activities: breathing exercises, cognitive training, balance exercises, strengthening exercises, stretching, aerobic dance and karaoke singing. Each session lasted 30 minutes and comprised at least two types of exercises. The aerobic dance routines developed for this study incorporated movements relevant to self-care during the COVID-19 pandemic, such as hand washing and mask-wearing.



Fig. 1. Tele-exercise training protocol at Streaming Studio room

Table 1. Participant criterion

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> - Age \geq 60 years - Barthel Index score $>$ 11 - Capacity for auditory, visual, cognitive and verbal communication including proficiency in the Thai language - Ubon Ratchathani Province residency required - Access to smartphone or computer with internet at home 	<ul style="list-style-type: none"> - Severe medical conditions (e.g., cancer, bloodstream infections and tuberculosis) - High risk of COVID-19 transmission - Presence of unstable congenital diseases - Blood pressure exceeding 160/90 mmHg - Pre-existing cardiac conditions - Presence of joint, bone or muscle disorders exacerbated by physical exertion

Telehealth Equipment

1. TV LED: two screens, one sized 50 inches and the other 45 inches.
2. Google Meet: video conferencing platform.
3. Open Broadcaster Software (OBS) 30.1.2: Software for live broadcasting and video recording.
4. Windows 10: Operating System.
5. Wireless Portable Microphone: Utilized to capture the instructor's voice.
6. Camcorder: Used for recording trainers.
7. Desktop Computer: One set.
8. Computer Monitors: Two 19-inch monitors for image display and graphic work (operator).
9. Green Screen: Employed for background alteration in videos.
10. Illumination: Lighting setup to enhance video brightness.

Study Measurements

1. QoL Assessment

In the Thai abbreviated version of the World Health Organization Quality of Life (WHOQOL-BREF-THAI), a total of 26 questions were included. Responses were recorded on a 5-point Likert scale, ranging from “none” to “very much”, across four distinct domains: physical health, psychological, social relationships, and environmental factors. The scoring of the WHOQOL-BREF-THAI was standardized, yielding a total score range of 26 to 130 points and divided into categories of low (26-60 scores), average (61-95 scores), and good (96-130 scores) for overall QoL (Mahatnirunkul et al., 1998). These encompassed 7 questionnaires for physical health (7-16 scores = low, 17-26 scores = average, 27-35 scores = good), 6 focusing on mental health (6-14 scores = low, 15-22 scores = average, 23-30 scores = good), 3 examining social relationships (3-7 scores = low, 8-11 scores = average, 12-15 scores = good), and 8 addressing environmental domains (8-18 scores = low, 19-29 scores = average, 30-40 scores = good). Data collection procedures involved the utilization of online information forms administered *via* Google Forms, completed by self-evaluation *via* a LINE group.

2. Body composition measurement

2.1. Waist circumference (WC); WC measurement was conducted at the level of the navel while participants maintained a standing position (Yamamoto et al., 2024). The measuring tape was positioned horizontally on the floor and perpendicular to the body's long axis. It was taut but did not press against the abdominal wall.

2.2. Bioelectrical impedance analysis (BIA); BIA equipment (SecamBCA, Hamburg, Germany) was used for five minutes to evaluate body composition (Namboonlue et al., 2021). This instrument analyzes body weight, body fat mass, muscle mass and visceral adipose tissue.

Statistical Analysis

IBM SPSS Statistics version 19.0 was employed for the statistical analyses (IBM Corp., NY). The Shapiro-Wilk test was utilized to assess a normal distribution by examining the mean and standard deviation. The Wilcoxon Signed Rank Test was employed to compare mean variables within the group between pre- and post-tests. A significance level of $p < 0.05$ was established.

Results

Table 2 displays the baseline characteristics of the participants. The majority of participants were aged between 60 and 69 years, reported having chronic diseases necessitating regular medication and exhibited a normal body mass index (BMI).

Table 2. Baseline characteristics of the participants

Parameters	Number	%	
Age (y)	60-69	9	60.00
	≥70	6	40.00
Chronic disease	Yes	9	60.00
	No	6	40.00
Regular medicine	Yes	10	66.67
	No	5	3.33
BMI (kg/m ²)	18.50-22.90	3	20.00
	23.00-24.90	7	46.67
	25.00-29.90	5	33.33
	≥30	0	0.00

Description: BMI; body mass index

Figure 2 depicts the QoL at the PRE-POST assessment stages. In the physical health domain, the intervention yielded average pre- and post-scores of 27.80 ± 3.69 and 29.40 ± 2.23 , respectively, with a p-value of 0.130. These findings suggest a favorable QoL both before and after the intervention. Similarly, in the psychological domain, the average pre- and post-scores were 26.60 ± 2.95 and 27.67 ± 2.44 , respectively, with a p-value of 0.269, indicating a consistent good QoL across assessments. Notably, the social relationships domain exhibited average pre- and post-scores of 10.47 ± 2.36 and 13.33 ± 1.63 , respectively, with a significant p-value of 0.002, signifying an improvement from average to good QoL. In the environmental domain, the average pre- and post-scores were 31.60 ± 3.94 and 38.00 ± 2.10 , respectively, with a significant p-value of 0.001, indicating good QoL levels both pre- and post-intervention. Additionally, a statistically significant improvement in overall QoL was observed with a p-value of 0.004. The average scores for pre- and post-

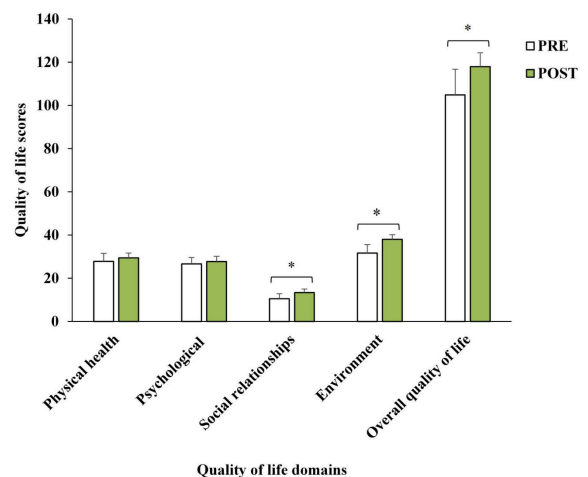


Fig. 2. Comparison of pre- and post-quality of life scores. *Significant $p < 0.05$ (pre vs post)

Table 3. The body composition of the participants

Parameters	Pre-test	Post-test	Z	p-value
Waist circumference (cm)	88.20±5.89	83.00±6.71	-3.088	0.002*
Muscle mass (kg)	13.67±2.36	15.18±5.32	-1.886	0.059
Body fat mass (%)	43.02±3.14	42.67±3.27	-0.966	0.334
visceral adipose tissue (L)	2.62±0.42	2.26±0.51	-3.118	0.002*

*Significant $p < 0.05$ (pre vs post)

assessments were classified as indicative of good QoL at 104.80 ± 11.92 and 117.93 ± 6.42 , respectively.

Table 3 presents the body composition data derived from WC measurement and BIA. A significant decrease in WC was observed with a p-value of 0.002. Regarding BIA results, there was a significant reduction in visceral adipose tissue with a p-value of 0.002. Furthermore, there was an increasing trend noted in muscle mass and body fat mass, although these changes were not statistically significant, with p-values of 0.059 and 0.334, respectively.

Discussion

The 8-week tele-exercise program resulted in significant improvements in both QoL and body composition among participants, particularly female older adults and during the COVID-19 pandemic. The effectiveness of multimodal exercise in female older adults has been corroborated by studies indicating an elevation in brain-derived neurotrophic factor (Vaughan et al., 2014), a biomarker of neurogenesis induced by physical exercise (Titus et al., 2021). Under the COVID-19 epidemic, mobile and online communication emerged as popular alternatives for older individuals to retain social contacts, engage in community events, relieve stress and loneliness (Greenwood-Hickman et al., 2021). Additionally, beyond the distancing period, tele-exercise programs have the potential to enhance physical activity levels in older adults (Chan et al., 2023). Moreover, a systematic review and meta-analysis have shown no significant difference between face-to-face and tele-exercise programs (Wicks et al., 2023). However, challenges such as effort and performance expectations, as well as underlying health conditions, remain prominent concerns (Turcotte et al., 2023).

According to the findings, it appears that the COVID-19 epidemic and the ensuing social distancing measures may have influenced the social factors. This is illustrated by the baseline categorization, which primarily identified the social relationships domain as having an average QoL, while the other domains were classified as having a good QoL (Fig. 2). These results are consistent with previous studies that have demonstrated improvements in QoL among older adults experiencing social isolation due to the COVID-19 pandemic (Solis-Navarro et al., 2022; Zengin Alpozgen et al., 2022). Moreover, significant differences in QoL have been observed among non-hospitalized post-COVID-19 individuals (Poon et al., 2024). However, a systematic review and meta-analysis investigating QoL prior to the COVID-19 pandemic did not identify significant differences in health-related QoL (Chan et al., 2021). This suggests that crises or vulnerable situations among older adults could potentially be mitigated by tele-exercise programs, thereby enhancing QoL.

Regarding body composition, the WC exhibited statistically significant improvements in this study, aligning

with previous findings in older adults (Kuhle et al., 2014) and individuals residing in long-term nursing homes (Arrieta et al., 2018). Furthermore, a systematic review and meta-analysis revealed that regular aerobic exercise led to a decrease in WC of approximately 3 cm among overweight or obese individuals (Armstrong et al., 2022). Comparatively, the WC reduction observed in this study was approximately 5 cm, despite only one-third of the participants being overweight and no cases of obesity present. In the context of BIA, this study revealed statistically significant enhancements in visceral adipose tissue and observed trends suggestive of potential increases in muscle mass and body fat mass over the 8-week intervention period (Table 3). According to Silva et al. (2022), their study juxtaposing tele-exercise alone and tele-exercise supplemented with nutritional coaching demonstrated that an 8-week tele-exercise regimen led to enhancements in exercise capacity. However, the intervention did not yield statistically significant changes in anthropometric or body composition-related parameters (Silva et al., 2022). This finding aligns with a previous systematic review and meta-analysis, which indicated improvements in muscle strength and performance, although not specifically in muscle mass (Escriche-Escuder et al., 2021). Additionally, a study investigating tele-exercise at home in older adults reported improvements in muscle mass after 12 weeks (Hong et al., 2017). Furthermore, various additional factors are associated with enhancing their overall state of well-being and aspects of QoL (Amorese & Ryan, 2022; Najafi et al., 2023). Moreover, a previous study demonstrated statistically significant enhancements in body composition after 15 weeks (Blasco-Lafarga et al., 2020), suggesting that extended or long-term tele-exercise interventions may yield distinct effects on body composition. Notably, low muscle mass has been linked to mortality in older adults, underscoring the potential benefit of tele-exercise in increasing muscle mass and attenuating mortality (de Santana et al., 2021).

The main limitations of this study include a small sample size, a lack of a control group, a short duration of the exercise intervention, and a focus exclusively on female older adults. Additionally, there may be concerns regarding the accuracy of the measurement tools utilized. Future research should aim to address these limitations by implementing randomized controlled trials with predefined protocols, longer intervention durations, inclusion of both genders, and the utilization of high-accuracy instruments for body composition assessment, such as dual-energy X-ray absorptiometry.

Conclusions

The 8-week tele-exercise program significantly improved QoL and body composition among female older adults. This intervention, particularly valuable during the COVID-19

pandemic, offers a practical solution for maintaining well-being while adhering to social distancing measures. Significant QoL enhancements, especially in social relationships and environmental domains, were observed, along with notable reductions in WC and visceral adipose tissue.

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Conflict of interest

The authors guarantee that no conflicts of interest exist.

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Оцінка ефективності програми дистанційних фізичних тренувань на показники якості життя та композиції тіла серед жінок похилого віку

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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., 2 рис., 37 джерела.

Мета дослідження. Дослідження спрямовано на оцінку впливу 8-тижневої програми дистанційних фізичних тренувань на якість життя (ЯЖ) та композицію тіла серед жінок похилого віку.

Матеріали та методи. У дослідженні з застосуванням квазі-експериментального дизайну взяли участь жінки віком 60 років і старше. Режим дистанційних фізичних тренувань складався з мультимодального підходу, сеанси тривалистю 30 хвилин проводилися тричі на тиждень протягом 8 тижнів. Програма охоплювала дихальні вправи, когнітивне тренування, вправи на рівновагу, силові тренування, розтяжку, аеробні танці та спів у караоке. Заняття проводилися за допомогою студії потокового мовлення в комп'ютерному центрі Убонратчатханського університету Раджабхат (Таїланд). Обладнання для проведення дистанційних фізичних тренувань було представлено наступними технічними засобами: 50-дюймовий LED-телевізор, програмне забезпечення OBS (Open Broadcaster Software) версії 30.1.2 для прямої трансляції та відеозапису, Google Meet для віртуальної взаємодії, бездротові портативні мікрофони, настільний комп'ютер і два 19-дюймові комп'ютерні монітори. Збір даних до та після інтервенції включав оцінку ЯЖ з використанням тайської скороченої версії опитувальника якості життя Всесвітньої організації охорони здоров'я та вимірювання показників композиції тіла (окружність талії та біоімпедансний аналіз; БІА).

Результати. Після впровадження інтервенції у формі дистанційних фізичних тренувань спостерігалось статистично значуще покращення як показників ЯЖ, так і композиції тіла. Показники ЯЖ продемонстрували значне поліпшення загального рівня ЯЖ ($p = 0,004$), а також сфери соціальних відносин ($p = 0,002$) та навколишнього середовища ($p = 0,001$). Що стосується показників композиції тіла, зменшення окружності талії та вісцеральної жирової тканини було статистично значущим ($p < 0,05$), тоді як м'язова маса та жирова маса тіла показали тенденцію до покращення, проте не були статистично значущими.

Висновки. Результати дослідження свідчать про перспективність проведення дистанційних тренувань з метою покращення якості життя та позитивного впливу на показники композиції тіла серед жінок похилого віку. Це підкреслює потенціал дистанційних тренувань як дієвого методу активності для осіб похилого віку, що дозволяє заощадити кошти та час, особливо в ситуаціях, коли транспортування може бути проблематичним.

Ключові слова: композиція тіла, особи похилого віку, якість життя, дистанційне фізичне тренування.

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Analyzing the Impact of VMBR Training on Table Tennis Players' Competence in Performing Alternate Counter and Forehand Drive Shots With Precision

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Abstract

Objectives. The study aimed to examine the impact of VMBR training on performing certain table tennis skills.

Materials and methods. A total of 50 male state table tennis players, aged between 17 and 23, were selected at the Inspire Table-Tennis Academy in Secunderabad, Telangana. These players were randomly divided into two groups: an experimental group and a control group, each comprising 25 participants. The experimental group underwent a 12-week VMBR training regimen three times a week, while the control group simply continued with their regular daily practice routines. Prior to the study and after the 12-week period, assessments were conducted using Pushpendra Purashwani's table tennis skill tests, specifically the alternate counter test and the forehand drive techniques on target test, developed in 2011. Statistical analyses involved the application of dependent t-tests and descriptive statistics to evaluate the outcomes.

Results. The experimental group's results indicated that both the alternate counter test and the forehand drive on target test had a marked positive effect on players of table tennis at the 0.01 significance level. The study contributes to our understanding of psychological elements' crucial role in influencing skill performance.

Conclusions. The research delves into how various psychological factors affect performance. Previous studies have demonstrated that visualization and images can significantly enhance performance. Table tennis players can overcome mental hurdles through a systematic psychological technique called rehearsal. This process involves mentally replaying an event in a step-by-step manner. The phases of Visual Motor Behavior Rehearsal (VMBR) that lead to better performance include technique refinement, error analysis and correction, preparation for competition, and enhancement of psychological aspects. Future studies could investigate VMBR's impact on specific table tennis skills or other sports in order to assist athletes in improving their psychological parameters and performance.

Keywords: VMBR Training, Table Tennis, Alternate Counter, Forehand Drive, Skill Performance, Psychological Factors.

Introduction

Being a top player is not simple. Players must have the right psychological traits in order to succeed in addition to having the necessary technical skills, physical capabilities, and physical fitness (Weinberg, 1998). According to Salazar et al., the most important element influencing how well athletic

talent's function is the mental state just before the skill is executed (Salazar et al., 1990). Psychological concepts like wisdom, feeling, inspiration, joy, zeal, and sportsmanship (Santosa & Soegiyanto, 2016).

Table tennis is essentially a straightforward game that involves striking the ball after it has landed on the table and constantly hitting, guiding, and positioning the ball to the opponent's table with the expectation that the opponent would be unable to return the ball (Carrasco, Pradas, Floría, Martínez, Herrero, & González Jurado, 2010). In this sport, the ball is constantly hit, directed, and placed on the

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opponent's table with the aim that the opponent will be unable to retrieve the ball (Mahendra, Nugroho & Junaidi, 2012). Mastering the technical aspects of the game is crucial for success in table tennis since they may determine a player's outcome. Table tennis as a racquet sport with a limited playing area that requires remarkable precision, speed, and self-assurance. High levels of anxiety might be detrimental to a player, since they could cause issues including trembling, poor coordination, and a loss of confidence (Schlager & Gross, 2011). A psychology skill-training course benefits national table tennis players' performance (Lim et al., 2018). In addition, technical, physical, and mental elements govern the game of table tennis. principles of technique, including movement, strokes, and grip. Physical attributes including strength, power, agility, balance, stamina, flexibility, and precision (Pluta et al., 2020). Most attacking techniques in Table Tennis are both the forehand and backhand drives (Maheshwari et al., 2023).

In modern world of competition cognitive intervention for players become a very essential and widely accepted by everyone. In performance psychology, visualization technique has been widely popularized and VMBR is a standardized training method contributes to improving athletic performance in a wide range of sports. It is a mental practice required the combined involvement of both relaxation and mental imagery. The VMBR makes it possible for the player to train under actual match circumstances. Anxiety and mental toughness are the most common concepts related to sports competitive environment and are widely discussed by the performers and the trainers. Anxiety disrupted the attention and worries about the performance in competitive situation (Sharma & Prasad, 2023).

Achievement in a competitive sporting environment, motivation is essential for achieving the highest degree of improved athletic performance (Sharma & Purashwani, 2021). In VMBR, an event is mentally recorded and then replayed piece by piece. Athletes can increase their performance through the VMBR phases of technique development, error analysis and correction, and completion preparation. the raising of psychological barriers and skill development (Chauhan et al., 2020). The premise of VMBR is that tasks may be made easier and more exact by employing imagination before they are carried out. It is also possible to use imagination that extends beyond what is practical for athletes to do both intellectually and physically. VMBR training helps athletes eliminate mistakes and improve performance by making them understand their motor controls defects through visualization exercises (Chaudhary, 2018). VMBR has been demonstrated to be one of the techniques that may speed up and improve the learning process for beginners. VMBR training and physical practice together improve skill performance and increase effectiveness (Sa'ari & Isa, 2018).

Relaxation training, visualization, and simulation of stressful environments are all components of VMBR. The foundation of the VMBR is the knowledge that past imagination is used to carry out the task; this makes the task easier and more accurate to perform and imagination of exercise make physical and intellectual achievement (Alrahamneh & Elbokai, 2011; Sharma & Prasad, 2023).

Therefore, Investigating the impact of VMBR training on certain table tennis skill executing skills was the goal

of this study. Through some earlier research on VMBR training, it was discovered that the intervention was carried out among athletes who mostly participated in team sports, and other closed skill games with pre-defined motions, like archery (Sa'ari & Isa, 2018). In racket sports, where the demands are so high and the emotions so high, the mental aspect of performance has a distinct role (Cece et al., 2020), and considering table tennis as a most popular racket sports on earth (Jiangzhou et al., 2020), The researchers planned to undertake VMBR training for table tennis players in order to investigate its impact on certain playing skills through skill performance capabilities.

Materials and Methods

Subjects

Fifty male table tennis players at the state level were chosen from the Inspire Table-Tennis Academy in Secunderabad, Telangana, to participate in the study. The individuals' ages varied from 17 to 23 years old. Two complete groups were developed for administration feasibility; one was an experimental group and the other was a control group. The participants had a minimum of three years of playing experience at the time the data was collected. Men who play state-level table tennis and are physically active were the only volunteers chosen at random for the study. The participants were asked to sign written consent forms before to data collection. The subjects received a thorough explanation of the study's objectives as well as an orientation to the training and skill testing.

Procedure

Alternate Counter Test and Forehand Drive on Target Test were the variables chosen for the study based on the literature that was accessible and the results of comparable research investigations. Pre-Test Post-Test Randomized group design was employed for this investigation.

In the experimental group, participants engaged in a structured regimen known as VMBR training over a period of twelve weeks. Sessions were scheduled from six thirty to seven twenty in the morning on Mondays, Wednesdays, and Fridays. The training commenced with a 6–10-minute warm-up, encompassing stretching and running exercises. Participants resumed their regular evening table tennis activities following the morning sessions.

The VMBR training protocol comprised three stages:

1. This initial stage spanned eight to ten minutes and involved progressively tensing and relaxing specific muscle groups, starting from the forehead and scalp, then moving to the neck and shoulders, upper chest, thighs, and concluding with the calves.

2. Lasting 8 to 10 minutes, this stage utilized a projector to deliver visual presentations on game-related topics like inspiration, talent, and strategy. Participants were then prompted to engage in visualization exercises, meticulously recreating mental images and focusing on every detail presented.

3. In this final stage, participants employed visualization techniques to link the content observed in the previous stage with their own abilities. They immersed themselves

in imagined scenarios, incorporating sensory experiences such as crowd noise, the encouragement of teammates, and the physical sensations associated with real game situations.

Contrarily, individuals in the control group solely participated in regular table tennis sessions without the additional VMBR training components.

Data Analysis

The tools used for conducting the skill test were scoresheet, pen, stopwatch, chalk marker, ball picker, table tennis racket, table tennis table and balls.

Alternate Counter Test: As shown in Figure 1, the participants were instructed to make the numbers of rallies with the controller for a period of 30 seconds after sufficient warming up and practice. A sufficient number of balls were in the controller's hand or pocket when the instruction to "Start" was given, allowing the rally to continue even if the ball was taken out of play. Two chances were given, maximum numbers of returns were counted by the researcher out of two chances of 30 seconds each (Purashwani, 2011).



Fig. 1. Player performing Alternate Counter Test

Forehand Drive on Target: As shown in Figure 2, the controller feed the ball and the subjects were asked to attack forehand drive with foot movement from left side of a particular half after playing back hand push from at the left corner of the table (in case of right-handed player). Enough trials were provided. Two chances comprising three attempts each were given. Score was given according to the bounce of the ball in the marked areas. The best of two chances (each comprising of three attempts) was counted as the score of the subjects (Purashwani, 2011).



Fig. 2. Player performing Forehand Drive on Target

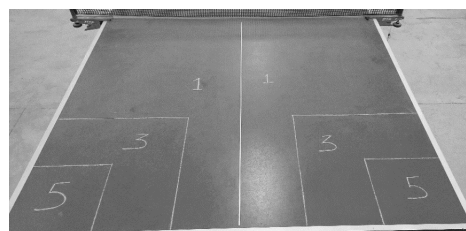


Fig. 3. Marking on the table for scoring as per Forehand Drive on Target

Statistical Analysis

The collected data were statistically analysed using IBM SPSS (version 26.0.0) software. The Shapiro-Wilk test for the parametric test was used to confirm the assumptions of data normality, and the data did not deviate from the assumptions (Das & Jhajharia, 2022). The Shapiro-Wilk test so revealed that the data had a normal distribution. When comparing the experimental and control groups, Levene's test identified homogeneity in the variances. The requirements of homogeneity were upheld; hence a parametric test was used to statistically analyse data both before to and during the experimental period from the control and experimental groups using a dependent t-test.

Results

Table 1 displayed descriptive data (mean and standard deviation) for the control group and the experimental group on a set of table tennis skill competencies before and after 12 weeks of training.

Table 1. Table tennis players' skill abilities are described using descriptive statistics (mean and standard deviation)

Table Tennis Skill Tests	Control Group		Experimental Group	
	Mean	Standard Deviation	Mean	Standard Deviation
1. Pre-Alternate Counter Test	25.00	2.19	26.76	2.27
2. Post-Alternate Counter Test	24.48	2.40	28.40	1.77
3. Pre-Forehand Drive on Target	06.24	1.85	06.60	2.16
4. Post-Forehand Drive on Target	06.72	1.45	08.44	1.38

Table 2. Table tennis players in the control and experimental groups were compared using a dependent sample t-test to measure their skill levels

Table Tennis Skill Tests	Control Group			Experimental Group		
	t- Value	p-Value (0.05)	Sig.	t- Value	p-Value (0.05)	Sig.
Alternate Counter Test	1.236	0.229	Not Sig.	4.389	0.000	Sig.
Forehand Drive on Target	1.423	0.168	Not Sig.	5.754	0.000	Sig.

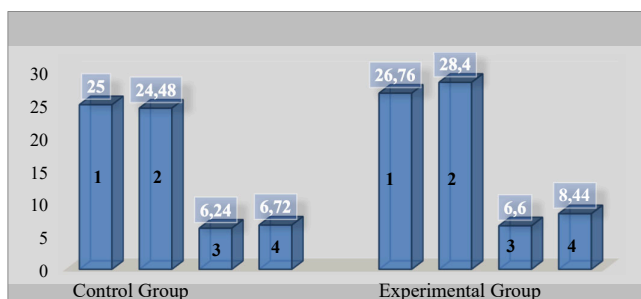


Fig. 4. Mean value of Table Tennis Skill Competencies

Table 2 showed the inferential statistics (dependent t-test) of the control group and experimental group before and after 12 weeks of training on a subset of table tennis skill competencies. At the 0.01 level of significance, the experimental group showed a significant effect on both the alternate counter test and the forehand drive on target.

Discussion

The aim of the research was to analyse the impact of a 12-week VMBR training programme on certain table tennis players' skill abilities. The findings show significant improvement of table tennis skill performing ability among those who actively participated in the VMBR training sessions, i.e., the experimental Group found significant effect at 0.01 level of significance for both alternate counter test and forehand drive on target test among table tennis players. The study helps us understand how crucial psychological elements are in influencing skill performance. Technique improvement, error analysis and repair, competition readiness, and enhanced playing abilities are all aspects of VMBR training that lead to better performance.

One open skill sport where it might be difficult to control a player's emotions is table tennis. In this activity, fear and doubtful thoughts can quickly rise. The ability to consistently perform at one's best in table tennis is among most difficult aspects of the sport. Self-assurance, positive thinking, and the ability to unwind and control emotions were shown to be the psychological factors that Table Tennis best mirrored (Martinent & Decret, 2015).

A research found that VMBR considerably reduced state anxiety and activation over time compared to controls. For all three karate performance metrics (skill, combos, and sparring), VMBR showed better levels of progress over time than controls. Results are examined in terms of the connection between arousal and performance as well as the value of customised practise and instruction when utilising cognitive intervention approaches (Seabourne et al., 1984).

A research looked into how self-administered VMBR training affected athletes' ability to execute. Results showed that the VMBR group showed much larger gains in athletic compared to the delayed-training control group's performance, which included 36 male and female collegiate athletes competing in 7 sports (Lohr & Scogin, 1998).

As for the results, novice archers shot score increased when comparing pre-test score 73.83 (9.806) and post-test score 81.83 (7.80) with $t_{(5)} = 4.619$, $p = 0.0057$. VMBR has been found to be an effective psychological aid in increasing sports performance. In the shooting test, the inexperienced archers likewise shown positive correlation with $r = 0.9085$, $p = 0.00$, and $R^2 = 0.8101$. This study came to the conclusion

that using images as a training tool really did increase beginner archers' shot accuracy (Sa'ari & Isa, 2018).

In contrast to the control group, which received 16 sessions of standard archery skill instruction, the experimental group endured 4 sessions of VMBR training. The physical practical group outperformed the VMBR group on the archery shooting skill after 4 weeks (4 days/week) of archery instruction, with a substantial difference being seen (Dachen, 2019).

It was clear that VMBR training and a composite bio-feedback intervention routine were sufficient to boost athletes' physical performance indices, particularly their agility. Less weariness was felt by the athletes in the VMBR group, and this, combined with other mood characteristics, predicted quicker agility (Soumendra, 2021).

In a study, it was investigated how imagery training affected skilled tennis players' ability to increase their motor performance when returning serves accurately. Results showed that the motor imagery intervention greatly increased the skillful players' accuracy of the service returns. Additionally, individuals considered to be excellent imagers considerably increased their directional accuracy and were less variable than those with lesser imaging ability after the 15 imagery sessions (Robin, Dominique, Toussaint, Blandin, Guillot, & Le-Her, 2007).

Thirty systematic, meta-analytic, and narrative reviews that (a) examined research involving the use of PST to athletes and (b) summarised the effects of PST treatments on sport performance, or a motor performance-based substitute for a sports activity, were included. 90% of evaluations came to the conclusion that PST treatments might improve performance (Lange-Smith, Cabot, Coffee, Gunnell, & Tod, 2023).

Limitations

In this research, we did not consider the anthropometric variables, which could affect the measured parameters. Namely, for highly overweighted category player may find difficulty in movement while playing alternate counter as it requires agility and precision. This study was conducted with 12 weeks of training, so, being inactive by any player in frequent sessions due to their personal thought of control could be taken and considered as the limitations of the study.

Conclusions

The study helps us comprehend the numerous psychological factors that influence performance. The visualization and images have been employed as a powerful aid for improving performance, according to earlier literature. Visual Motor Behaviour, while Table tennis players can overcome psychological obstacles by using a methodical psychological strategy called rehearsal. In VMBR training, an event is mentally filmed and then repeatedly played back step by step. The VMBR phases that lead to better performance are: technique improvement, error analysis & rectification, completion preparation, and improvement of psychological aspects. Using a mental movie, VMBR entails step-by-step reliving an event. In order to determine the impact of VMBR on playing ability or skill competency and use it in accordance with the needs of the athlete, future research could be conducted with more table tennis-related skill-related parameters or playing abilities on other sports. This would help an athlete improve psychological parameters and enhance performance.

Conflicts of interest

The authors declare no conflicts of interest.

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Аналіз впливу тренувань відпрацювання зорово-моторної реакції на компетентність гравців у настільний теніс у точному виконанні поперемінних контр- та прямих ударів праворуч

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

Реферат. Стаття: 6 с., 2 табл., 4 рис., 26 джерел.

Мета дослідження. Метою дослідження було вивчити вплив тренувань відпрацювання зорово-моторної реакції на виконання певних навичок гри в настільний теніс.

Матеріали та методи. В Академії настільного тенісу Inspire в Секундерабаді, штат Телангана, було відібрано 50 гравців чоловічої статі у віці від 17 до 23 років. Учасників дослідження було розподілено методом рандомізації на дві групи: експериментальну та контрольну, кожна з яких складалася з 25 осіб. Експериментальна група проходила 12-тижневу програму тренувань відпрацювання зорово-моторної реакції тричі на тиждень, тоді як контрольна група продовжувала дотримуватися звичайного режиму щоденних тренувань. До початку дослідження і після 12-тижневого періоду було проведено оцінювання результатів за допомогою тестів на володіння навичками настільного тенісу за методикою професора Пушпендри Пурашвані, зокрема, тестів на виконання техніки поперемінних контр- та прямих ударів праворуч по цілі, розроблених у 2011 році. Методи статистичного аналізу включали застосування t-критеріїв для залежних вибірок та описової статистики для оцінки результатів.

Результати. Результати експериментальної групи показали, що виконання обох тестів, а саме — поперемінних контр- та прямих ударів праворуч по цілі, мають виражений позитивний вплив на гравців у настільний теніс на рівні значущості 0,01. Це дослідження сприяє нашому розумінню вирішальної ролі психологічних елементів з точки зору впливу на результативність навичок.

Висновки. Дослідження поглиблює розуміння того, як різні психологічні фактори впливають на показники результативності. Попередні дослідження продемонстрували, що візуалізація та уявлення можуть значно підвищити результативність. Гравці в настільний теніс здатні долати психологічні бар'єри шляхом застосування систематичної психологічної техніки, яка називається відпрацюванням. Цей процес передбачає покрокове відтворення події на рівні мислення. До етапів відпрацювання зорово-моторної реакції (ВЗМР), які сприяють покращенню показників результативності, належать: вдосконалення техніки, аналіз та корекція помилок, підготовка до змагань, а також поліпшення психологічних аспектів. Майбутні дослідження можуть бути присвячені вивченню впливу ВЗМР на конкретні навички гри в настільний теніс або інші види спорту з метою допомогти спортсменам покращити свої психологічні параметри та результативність.

Ключові слова: тренування ВЗМР, настільний теніс, поперемінний контрудар, прямий удар праворуч, результативність навичок, психологічні фактори.

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Estimating the Total and Regional Body Fat of Physically Active Men Is Not Appropriate for Sedentary Men

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Abstract

Objectives. The reliability of predictive body fat equations remains unclear due to their inappropriate use across different subject cohorts and conditions. The objective of this study was to validate and cross-validate equations to predict total and regional body fat in young physically active males.

Materials and methods. Three hundred and five young male participants were divided into the following groups: active validation ($n = 165$), active cross-validation ($n = 70$), or sedentary cross-validation ones ($n = 70$). The study used a stratified random sampling based on weekly physical activity level. The total and regional body fat mass were measured using dual-energy X-ray absorptiometry (DEXA) after an overnight fast. Simultaneous measurements of height, body mass, skinfold thickness, body mass index, and body circumferences were taken. The total and regional body fat predictive equations were generated using multiple linear stepwise regression models. The coefficient of determination (R^2) and standard error of estimation (SEE) were calculated to examine the accuracy of the predictive equations. Furthermore, cross-validation groups were analysed.

Results. The percentage of total body fat, trunk fat, legs fat, arms fat, and body mass index of active cross-validation were found to be significantly lower than in the sedentary cross-validation groups. The total body fat percentage was highly associated with abdominal skinfold thickness ($r = 0.68-0.74$, $p < 0.001$), body mass index ($r = 0.55$, $p < 0.001$), and suprailiac skinfold thickness ($r = 0.67-0.71$, $p < 0.001$) in the active validation group. The predictive total and regional body fat equations of physically active men showed adjusted R^2 values ranging from 0.35 to 0.66, with standard error of estimation values between 2.74 to 4.35%. The standard error of estimation for the predictive percentage of total and regional body fat in the active cross-validation group was lower than in the sedentary cross-validation group.

Conclusions. The findings demonstrate that new predictive total and regional body fat equations can be used to accurately estimate body fat in healthy young active males under fast conditions.

Keywords: inactive men, young men, body composition, skinfold thickness, circumference.

Introduction

The body fat associated with cardiovascular diseases, diabetes, hypertension, and physical fitness (Chun, Suh, Byun, Park, & Shim, 2015; Ortega, Lavie, & Blair, 2016; Takeoka et al., 2016). Therefore, assessing body fat for monitoring and preventing health problems is essential. However, using an accurate instrument to measure body fat in the field can be expensive and inconvenient. Previous studies have shown that predictive equations for estimating

body fat in Western and Asian men have been developed (Ball, Cowan, Thyfault, & LaFontaine, 2014; Leahy, O'Neill, Sohun, Toomey, & Jakeman, 2013; Liu et al., 2015). It should be noted that most of the previous studies developed predictive total body fat equations. It has been reported that trunk fat mass is associated with cardiovascular diseases, arterial stiffness, and insulin resistance in men (Ganpule-Rao et al., 2013; Kouda et al., 2021; M. Lee et al., 2012). Therefore, it is important to assess not only total body fat but also regional fat mass. However, only a few studies developed predictive regional body fat equations from Caucasian men (Ritchie & Davidson, 2007; Scafoglieri et al., 2013). The validation of the predictive total and regional body fat equations developed

from Western and Asian men applied to Thai men is still unclear and needs to be examined. Conversely, equations for estimating total and regional body fat need to be developed and cross-validated for specific populations.

They correlate the percentage of body fat with ethnic differences (Davidson et al., 2011; Jensen et al., 2019; Stults-Kolehmainen et al., 2013), as demonstrated by its under-estimation and over-estimation when validating predictive body fat equations between Western and Asian men (Davidson et al., 2011; Hastuti, Kagawa, Byrne, & Hills, 2013). The predictive body fat equation developed from the Western population might not be appropriate for application to the Asian population. It has been demonstrated that body fat values are not consistent between young, middle-aged, and older-aged males (Coin et al., 2012; Ihasz, Finn, Lepes, Halasi, & Szabo, 2015; Larsson et al., 2015). Previous studies have shown that lower body fat was observed by active men compared to sedentary counterparts (Kyle, Morabia, Schutz, & Pichard, 2004; Scheers, Philippaerts, & Lefevre, 2013). Additionally, there is a relationship between sedentary time and visceral fat in men (Henson et al., 2015). Therefore, the predictive body fat equation developed by active men might not be suitable to apply to sedentary men. Additionally, the amount of food and water consumed before the assessment of body fat contributed to varying fat mass in different methods (Kerr, Slater, & Byrne, 2017). Consequently, the validity of predictive total and regional body fat equations might have been associated with participants' fasted or non-fasted states.

It has been demonstrated that body fat mass is associated with differences in ethnicity, age, food intake, and physical activity level (Coin et al., 2012; Jensen et al., 2019; Scheers et al., 2013). However, many previous studies have derived body fat equations using participants from across a range of ages, without providing food consumption status, and/or classification of the physical activity level (Leahy et al., 2013; D. H. Lee et al., 2017; Pongchaiyakul et al., 2005). Therefore, non-specific predictive body fat equations, which have been developed from the general male population, may be inaccurate in estimating body fat under certain conditions. Consequently, specific predictive total and regional body fat equations that represent males of a particular ethnicity, age range, and physical activity level, who have assessments taken in a fasted state, are required to provide a better estimation of total body and regional fat mass. Consequently, the objective of the present study was to validate and cross-validate predicted total body and regional fat equations of active young Thai males under fasted conditions.

Materials and Methods

Participants

Three hundred and five young Thai male participants provided their written informed consent to take part in this study, which was approved by the Institutional Research Ethics Committee. To separate the participants into sedentary and active groups, the participants were asked to complete PAR-Q (Physical Activity Readiness Questionnaire) and physical activity questionnaires. In the active group, participants performed regular physical activity for a duration of greater than 50 minutes and greater

than 3 times per week. In the sedentary group, participants performed physical activity for less than 30 minutes and less than 3 times per week. The participants' resting heart rate (Omron, Japan) and blood pressure (Omron, Japan) were also measured.

Study Design

They randomly divided participants into three groups; validation, cross-validation with an active group, and cross-validation with a sedentary group. Anthropometry and body fat mass were assessed after an overnight fast. Estimated total and regional fat mass equations were developed. The difference in fat mass between the predictive equations and the reference method was analyzed in the sedentary and active groups.

Assessment of the Reference Method

They performed a total body scan after an overnight fast using dual-energy X-ray absorptiometry (DEXA, Hologic Inc, United States) as the reference method. The procedure of the total body scan followed the manufacturers' guidelines. The total percentage of fat mass, and the regional fat mass of the trunk, arms, and legs, were recorded and analyzed.

Assessment of Anthropometry

Anthropometry measurements included height, body mass, and body circumferences, which were recorded after an overnight fast. In addition, the skinfold thickness of the biceps, triceps, vertical abdominal, transverse abdominal, suprailiac, chest, subscapular, mid-thigh, and medial-calf (Lange skinfold caliper, United States), were taken on both sides of the body (Lohman, Roche, & Martorell, 1991). Body mass index (BMI) was calculated using the ratio between body mass in kilograms and height in square meters. Chest, waist, abdominal, hip, arm, forearm, upper thigh, and calf circumferences were measured using a measuring tape (Swain et al., 2014). Waist and hip measurements were taken at the narrowest part of the waist, and the widest part of the hip, respectively, and the waist-to-hip ratio was subsequently determined.

Statistical Analysis

All data were analyzed using statistical software (SPSS Statistics for Windows, Version 22, Armonk, NY: IBM Corp). The sample size was calculated using multiple regression analysis (Dupont & Plummer, 1998). Based on a previous study (Ohta et al., 2017), the population of the regression equation was 150 men to provide an R^2 value between 0.867 to 0.932, and the standard error of estimation (SEE) between 0.18 and 1.44 kg (5.9-8.7%). The cross-validation sample size was calculated using a Bland-Altman plot (Bland & Altman, 2010) to determine the difference between the validation and cross-validation groups.

Paired t-tests were used to analyze differences between groups, with the relationship between parameters, were examined using the Pearson product-moment test. They analyzed the accuracy of the predictive body fat equations using the correlation coefficient (R^2) and the standard error

of estimation (SEE). They developed predictive equations of total and regional body fat mass using multiple linear stepwise regression models, derived from (1) body mass, skinfold thickness, and circumferences, and (2) body mass index and circumferences, respectively. The standard error of estimation was used to analyze the difference in fat mass between the predictive equations and the reference method. The waist and hip ratio was calculated from body circumferences. Data were presented as means \pm standard deviation and the α level of statistical significance was accepted at $p < 0.05$.

Results

Participant Characteristics

The participants' age, body mass, height, body mass index, waist-to-hip ratio, resting heart rate, resting blood pressure, and percentage of body fat, are shown in Table 1. There were no statistical differences in age, height, or blood pressure between the three groups ($p > 0.05$). The resting heart rate, body mass, body mass index, the percentage of total body fat, legs fat, and arms fat in the sedentary group were significantly higher compared to the active group ($p < 0.05$). There were no significant differences in age, height, waist-to-hip ratio, and blood pressure between the active and sedentary groups ($p > 0.05$; Table 1).

Relationship Between Variables

Total body fat mass was significantly correlated with body mass index, body mass, abdominal circumference, waist circumference, transverse abdominal skinfold thickness, vertical abdominal skinfold thickness, left suprailiac skinfold thickness, and suprailiac skinfold thickness ($p < 0.001$; Table 2).

The highly correlated total percentage of body fat with body mass index, transverse abdominal skinfold thickness, vertical abdominal skinfold thickness, and suprailiac skinfold thickness ($p < 0.001$; Table 2).

Table 2. The correlation (r) between total body fat mass, total percentage of body fat, and trunk fat mass with body mass index, body mass, abdominal circumference, waist circumference, and skinfold thickness (SF) in the validation active group

r	Total body fat mass	Total percentage of body fat	Trunk fat mass
Body mass index (kg/m^2)	0.71*	0.55*	0.71*
Body mass (kg)	0.67*	0.43*	0.66*
Abdominal circumference (cm)	0.57*	0.46*	0.55*
Waist circumference (cm)	0.56*	0.41*	0.55*
Left transverse abdominal SF (mm)	0.70*	0.74*	0.71*
Right transverse abdominal SF (mm)	0.55*	0.70*	0.54*
Left vertical abdominal SF (mm)	0.67*	0.68*	0.66*
Right vertical abdominal SF (mm)	0.67*	0.70*	0.67*
Left suprailiac SF (mm)	0.68*	0.67*	0.68*
Right suprailiac SF (mm)	0.69*	0.71*	0.69*

* Significantly associated between parameters ($p < 0.001$)

They significantly associated trunk fat mass with body mass index, body mass, waist circumference, abdominal circumference, transverse abdominal skinfold thickness, suprailiac skinfold thickness, and vertical abdominal skinfold thickness ($p < 0.001$; Table 2).

Predictive Body Fat Equations

Multiple linear stepwise regression revealed the predictive equations of percent body fat derived from; (1) body mass, body mass index, and circumferences,

Table 1. Participant characteristics of validation active group, cross-validation active and sedentary groups (mean \pm SD)

Indicators	Validation active group (n=165)	Cross-validation active group (n=70)	Cross-validation sedentary group (n=70)
Age (years)	20.00 \pm 1.0	19.00 \pm 1.09	20.00 \pm 1.26
Body mass (kg)	66.00 \pm 8.51	62.00 \pm 7.63	70.00 \pm 9.53*
Height (cm)	173.00 \pm 6.17	164.00 \pm 5.31	173.00 \pm 5.82
Body mass index (kg/m^2)	22.00 \pm 2.30	21.00 \pm 2.36	23.00 \pm 2.46*
Waist / Hip ratio	0.80 \pm 0.07	0.82 \pm 0.08	0.80 \pm 0.05
Systolic blood pressure (mmHg)	115.00 \pm 16.21	114.00 \pm 13.92	114.00 \pm 19.82
Diastolic blood pressure (mmHg)	71.00 \pm 15.09	71.00 \pm 13.96	75.00 \pm 14.74
Resting heart rate (beat/min)	68.00 \pm 12.00	66.00 \pm 12.13	71.00 \pm 10.77*
Total body fat (%)	15.00 \pm 4.88	15.00 \pm 5.25	24.00 \pm 6.36*
Trunk fat (%)	18.00 \pm 5.94	18.00 \pm 6.43	29.00 \pm 7.58*
Right leg fat (%)	15.00 \pm 4.86	14.00 \pm 5.09	23.00 \pm 5.95*
Left leg fat (%)	15.00 \pm 4.86	14.00 \pm 5.07	23.00 \pm 5.95*
Right arm fat (%)	9.00 \pm 3.64	8.00 \pm 3.96	16.00 \pm 6.09*
Left arm fat (%)	9.00 \pm 3.66	8.00 \pm 3.95	16.00 \pm 6.10*

* Significant difference between cross-validation active and sedentary groups ($p < 0.05$)

and (2) skinfold thickness and circumferences. Predictive equations of percent body fat exhibited adjusted R² values ranging between 0.35 to 0.66, with standard error of estimation (SEE) ranging between 2.74 to 4.85%. The percentage of total body fat, trunk fat, legs fat, and arms fat predictive equations are shown in Table 3.

Total and trunk fat mass predictive equations revealed adjusted R² values between 0.77 and 0.78 with a standard error of estimation between 1.09 and 1.93 kg.

Standard Error of Estimation

The standard error of estimation of equations for the percentage of total body fat in the sedentary cross-validation group (3.83-5.04%) was higher compared to the active cross-validation group (1.88 to 4.21%). In the active group, the standard error of estimation for the percentage fat equations in the active cross-validation of the trunk, legs, and arms, ranged between 2.56 to 4.21%, while in the sedentary group, the values ranged between 3.95 to 4.56%. The standard error of estimation for the percentage of total body fat, trunk fat, leg fat, and arm fat are presented in Table 3.

The standard error of estimation in the active cross-validation group for total and trunk fat mass in the sedentary group (1.67-3.84 kg) was lower compared to the active cross-validation group (2.09-3.82 kg).

Discussion

The percentage of total body fat and regional fat in the active men was significantly lower compared to the sedentary men. In the present study, we generated predictive equations for total and regional body fat using dual-energy X-ray absorptiometry as the reference method. The low standard error of estimation demonstrated the accuracy of the equations when applied to active men. Predictive body fat equations derived under fasted conditions from body mass, body mass index, circumferences, and skinfold thickness, may estimate the percentage of total and regional body fat in young Thai men who perform regular exercise.

Muscle mass and body fat mass influence and reflect physical performance (Drey et al., 2016; Guiraudou et al., 2015; Rodriguez, de la Rosa, Flores, Zuleta, & Briceno, 2012), with physical activity associated with body fat (da Silva et al., 2019; Scheers et al., 2013; Suminski, Patterson, Perkett, Heinrich, & Poston, 2019). Consistent with previous findings (Tarnus & Bourdon, 2006), we observed lower levels of body fat in the active compared to the sedentary group. In the present study, the percentage total and regional body fat predictive equations, which were developed from active participants, provided a lower standard error of estimation when applied to active men. This led to an underestimation of body fat when the equations were applied to the sedentary participants. In contrast to our findings, previous studies

Table 3. The predictive equations for the percentage of total body fat, trunk, legs, and arms are derived from skinfold thickness (SF), body mass index (BMI), and circumferences

%Fat	Equations	Adjusted R ²	SEE1	SEE2	SEE3
Total	$(0.313 \times \text{Left transverse abdominal SF}) + (0.512 \times \text{BMI}) - (0.133 \times \text{Left mid-thigh SF}) + (0.160 \times \text{Rt. suprailiac SF}) + (0.133 \times \text{Left triceps SF}) - (0.198 \times \text{Right biceps SF}) - 2.817$	0.66	2.85	2.17	5.04
Total	$(0.305 \times \text{Left transverse abdominal SF}) + (0.547 \times \text{BMI}) - (0.191 \times \text{Left mid-thigh SF}) + (0.152 \times \text{Right suprailiac SF}) + (0.103 \times \text{Left triceps SF}) - 3.519$	0.65	2.90	1.88	4.58
Total	$(\text{BMI} \times 1.015) + (\text{Abdominal circumference} \times 0.177) - (\text{Chest circumference} \times 0.269) - (\text{Left lower arm circumference} \times 0.854) + (\text{Waist circumference} \times 0.300) + (\text{Right upper arm circumference} \times 0.375) - 8.736$	0.45	3.63	3.37	3.83
Trunk	$(\text{BMI} \times 1.279) + (\text{Abdominal circumference} \times 0.183) - (\text{Left lower arm circumference} \times 1.178) + (\text{Right upper arm circumference} \times 0.483) - (\text{Chest circumference} \times 0.298) + (\text{Waist circumference} \times 0.392) - 11.322$	0.47	4.35	4.21	4.56
Right leg	$(\text{BMI} \times 0.970) + (\text{Abdominal circumference} \times 0.308) - (\text{Chest circumference} \times 0.239) - 9.080$	0.35	3.92	3.31	4.06
Left leg	$(\text{BMI} \times 0.969) + (\text{Abdominal circumference} \times 0.308) - (\text{Chest circumference} \times 0.239) - 9.093$	0.35	3.92	3.30	4.06
Right arm	$(\text{BMI} \times 0.714) + (\text{Abdominal circumference} \times 0.131) - (\text{Chest circumference} \times 0.196) - (\text{Left lower arm circumference} \times 0.608) + (\text{Waist circumference} \times 0.228) + (\text{Right upper arm circumference} \times 0.281) - 9.636$	0.43	2.74	2.58	3.95
Left arm	$(\text{BMI} \times 0.718) + (\text{Abdominal circumference} \times 0.130) - (\text{Chest circumference} \times 0.195) - (\text{Left lower arm circumference} \times 0.620) + (\text{Waist circumference} \times 0.232) + (\text{Right upper arm circumference} \times 0.284) - 9.815$	0.44	2.76	2.56	3.97

SEE1: Standard error of estimation for the validation group; SEE2: Standard error of estimation for cross-validation in the active group; SEE3: Standard error of estimation for cross-validation in the sedentary group

(Davidson et al., 2011; Henry, Ponnalagu, Bi, & Tan, 2018; Pongchaiyakul et al., 2005) have shown predictive total body fat equations to both underestimate and overestimate body fat compared to reference method when applied to sedentary and active men. Consequently, estimating body fat equations derived from a combination of sedentary and active participants may not be suitably applied to active young men. Our findings also imply that it's necessary to create more accurate body fat equations for sedentary males.

In the present study, we observed a lower percentage of fat located in the trunk, arms, and legs of active men compared to sedentary participants. This is consistent with previous studies presented that there is an association between visceral fat and sedentary time (Henson et al., 2015). Previous studies have developed equations to estimate body fat in the trunk, legs, and arms (Ritchie & Davidson, 2007; Scafoglieri et al., 2013). However, our present findings suggest that there was an underestimate of these predictive percentages of trunk fat equations in a previous study (Scafoglieri et al., 2013) compared to our predicted equations and reference method of both active and sedentary men. Compared to active and sedentary men in the present study, we observed a lower percentage of trunk fat and higher legs fat in the previous study (Scafoglieri et al., 2013). Therefore, there was a difference in fat distribution between the participants of this study and the previous study (Scafoglieri et al., 2013). The accuracy of predicted regional fat equations may be associated with body fat distribution which is a difference between the previous study and this study.

Skinfold thickness, in particular abdominal skinfold thickness, had the highest correlation with total body fat when measured using the reference method. Indeed, skinfold thickness has been highly correlated with body fat using dual-energy X-ray absorptiometry (Burns, Fu, & Constantino, 2019). In the present study, predictive body fat equations derived from skinfold thickness combined with body circumferences provided greater precision and accuracy than those derived from body circumferences combined with body mass index. In comparison with body mass index, estimating body fat from skinfold thickness provided a low standard error of estimation and a high mean body fat percentage compared with the 4-compartment model (Nickerson et al., 2018). In addition, we also observed visceral adipose tissue to be highly correlated with total body fat. However, it should be noted that measuring skinfold thickness might not be accessible or appropriate for many practitioners who need to assess body composition.

It has generated several predictive equations for estimating the percentage of body fat using Western populations (Durnin & Womersley, 1974; Jackson & Pollock, 1978). However, there are differences in the percentage of body fat, fat distribution, and skinfold thickness, between the Asian and Caucasian populations (Davidson et al., 2011; Stults-Kolehmainen et al., 2013). These morphological differences likely explain the higher body fat values obtained from equations derived from Asian men (Davidson et al., 2011; Henry et al., 2018) than presently observed. Therefore, it is apparent that ethnic differences exist, implying that predicted body fat equations generated by Western men may not provide accurate results. However, the percentage of body fat determined from equations created by the Thai population, aged between 20 and 84 years old (Pongchaiyakul et al., 2005),

was lower than the dual-energy X-ray absorptiometry reference method used in the present study. Therefore, it is likely that the precision of predictive body fat equations is largely determined by both ethnicity and age differences.

Previous studies have estimated body fat using equations based on data from young, middle, and older male participants (Henry et al., 2018; Leahy et al., 2013; Pongchaiyakul et al., 2005). Compared to the dual-energy X-ray absorptiometry reference method in our investigation, these studies have either overestimated (Henry et al., 2018) or underestimated (Pongchaiyakul et al., 2005) predictive total body fat values. Therefore, it is likely that the percentage of body fat equations, which are derived across broad age ranges, is not appropriate for predicting the body fat of young men. A previous study derived a body fat mass equation using Chilean males aged between 17 and 27 years (Campos, Carrillo, Fierro, Albornoz, & Cossio-Bolanos, 2018). Nevertheless, the standard error of estimation for estimated body fat mass was higher than we calculated.

Previously developed predictive body fat equations have not defined the participants' feeding or fasting state (Campos et al., 2018; Davidson et al., 2011). This is important to consider, as they associate body fat mass with the magnitude of food consumption before body fat assessment (Kerr et al., 2017). For this reason, predictive body fat equations developed from participants who were in a fed or mixed-state (Fast and fed state) of food consumption may be inaccurate in assessing body fat in overnight fasted participants. Whilst a predictive body fat equation has previously been developed using fasted-state participants, it formulated the equation from across a broad age range (Henry et al., 2018). This likely explains the overestimation in the percentage of body fat compared with the reference method used in this study.

Conclusions

The percentage of total body fat, leg fat, and arm fat in the active men was significantly lower compared to the sedentary men. Predictive body fat equations derived from skinfold thickness combined with circumference provided more precision and accuracy than those derived from circumference combined with body mass index. They may use our newly predicted fat equations to accurately estimate body fat mass in healthy active young Asian men who perform regular exercise. We developed a new predictive body fat equation, which could apply to active young men assessed in a fasting state. Our use of a validated and cross-validated method showed that whilst our equations could be accurately applied to young men who perform regular exercise, they were not suitable to be used with sedentary men. Therefore, the findings of this study emphasize the need to develop specific body fat equations to provide precise measurements of body fat across different ages, ethnicities, and physical activity levels.

Conflict of interest

The author declares that there is no conflict of interest.

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Оцінка загальної та регіональної жирової маси тіла фізично активних чоловіків — не є доцільною для чоловіків з гіподинамією

СупапORN Силалертдеткул^{1ABCDEF}

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

Реферат. Стаття: 8 с., 3 табл., 41 джерело.

Мета дослідження. Достовірність прогностичних рівнянь для визначення вмісту жиру в організмі залишається незрозумілою через їх неналежне використання в різних когортах учасників дослідження та умовах. Метою цього дослідження була валідація та застосування методу перехресного затвердження (також відомо як перехресна валідація) рівнянь для прогнозування загального та регіонального вмісту жиру в організмі молодих фізично активних чоловіків.

Матеріали та методи. У дослідженні взяли участь триста п'ять молодих чоловіків, які були розподілені на такі групи: активна валідація ($n = 165$), перехресна валідація з високою фізичною активністю ($n = 70$) або перехресна валідація з низькою фізичною активністю ($n = 70$). Дослідження було проведено із застосуванням стратифікованої випадкової вибірки, що базувалася на щотижневому рівні фізичної активності. Загальна та регіональна жирова маса тіла вимірювалася за допомогою методу двоенергетичної рентгенівської абсорбціометрії (ДРА) після нічного голодування. Також проведено одночасні вимірювання показників зросту, маси тіла, товщини шкірної складки, індексу маси тіла та окружності тіла. Прогностичні рівняння загального та регіонального вмісту жиру в організмі були отримані шляхом застосування моделей множинної лінійної ступеневої регресії. З метою перевірки точності прогностичних рівнянь було розраховано коефіцієнт детермінації (R^2) і стандартна похибка оцінки (SEE). Крім того, проаналізовано групи перехресного затвердження.

Результати. Встановлено, що відсоток жирової маси тіла, жирових відкладень на тулубі, ногах, руках та індекс маси тіла в групі перехресної валідації з високою фізичною активністю був значно нижчим, ніж в групі перехресної валідації з низькою фізичною активністю. Показник відсотка загальної жирової маси тіла був тісно пов'язаний з товщиною шкірної складки черевної порожнини ($r = 0,68-0,74$, $p < 0,001$), індексом маси тіла ($r = 0,55$, $p < 0,001$) та товщиною шкірної складки над клубовою ділянкою ($r = 0,67-0,71$, $p < 0,001$) в групі активної валідації. Прогностичні рівняння загальної та регіональної жирової маси тіла фізично активних чоловіків показали скориговані значення коефіцієнта детермінації R^2 в діапазоні від 0,35 до 0,66, зі стандартною похибкою оцінки показників у межах від 2,74 до 4,35%. У досліджуваній групі перехресної валідації з високою фізичною активністю спостерігалися нижчі показники стандартної похибки оцінки прогнозованого відсотка загальної та регіональної жирової маси тіла, ніж у групі перехресної валідації з низькою фізичною активністю.

Висновки. Результати дослідження демонструють, що нові прогностичні рівняння загальної та регіональної жирової маси тіла можна використовувати для визначення точної оцінки жирової маси тіла у здорових молодих активних чоловіків в умовах підвищеної фізичної активності.

Ключові слова: чоловіки з низькою фізичною активністю, молоді чоловіки, композиція тіла, товщина шкірної складки, окружність.

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Adapting the Motivation Scale for Participation in Physical Activity

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Abstract

Objectives. This study aimed to adapt the Motivation Scale for Participation in Physical Activity (MSPPA), originally developed by Demir and Cicioğlu, (2018) in Turkish, into English. The objective was to provide a reliable and valid tool for assessing motivation for physical activity in English-speaking populations.

Materials and methods. The adaptation process involved two phases. Firstly, the MSPPA was translated from Turkish to English, back-translated, and reviewed by experts in sports science and translation. Secondly, data were collected from 224 school students in the Malappuram district, Kerala, India. The collected data were subjected to Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) to validate the scale's factors. The reliability and construct validity were assessed using appropriate statistical methods.

Results. The analysis of the collected data revealed three factors in the adapted MSPPA: "Individual Causes", "Environmental Reasons", and "Causelessness", corresponding to intrinsic motivation, extrinsic motivation, and amotivation, respectively. The factors identified through EFA were confirmed via CFA. The scale demonstrated reliability and construct validity in assessing motivation for physical activity in English-speaking populations.

Conclusions. The adapted MSPPA was found to provide a reliable and valid instrument for assessing motivation for participation in physical activity among English-speaking individuals. This adaptation has facilitated cross-cultural research and interventions aimed at promoting physical activity and its associated benefits.

Keywords: motivation, physical activity, adaptation, exploratory factor analysis (EFA), confirmatory factor analysis (CFA).

Introduction

Physical activity is an important component that supports physical, emotional, social, motor, and mental development, and provides energy balance and healthy life through the activation of the human body. With participation in physical activity, human beings can increase their quality of life as well as take important steps to protect themselves from diseases (Demir & Cicioğlu, 2018). World Health Organization (WHO) defines physical activity as any body movement produced by skeletal muscle that requires energy expenditure including activities undertaken while working, playing carrying out household chores, traveling, and engaging in recreational pursuits (Physical Activity, 2019). Generally,

physical activity means any movement of the body that uses energy. But in this study physical activity means those activities which are planned, structured, and repetitive, and aim to develop and maintain components of physical fitness. Example walking, running, jumping, bicycling, playing games etc.

Regular and adequate levels of physical activity strengthen the bones and muscles, maintain a healthy body weight, lose excess body weight, reduce cardiovascular disease, diabetes, and some cancers, and increase chances of living longer and wellness (Ruegsegger & Booth, 2017). Also provides a healthier state of mind such as reducing hypertension, blocking negative thoughts, improving sleep patterns, reducing the risk of depression having fun and self-confidence, forgetting daily problems, and improving the structure and function of the brain. Physical activity improves not only refreshment and health but also improve social health. Physical activity connects people of society. It makes someone a socially responsible person.

An individual engages in physical activity for several reasons. Sometimes they are very pleased and interested in participating in physical activity and they consider physical activity as a hobby. On the other hand, compelling prompts from others such as parents, teachers, coaches, and friends and getting rewards and punishment may lead to participation in physical activity. So it can be said that different types of support lead an individual to participate in physical activity. Generally, this support may be known as motivation (Kajlas-Tilga et al., 2020). Motivation has an immense effect on learning. Motivation is the power that allows someone to act in the direction of a particular goal (Asmara Indahingwati et al., 2019). The motivation is like determining results such as productivity, performance and endurance (Paais & Patiruhu, 2020). So motivation is a force that includes or arouses a person's interest in learning the activity. This force may come from an inner urge or may be external pulls. Based on the forces motivation can be classified into Intrinsic and extrinsic motivation and sometimes motivation is absent.

According to the self-determination theory of motivation (Deci & Ryan 1985), motivation consists of three sub-dimensions that are, Intrinsic-motivation, Extrinsic-motivation, and Amotivation. Intrinsic motivation; is to do an activity for itself and because of the pleasure and happiness of participation (Tenenbaum & Eklund, 2007). People are motivated to participate in physical activity because of internal factors (such as enjoyment or skill development and mastery) and external factors (such as rewards, improved health, good looks) (Moradi et al., 2020). Inherent interest compels an individual to initiate and maintain the activity, it is said that he/she is intrinsically motivated. Here person participates in a physical activity for their own sake and participates for the enjoyment and satisfaction he/she derives from the activity itself. Whereas in extrinsic motivation environmental causes are the reason that enables the person to take action to realize the activity or purpose he/she will perform by being affected by environmental factors (Tekkursum Demir and Cicioğlu, 2018). Here individuals initiate and endure an activity as a result of external pulls, attraction, forces, incentives etc. When an individual participates due to some other goals or rewards, it can be extrinsic motivation. The concept of Amotivation describes people's lack of intentionality and motivation that is, to describe the extent to which they are passive, ineffective, or without purpose concerning any given set of potential actions (Deci & Ryan, 1985).

This study, it is aimed to adapt the the Motivation Scale for Participation in Physical Activity (MSPPA) developed by Demir and Cicioğlu (2018) in Turkish into English. The English language is intentionally selected. Because, in the scientific area, English is one of the most commonly used languages. This way, other cultures can use the scale by translating from English to the original language of other researchers.

Materials and Methods

Study Participants

A total of 224 school students from Malappuram district, Kerala participated in this study. The age ranged from 13 to 17 years old, with an average age of 15.01 years old ($SD = 1.17$) in the valid questionnaire. There were 119 males (53.12%) and 105 females (46.88%). Data collection proceeded only

subsequent to obtaining parental permission. The authors declare that they strictly adhered to the APA guidelines on ethical research practices.

Data Collection Tool

This study, it is aimed to adapt the scale developed by Demir and Cicioğlu, (2018) in Turkish to English. The scale consists of 16 items and 3 factors and explains 54.69 % of the total variance. The first factor consists of 6 items; under this factor, 6 items are related to intrinsic motivation. The second factor also has 6 items and this factor covers extrinsic motivation. The third factor contains 4 items related to Amotivation.

Procedures

The scale was translated into English. During the process of translating this scale from Turkish to English, the back translation technique was employed. Three independent translators were involved in the translation process. The first step was to translate the scale from Turkish to English. Then, by considering the similarities and differences in the translated forms, a single form was created. This form was then translated back from English to Turkish by another translator. Finally, the English and Turkish forms were reviewed and approved by three experts in the field of sports sciences, and a translator. The translated scale has 16 item and three factors. The first factor consists of 6 items and labeled as 'Individual Causes'. Under this factor, 6 items are related to intrinsic motivation. The second factor also has 6 items and is called 'Environmental Reasons'. This factor covers extrinsic motivation. The third factor containing 4 items is called Causelessness. Items under this factor are related to Amotivation. In this 5-point scale, the items are listed as "Strongly Disagree", "Disagree", "Moderately Agree", "Agree" and "Strongly Agree". It is rated as 1, 2, 3, 4, and 5. Inverse items should be coded as 5, 4, 3, 2 and 1. Since only item 6 contains negative expression in the scale, it should be reversed. Their scores from MSPPA indicate that they have the motivation to participate in physical activity, 1-16 very low, 17-32 low, 33-48 medium, 49- 64 high, and 65-80 very high. Then the translated scale was employed to school students.

Statistical Analysis

The scale is used to measure the dimension of MSPPA is validated in two steps. Firstly, an Exploratory Factor Analysis (EFA) and then Confirmatory Factor Analysis (CFA) are performed in total 224 samples. Here, the factors derived from Exploratory Factor Analysis (EFA) were confirmed by applying Confirmatory Factor Analysis (CFA) and then check its reliability and construct validity by using appropriate methods. It is applied to assess the quality of the factor structure by statistically testing the significance of the overall model, as well as relationships among items and scales based on sample data.

Results

Exploratory Factor Analysis (EFA) – MSPPA

Exploratory Factor Analysis (EFA) requires certain assumptions to be fulfilled namely correlation and sampling

adequacy. The KMO Bartlett test include Bartlett test of sphericity that measures the multivariate normality of variables in addition to analyzing whether the correlation matrix is an identity matrix. The Kaiser-Meyer-Olkin (KMO) test can measure whether the sample size is adequate for conducting factor analysis (George & Paul Mallery, 1999). Cronbach's alpha Co-efficient is used to test the reliability. A Cronbach's alpha value of greater than or equal to 0.7 is considered acceptable for the factor to be reliable (Hair et. al. 2010). Exploratory Factor Analysis (EFA) using Principal Component Method (PCM) is employed for analyzing the factor structure and correlation between 16 statements included in the scale for measuring the MSPPA.

A Principal Component Analysis is conducted on the 16 statements with Varimax Rotation. The Kaiser-Meyer-Olkin (KMO) measure verifies the sample adequacy for the analysis, KMO value is 0.882 which is above the recommended limit of 0.70. Bartlett's test is another indication of the

strength of the relationship among variables. Bartlett's Test of Sphericity Chi-Square = 1837.254, $p < 0.01$ indicates that the correlation between the items is sufficiently large for Principal Component Analysis (PCA).

An initial analysis is run to obtain Eigen Values for each component in the data. Three components have eigen values over and above Kaiser's criterion of 1 and in combination explained 65.511% of the variance. The result is presented table 2.

The result of Exploratory Factor Analysis (EFA) shows that the solution is based on 3 constructs and all items are loading on their own factors. The three-factor solution is explaining 65.511 per cent of variance of the total variance. Six items/statements are included in first factor 'Individual Causes' (IC) which explaining over 34.90 per cent of variance, six items/statements are included in the second factor 'Environmental Reasons' (ER) which explaining over 18.72 per cent of variance and four items/statements are included in the third factor 'Cause lessness' (C) which explaining over 11.88 per cent of variance. In total, three factors explaining over 65.511 per cent of variance of the total variance explained.

The scree plot displays the Eigen values in a downward curve, ordering the Eigen values from largest to smallest. According to the scree-test, the 'elbow' of the graph where the eigen values seem to level off is found and factors or components to the left to this point should be retained is significant. Here, three are three factors have Eigen value of greater than 1 and it can be shown in the scree plot. Therefore, it is a three-factor solution of variable MSPPA.

Table 1. Result of KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.882
	Approx. Chi-Square	1837.254
Bartlett's Test of Sphericity	df	120
	p	0.000

Source: Primary Data; df – degrees of freedom p – statistical significance

Table 2. Result of Exploratory Factor Analysis

Constructs	Statements	Code	Factor Loadings	Eigen Value	Variance Explained	Cronbach's Alpha (α)
Participating in a Physical Activity						
Individual Causes (IC)	Makes me feel good	IC1	0.801	5.585	34.90%	0.863
	Allows me to be motivated for lessons more easily	IC2	0.804			
	Makes me uneasy	IC3	0.724			
	Entertains me very much	IC4	0.773			
	Increases self-confidence	IC5	0.713			
	Allows me to avoid negative thoughts	IC6	0.668			
Environmental Reasons (ER)	Makes me popular in school	ER1	0.800	2.996	18.72%	0.884
	Improves my relations with school administrators and teachers	ER2	0.810			
	Reduces my academic success in the classes	ER3	0.774			
	Allows me to prove my skills to my friends	ER4	0.790			
	Is an opportunity to use the sports equipment in the school	ER5	0.748			
	Allows me to eliminate my teachers' negative thoughts about me	ER6	0.701			
Cause lessness (C)	Seems like a waste of time, I'm not sure	C1	0.857	1.901	11.88%	0.879
	Might be an advantage for me, I'm not sure	C2	0.793			
	Is/isn't important, it does not make any sense	C3	0.890			
	Is necessary or not, I don't really care	C4	0.879			

Total Variance Explained – 65.511%

Source: Primary Data; (α) – Cronbach's Alpha

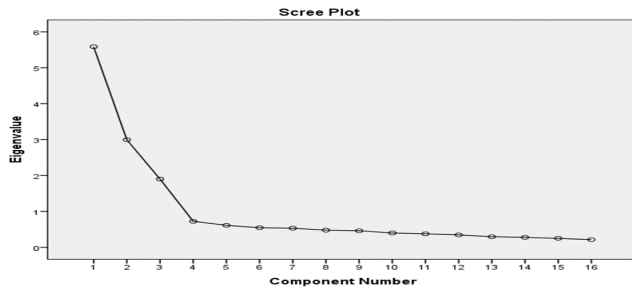


Fig. 1. Scree Plot of Exploratory Factor Analysis, Source: Primary Data

Construct Validity

The above table shows all the factor loadings are above 0.40, and criteria of Construct Validity including both the Discriminant Validity (loading of at least 0.40, no cross-loadings of items above 0.40) and Convergent Validity (Eigen values of 1, loadings of at least 0.40, items that load on posited constructs) (Straub et al., 2004). The result of Exploratory Factor Analysis shows that the selected factors under the dimension ‘MSPPA’ have good level of validity.

Reliability

Reliability of the factors is measured using Cronbach’s Alpha Co-efficient. An alpha value of 0.70 or above is considered to be a criterion for demonstrating strong internal consistency. In this context, the constructs and variables used for the study have been measured. Accordingly, the 3.1.3. Cronbach’s Alpha Reliability Co-efficient values of all the variables coming under the constructs of the study namely, Individual Causes (0.863), Environmental Reasons (0.884) and Causelessness (0.879) are above 0.7, hence strong internal consistency is assured and the questionnaire is considered as highly reliable.

The next step is to conduct a Confirmatory Factor Analysis (CFA) for the ‘MSPPA’ variable and its constructs identified from Exploratory Factor Analysis (EFA) to assess whether the factors generated from results have the same underlying structure as the intended measurement structure (The underlying factors of each construct in the same dimensions).

Confirmatory Factor Analysis

A Confirmatory Factor Analysis (First Order CFA) is applied to validate the measurement scales used for the study. CFA is a multivariate statistical method used to check the relationship between measured variables and their constructs. It explains the quality of factor structure for measuring proposed constructs of the study. The result of CFA is explained with the help of Proposed Model, Model Fit Indices, Measurement Model, Path Estimates and Validity & Reliability Results.

The above specified proposed model is tested with the with the help of model fit indices including Normed chi-square (CMIN/df), Root Mean Square Residuals (RMR), Comparative Fit Index (CFI), Goodness of Fit Index (GFI), Adjusted GFI (AGFI), Incremental Fit Index (IFI), Tucker

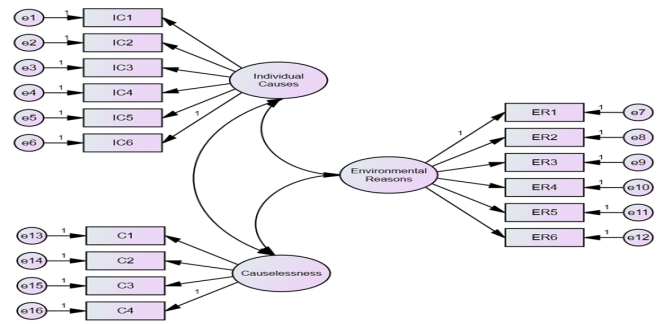


Fig. 2. The Proposed Model of First Order CFA, Source: Primary Data

Fit Index (TLI), Normed Fit Index (NFI), Relative Fit Index (RFI) and Root Mean Square Error of Approximation (RMSEA). Accordingly, the result of Model Fit Indices, Measurement Model, Path estimates, and Reliability & Validity Statistics of the model are presented in table 3.

The acceptability of first order CFA (Figure 1) is measured with the help of the above specified modification indices. Here, all the important measures (CFI, GFI, AGFI, IFI, TLI, NFI, and RFI) are within the recommended limit of good fit with values of greater than 0.90. Similarly, the values of CMIN/df is 1.356 which is less than the recommended values of good fit of less than 3. Furthermore, the value of RMR (0.038) is within the limit of less than 0.05 and the values of RMSEA (0.040) also within the limit of less than 0.08. Accordingly, the model used to measure the ‘MSPPA’ is acceptable to measure the validity of scale. The result of analysis shows that there is adequate fit for the measurement model, there for we can confirm the result of Confirmatory Factor Analysis (CFA).

Table 3. Model Fit Indices

Indices	Value Obtained	Recommended Values of Good Fit	Recommended Values of Acceptable Fit
Normed chi-square (CMIN/df)	1.356	≤3	≤5
Root Mean Square Residuals (RMR)	0.038	≤0.05	≤0.08
Comparative Fit Index (CFI)	0.980	≥0.90	≥0.80
Goodness of Fit Index (GFI)	0.930	≥0.90	≥0.80
Adjusted GFI (AGFI)	0.906	≥0.90	≥0.80
Incremental Fit Index (IFI)	0.980	≥0.90	≥0.80
Tucker Fit Index (TLI)	0.976	≥0.90	≥0.80
Normed Fit Index (NFI)	0.928	≥0.90	≥0.80
Relative Fit Index (RFI)	0.914	≥0.90	≥0.80
Root Mean Square Error of Approximation (RMSEA)	0.040	<0.08	=0.08

Source: Primary Data

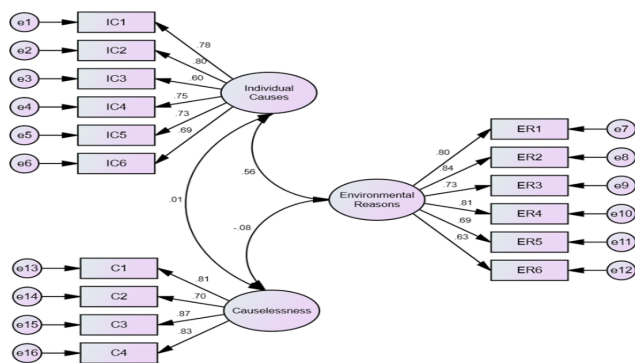


Fig. 3. Measurement Model of CFA, Source: Primary Data

Figure 3 is the measurement model used to explain the interrelationship between the constructs and items used to measure the ‘MSPPA’. Here, three constructs derived from Exploratory Factor Analysis are analyzed with the help of latent variables. The above measurement model comprised three sub-factors of MSPPA namely, Individual Causes, Environmental Reasons and Causelessness. All the factor loadings are above 0.50 and the model said to be fit with the indices specified above. Further, result of path estimates and validity and reliability statistics are presented below.

The table 4 shows the regression weights of each path included in the measurement model of MSPPA. The standardized regression weights of all the statements are satisfactory and standardized loadings of all the statements are above 0.50, which indicates that all the variables are satisfactorily contributes to the variance of the construct. The p-values of all the variables included in the construct are highly significant and indicates the desirability of respective

variables. An item with highest loading in a construct contributes more to the variance of the construct. The variable ‘Allows me to be motivated for lessons more easily’ (IC2) is the highest loading item (0.802) which contributes more to the factor ‘Individual Causes’. The variable ‘Improves my relations with school administrators and teachers’ (ER2) contributes more to the factor ‘Environmental Reasons’ with loading of 0.837, and the variable ‘Is/Isn’t important, it does not make any sense’ (C3) is the highest loading item (0.872) which contributes more to the factor Causelessness.

Table 5 describes the Standardized Factor Loadings, Composite Reliability (CR), Average Variance Extracted (AVE) and Maximum Shared Variance (MSV) of each construct used to measure the ‘MSPPA’ variable. Almost all the values of Standardized Factor Loadings are above 0.7, which indicates all the factors are satisfactorily contributes to the constructs.

In order to prove the Convergent Validity, three conditions need to fulfil namely, the values of Composite Reliability (CR) should be greater than 0.70 (Hair et al, 2010), the values of Average Variance Extracted (AVE) should be greater than 0.50 (Fornell and Larcker, 1981) and the values of Composite Reliability (CR) should be greater than Average Variance Extracted (AVE). Here, all these criteria are fulfilled with CR of Individual Causes – 0.869, Environmental Reasons – 0.886 and Causelessness – 0.881 and AVE of Individual Causes – 0.528, Environmental Reasons – 0.567 and Causelessness – 0.650, and the values of CR are greater than AVE, hence Convergent Validity is proved.

Furthermore, the Discriminant Validity of the scale is proved with the criteria of Average Variance Extracted (AVE) should be greater than Maximum Shared Variance (MSV). Here this condition is fulfilled with the Average Variance Extracted (AVE) of all the constructs is greater

Table 4. Regression Weights (Path Estimates)

Variables and Sub Constructs	Estimate	S.E.	C.R.	p	(λ)
IC6 <--- Individual Causes	1.000				0.686
IC5 <--- Individual Causes	1.003	0.103	9.697	<0.01	0.729
IC4 <--- Individual Causes	1.021	0.103	9.940	<0.01	0.749
IC3 <--- Individual Causes	0.936	0.115	8.113	<0.01	0.600
IC2 <--- Individual Causes	1.030	0.098	10.525	<0.01	0.802
IC1 <--- Individual Causes	0.987	0.096	10.236	<0.01	0.776
ER1 <--- Environmental Reasons	1.000				0.798
ER2 <--- Environmental Reasons	1.007	0.074	13.648	<0.01	0.837
ER3 <--- Environmental Reasons	0.791	0.068	11.576	<0.01	0.732
ER4 <--- Environmental Reasons	0.893	0.068	13.098	<0.01	0.809
ER5 <--- Environmental Reasons	0.802	0.074	10.833	<0.01	0.694
ER6 <--- Environmental Reasons	0.773	0.081	9.605	<0.01	0.627
C4 <--- Causelessness	1.000				0.829
C3 <--- Causelessness	0.986	0.067	14.716	<0.01	0.872
C2 <--- Causelessness	0.724	0.065	11.219	<0.01	0.700
C1 <--- Causelessness	0.941	0.069	13.660	<0.01	0.814

Source: Primary Data, S.E. – standard error; C.R. – Composite Reliability, p – statistical significance, λ – Standardized Factor Loadings

Table 5. Validity and Reliability Statistics

Constructs	Statements	Factor Loadings	CR $CR = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum Var(\varepsilon_i)}$	AVE $AVE = \frac{\sum_{i=1}^n \lambda_i^2}{n}$	MSV = square of highest correlation b/w latent constructs
Individual Causes (IC)	IC1	0.776	0.869	0.528	0.313
	IC2	0.802			
	IC3	0.600			
	IC4	0.749			
	IC5	0.729			
	IC6	0.686			
Environmental Reasons (ER)	ER1	0.798	0.886	0.567	0.313
	ER2	0.837			
	ER3	0.732			
	ER4	0.809			
	ER5	0.694			
	ER6	0.627			
Causelessness (C)	C1	0.814	0.881	0.650	0.006
	C2	0.700			
	C3	0.872			
	C4	0.829			

Source: Primary Data

than the values of Maximum Shared Variance (MSV). The criteria of Individual Causes (0.528>0.313), Environmental Reasons (0.567>0.313) and Causelessness (0.650>0.006) are fulfilled. Hence, the criteria for Discriminant Validity is also proved. The model said to be good fit for measuring the MSPPA variable.

Discussion

This study, is aimed at adapting the MSPPA scale, originally in Turkish, into English. The study employed a various methodological framework. Firstly, the original scale was translated into English. English version of the scale was applied to 228 high school students. The data are examined by high Kaiser Meyer Olkin (KMO) coefficient and Barlett's Test of Sphericity. KMO value is 0.882 and Sphericity chi-square = 1837.254, $p < 0.01$, it shows that the data are suitable for further analysis. Exploratory factor analysis (EFA) and Confirmatory Factor Analysis (CFA) were performed to prove the construct validity of the data.

The result of Exploratory Factor Analysis (EFA) shows that the solution is based on 3 constructs and all items are loading on their own factors same as the original form of the scale (MSPPA) developed by Tekkurşun Demir and Cicioğlu (2018). Items and sub-dimensions were confirmed in accordance with the structure of the original scale. As a result of the analysis of the data, a 16-item scale consisting of 3 sub-dimensions was obtained. Here the factor loadings in MSPPA vary between .668 and .890. As stated by Tekkurşun Demir and Cicioğlu (2018), the first sub-dimension is Individual Causes (IC), the second dimension is Environmental Reasons (ER) and third dimension is Causelessness (C). Individual Causes (IC) which explaining over 34.90 per cent of variance, six items/statements are included in the second factor Environmental Reasons (ER)

which explaining over 18.72 per cent of variance and four items/statements are included in the third factor Causelessness (C) which explaining over 11.88 per cent of variance. The total variance of the scale is 65.511.

The result of Exploratory Factor Analysis also shows that the selected factors under the dimension MSPPA have good level of validity. That means, it satisfies the criteria of construct validity. Then analysis of the reliability of the scale is made. In this context, Cronbach Alpha coefficient was applied. According to this, Cronbach Alpha coefficient of Individual Causes sub-dimension is 0.863, Environmental Reasons sub-dimension is 0.884 and Cause lessness sub-dimension 0.879 these values are above 0.70 and it is considered to be a criterion for demonstrating strong internal consistency, it is assured and the questionnaire is considered as highly reliable.

After Exploratory factor analysis, Confirmatory factor analysis is performed. Here fit indices obtained as a result of the CFA performed were RMSEA, CFI, GFI, AGFI, IFI, TLI, NFI, and RFI are obtained well-assumed range (Kline, 2011; Marsh et al., 2006; Meyers et al., 2006), acceptable range (Çelik & Yılmaz, 2013; Doğan, 2015; Schermelleh-Engel et al., 2003). In the model confirmed by CFA, the significance of the correlations between the sub dimensions was also examined (Tabachnick & Fidell, 2001; Tezcan, 2008; Thompson, 2004). All the factor loadings are above 0.50 and the model said to be fit with the indices specified.

The result of path estimates disclosed that the values of standardized regression weights explain the strength and direction of the relationship between variables and their constructs. The significant values of all the variables indicate the desirability of the respective variable on the construct. Critical Ratio (CR) assesses the significance of the estimated coefficient. A higher C.R. value suggests the greater significance of the path estimates. Here, second variable of the construct Individual Causes,

second variable of the construct Environmental Reasons and third variable of the construct Causelessness have highest factor loadings of 0.802, 0.837 and 0.872 respectively in this order.

Furthermore, result of validity and reliability statistics reveals the criteria for ensuring construct validity, precisely Convergent Validity and Discriminant Validity. Here, the values of Composite Reliability (CR), Average Variance Extracted (AVE) and Maximum Shared Variance (MSV) of different variables used to establish the statistics with specified threshold limits. All the values are specifically confirmed the criteria of convergent and discriminant validity of the measurement scale. Hence, the validity and reliability requirements of the MSPPA is proved.

Conclusions

In summary, the study successfully adapted and validated the Motivation Scale for Participation in Physical Activity (MSPPA) through a careful process involving EFA and CFA. The results provide convincing evidence for the reliability and validity of the scale in assessing motivation to participate in physical activity across various contexts. The vigorous psychometric properties of the MSPPA emphasize its utility as a valuable tool for researchers and practitioners to understand and measure individual motivation to participate in physical activity. It provides an accurate assessment across multiple dimensions, including Individual causes, Environmental causes and Causelessness. The results of the study contribute to the existing literature by providing a validated instrument for assessing motivation to participate in physical activity, thereby facilitating further research in this area. In addition, the rigorous methodological approach used in the development and validation of the scale increases the credibility and applicability of the MSPPA in both academic and practical settings.

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Conflict of interest

The author declares that there is no conflict of interest.

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Адапування шкали мотивації до участі у заходах з фізичної активності

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

Реферат. Стаття: 8 с., 5 табл., 3 рис., 22 джерела.

Мета дослідження. Дослідження спрямовано на адаптацію шкали мотивації до участі у заходах з фізичної активності (Motivation Scale for Participation in Physical Activity, MSPPA), вперше розробленої у 2018 році турецькою мовою науковцями Деміром та Чічіоглу (Demir and Cicioğlu), для її застосування англійською мовою. Мета полягала в забезпеченні надійного та валідного інструменту для оцінки мотивації до фізичної активності в англомовних категоріях населення.

Матеріали та методи. Процес адаптації включав два етапи. На першому етапі MSPPA було перекладено з турецької на англійську мову, здійснено зворотний переклад та рецензовано експертами в галузі спортивної науки та перекладу. На другому етапі проведено збір даних серед 224 учнів шкіл у окрузі Малаппурам, штат Керала, Індія. Зібрані матеріали підлягали проведенню розвідувального факторного аналізу (РФА) та підтверджувального факторного аналізу (ПФА) з метою валідації факторних складових шкали. Для оцінки показників надійності та конструктивної валідності застосовано відповідні статистичні методи.

Результати. Аналіз зібраних даних показав наявність трьох факторів в адаптованій моделі шкали мотивації до участі у заходах з фізичної активності: «Індивідуальні чинники», «Екологічні чинники» та «Безпричинність», що відповідають внутрішній мотивації, зовнішній мотивації та амотивації, відповідно. Фактори, визначені за допомогою РФА, були підтверджені шляхом проведення ПФА. Розробка шкали продемонструвала надійність і конструктивну валідність в оцінці мотивації до фізичної активності в англомовних категоріях населення.

Висновки. Встановлено, що адаптована модель MSPPA є надійним і валідним інструментом для оцінки мотивації до участі у заходах з фізичної активності серед англомовних осіб. Застосування даної адаптації сприяє проведенню кроскультурних досліджень та інтервенцій, спрямованих на популяризацію фізичної активності та пов'язаних із нею переваг.

Ключові слова: мотивація, фізична активність, адаптація, розвідувальний факторний аналіз (РФА), підтверджувальний факторний аналіз (ПФА).

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Physiological Effects of Zumba Exercise on Male College Students: An Intervention Study

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Abstract

Objectives. This study aimed to assess the effectiveness of Zumba exercise in improving physiological parameters among male students enrolled in an aerobic exercise program in Gwalior, Madhya Pradesh, India.

Materials and methods. A one-group pre-post-test design was used, involving fifteen male students aged between nineteen and twenty-four years old. The participants engaged in Zumba sessions supervised by health professionals three times per week for eight weeks. A series of measurements, including VO₂max, agility, and muscle strength, was evaluated at pretest and posttest stages using various equipment and methods.

Results. Statistical analysis using SPSS version 26 software included normality testing with the Shapiro-Wilk test and a significance level set at $p \geq 0.05$. A paired sample t-test was performed to compare pretest and posttest measurements of VO₂max, agility, and muscle strength. The results are presented as Mean \pm Standard Deviation (SD). The findings reveal significant improvements in all parameters assessed post-intervention. VO₂max increased from 26.5 ± 4.5 to 30.8 ± 4.2 mL/kg/min, agility improved from 15.8 ± 1.2 to 14.6 ± 1.3 seconds, limb muscle strength increased from 394.2 ± 66.4 to 411.1 ± 67.5 joules, and arm muscle strength increased from 123.5 ± 17.1 to 138.2 ± 13.9 joules (all $p \leq 0.001$). These results demonstrate the effectiveness of Zumba exercise in enhancing physical fitness among male college students.

Conclusions. The findings suggest that Zumba exercise is an effective non-pharmacological intervention for enhancing cardiovascular fitness, agility, and muscular strength among male students. Integrating Zumba exercise into regular physical activity routines may contribute to stimulating an active lifestyle and improving overall health outcomes.

Keywords: zumba exercise, physiological parameters, male students, cardiovascular fitness, physical activity intervention.

Introduction

Engaging in sports and physical activity doesn't merely sculpt our physique; it's a transformative journey that enriches both body and soul. Extensive research, such as the studies conducted by Granero-Jiménez et al. (2022) and Pranoto et al. (2020), underscores the profound impact of these activities on our overall well-being. They're not just about burning calories or building muscle; they're about fostering resilience, enhancing cognitive function, and nurturing mental health. Consider the vibrant world of Zumba. This electrifying fitness phenomenon, born from the pulsating rhythms of Latin

dance, embodies the essence of joyous movement. Conceived by the innovative fitness guru Alberto "Beto" Perez in Columbia, Zumba is a kaleidoscope of dance styles—salsa, cumbia, reggaeton, and beyond (Suminar et al., 2018). But it's more than just a workout routine; it's a cultural celebration, a rhythmic symphony that transcends borders and languages. Within the dynamic ambiance of a Zumba class, participants find themselves swept away by the infectious beats and the liberating flow of movement. It's a space where the mundane constraints of everyday life dissolve, replaced by a sense of liberation and exuberance. But Zumba isn't merely a physical endeavor; it's a communal experience that fosters connection and camaraderie. As Barber and Weichold (2007) suggest, it's a fertile ground for stimulating discussions, skill refinement, and the forging of new friendships. Indeed, the benefits of

Zumba extend far beyond the realm of fitness. Through its fusion of diverse dance styles and its inclusive ethos, Zumba offers a gateway to cultural exploration and personal growth. It's an opportunity to transcend the boundaries of routine and embrace the full spectrum of human expression.

Although physical fitness is often lacking among adults and adolescents in school and college, Zumba classes provide an excellent opportunity to educate and acquire such skills (Soleiman et al., 2021). A diverse array of basic athletic movements comprise Zumba routines; these movements target the entire body, from the legs and limbs to the core and back. Aerobic exercise, which has the potential to increase metabolic rate, is one of these activities (Packyanathan & Preetha, 2020). Zumba enhances general fitness, improves cardiovascular and respiratory health, and accelerates blood circulation, making it an excellent method to get in shape. Moreover, Soleiman et al. (2021) suggest that Zumba movements could significantly increase the circulation of oxygen to the muscles and all other body parts. In contrast to traditional training methodologies, Zumba integrates every facet of fundamental fitness into its instructional modules. Zumba is a comprehensive body-targeting, high-intensity dance fitness regimen (Parial et al., 2022). Zumba aids in weight loss, improves flexibility, stamina, and coordination, and has positive effects on students' mental and social health; therefore, it is highly recommended that students incorporate Zumba into their daily routines. Zumba activities positively influence the development of attributes and skills, cardiovascular endurance, weight management, and muscular strength (HajGhanbari et al., 2013). Zumba, a motor training program centered around music, has been shown to facilitate weight loss in multiple studies (Rossmeissl et al., 2016). Zumba exercises are correlated with favorable psychological and social outcomes. Prior studies have demonstrated that students who participated

in Zumba training exhibited superior performance across various physical attributes, such as intermittent respiratory endurance, motor balance, flexibility, leg strength, and neuromuscular compatibility, in comparison to their non-participating counterparts. As stated by Krishnan et al. (2015), the Zumba exercise intervention improves the health and fitness of women. VO_2 max testing is a method that can be employed to assess cardiorespiratory endurance. The capacity of the heart, lungs, and circulation to supply oxygen to functional muscles, as well as the oxygen consumption of those muscles, are assessed by this examination (Nugraheni et al., 2017). The gold standard for VO_2 max prediction is the multi-stage 20-m Shuttle Run Fitness Test, as demonstrated in research by Paradisis et al. (2014) and Sugiharto et al. (2022). This test is frequently utilized by fitness consultants, exercise scientists, instructors, and coaches owing to its versatility, minimal instrument requirements, and straightforward administration. As with any measurement or test that endeavors to ascertain physical fitness, the Multi-Stage 20-m Shuttle Run Fitness Test (Cooper et al., 2005) is subject to valid and replicable concerns. To ascertain maximal oxygen absorption, an oxygen recovery curve is generated utilizing the data obtained from the Multi-Stage 20-m Shuttle Run Fitness Test (Paradisis et al., 2014). Building upon the foundation of existing research, this study endeavors to empirically establish the efficacy of Zumba exercise in enhancing VO_2 max, agility, and muscle power among students within the locale of Gwalior, Madhya Pradesh, India.

Materials and Methods

Study Participants

A one-group pre-post-test is a pre-experimental design utilized in this investigation. The study involved fifteen male

Table 1. Methodological Overview of Zumba Exercise Intervention Study in Male Students: Equipment, Measurements, and Evaluation Timing

Measurement	Equipment/Method	Reference
Zumba Exercise	Supervised by professionals from the Faculty of Health and Sciences	
Session Duration	25 minutes	Andarianto et al., 2022
Frequency	3 times per week	
Intensity	80% of maximum heart rate (HRmax)	
Heart Rate Monitoring	Polar H10 Bluetooth Heart Rate Sensor & Fitness Tracker	Andarianto et al., 2022
Body Height	Stadiometer	Rejeki et al., 2021
Body Weight	Digital scale	Sugiharto et al., 2022
BMI Calculation	Body weight (kg) divided by body height (m ²)	Raharjo et al., 2021
Blood Pressure	Digital sphygmomanometer on the non-dominant arm, averaged from 3 consecutive measurements	Andarianto et al., 2022; Raharjo et al., 2021
Resting Heart Rate (HR- rest)	Beurer Pulse Oximeter PO-30	Rejeki et al., 2021
Oxygen Saturation (SpO ₂)	Beurer Pulse Oximeter PO-30	Rejeki et al., 2021
VO ₂ max Measurement	Multi-Stage 20-m Shuttle Run Fitness Test	Paradisis et al., 2014
Leg Muscle Power	Vertical Jump Test	García-Ramos et al., 2017; Cuk et al., 2014
Arm Muscle Power	Medicine Ball Throw Test	Leite et al., 2020
Evaluation Timing	Pretest and 1x24 hours posttest after each Zumba exercise session throughout the 8-week intervention	

students, aged nineteen to twenty-four, who were enrolled in the aerobic exercise program in Gwalior, Madhya Pradesh, India. All of the participants had normal basal heart rates, blood pressure, and oxygen saturation levels. Their voluntary participation in the research was noteworthy. Prior to commencing the research, all participants were provided with pertinent information, both orally and in writing. Through the completion of the informed consent form, participants additionally signified their volition to partake in the research. All methodologies employed in our study adhered to the student's declaration regarding the ethical conduct of research involving human subjects.

Study Organization

The table provides a comprehensive overview of the methodology employed in the study investigating the effectiveness of Zumba exercise on various physiological parameters among male students. It details the equipment used for measurements, including heart rate monitoring, body composition assessment, blood pressure measurement, and evaluation of physical fitness components such as VO_{2max} and muscle power. Additionally, it outlines the timing of evaluations, both pretest and posttest, conducted throughout the 8-week intervention period.

Statistical Analysis

Analysis of the data was conducted utilizing the Statistical Package for Social Science (SPSS) version 26 software. Normality testing was performed using the Shapiro-Wilk test, with a significance level set at $p \geq 0.05$. To compare the average values of VO_{2max} , agility, and muscle power between the pretest and post-test, a Paired Sample t-test was employed. Results are presented as Mean \pm Standard Deviation (SD). All statistical analyses were conducted using a significance level of $p \leq 0.05$.

Results

Table 2. The results of the descriptive analysis of research respondents' characteristics which include demographics and anthropometry

Parameters	n	Mean	Std. Deviation
Age (years)	15	21.5	1.8
Body height (m)	15	1.57	0.03
Bodyweight (kg)	15	54.2	6.1
Body mass index (kg/m ²)	15	22.3	1.4
Systolic BP (mmHg)	15	116.2	3.1
Diastolic BP (mmHg)	15	76.0	2.7
Resting heart rate (bpm)	15	76.8	3.0
Oxygen saturation (%)	15	97.5	1.0

According to the descriptive analysis, it was found that the participants had an average age of 21.5 years (± 1.8), an average body weight of 54.2 kg (± 6.1), and an average body height of 1.57 m (± 0.03). The participants had an

average body mass index (BMI) of 22.3 kg/m² (± 1.4). In addition, the average systolic blood pressure was measured at 116.2 mmHg (± 3.1), with an average diastolic blood pressure of 76.0 mmHg (± 2.7). In addition, the participants had a resting heart rate of 76.8 bpm (± 3.0) and an oxygen saturation level of 97.5% (± 1.0).

Upon analyzing the average VO_{2max} , agility, and muscular power during the pretest and posttest sessions, it was observed that there were significant changes in these measures. The findings, presented as Mean \pm standard deviation (SD), demonstrated a notable improvement in the average maximal oxygen volume (VO_{2max}), agility, and muscular strength over the two test sessions. The Paired Sample t-Test revealed significant differences in the average VO_{2max} between the pretest and posttest sessions (26.5 ± 4.5 vs. 30.8 ± 4.2 mL/kg/min; $p \leq 0.001$), average agility (15.8 ± 1.2 vs. 14.6 ± 1.3 seconds; $p \leq 0.001$), average limb muscle power (394.2 ± 66.4 vs. 411.1 ± 67.5 joules; $p \leq 0.001$), and average arm muscle power (123.5 ± 17.1 vs. 138.2 ± 13.9 joules; $p \leq 0.001$). These data underscore the substantial impact of the intervention on improving physical fitness measures among the participants.

Discussion

The current research sought to examine the effectiveness of Zumba exercise in improving maximal oxygen uptake (VO_{2max}), agility, and muscular strength in students from Gwalior, Madhya Pradesh, India. The results of our study showed a significant increase in VO_{2max} , agility, and muscular strength after participating in the Zumba fitness programme. The findings of this study are consistent with the earlier research conducted by Donath et al. (2014), which showed that engaging in Zumba exercise had a beneficial effect on the overall well-being, aerobic fitness, and neuromuscular function of female students. Vendramin et al. (2016) found that Zumba exercise significantly improved aerobic capacity, as measured by VO_{2max} , which is a crucial predictor of aerobic fitness (Poole & Jones, 2017). Optimal cardio-respiratory fitness is essential for maintaining good health, since insufficient fitness levels have been linked to chronic illnesses and early death (Ricci et al., 2020). Zumba exercise, which involves moderate to vigorous intensity movements that engage the entire body, has been proven to improve VO_{2max} through different physiological changes, such as increased heart size, stroke volume, and mitochondrial function (Chavarrias et al., 2020; Bacon et al., 2013; Wilson et al., 2016). In addition, the use of leaps, core workouts, and exaggerated arm motions in Zumba routines might enhance muscular strength, especially in persons with lower initial levels (Barranco-Ruiz & Villa-González, 2020). The World Health Organisation (WHO) classifies physical inactivity as a notable public health issue, placing it as the fourth most important risk factor for worldwide mortality (Benjamin et al., 2017). Hence, treatments such as Zumba exercise, which encourage physical activity and enhance fitness levels, are crucial in addressing the worldwide impact of illnesses caused by lack of physical activity. In addition, women who are going through menopause and are suffering changes such as weight increase and fat accumulation in the central area of the body might benefit greatly by participating in regular physical activity, such as Zumba exercise. This has been supported by

Table 3. Comparative Analysis of Pretest and Posttest Measurements for VO₂max, Agility, and Muscle Power

Measurements	Pretest Mean ± SD	Posttest Mean ± SD	t-value	p-value
VO ₂ max (mL/kg/min)	26.5 ± 4.5	30.8 ± 4.2	3.76	<0.001
Agility (seconds)	15.8 ± 1.2	14.6 ± 1.3	4.12	<0.001
Limb Muscle Power	394.2 ± 66.4	411.1 ± 67.5	3.98	<0.001
Arm Muscle Power	123.5 ± 17.1	138.2 ± 13.9	3.88	<0.001

studies conducted by Rossmeissl et al. (2016), Al-Safi et al. (2015), and Lovejoy (2009). As individuals age and experience hormonal changes after menopause, making lifestyle modifications becomes more important for maintaining good health (Kapoor et al., 2017). This study's results provide solid data that demonstrates the efficacy of Zumba exercise in enhancing VO₂max, agility, and muscular strength in students. Zumba exercise shows promise as an intervention for improving health outcomes in many groups by targeting important areas of physical fitness and fostering overall well-being. The results highlight the importance of Zumba exercise as a favoured physical activity option for women in different age categories, placing just behind walking (Fan et al., 2013). Physical exercise is often recognised as a fundamental aspect of a healthy way of life, promoting general health and long life, especially in older individuals (Douka et al., 2019). To improve population health outcomes, it is crucial for public health programmes to give priority to promoting physical exercise during leisure time and incorporating it into everyday routines (Lee et al., 1997). Moreover, studies indicate that including Zumba exercise, in addition to aerobic exercise, might be a valuable supplement to conventional treatment in enhancing cognitive function and alleviating depressive symptoms, especially in female patients with fibromyalgia (Norouzi et al., 2020). The aforementioned statement underscores the many advantages of exercise therapy, which go beyond physical well-being to embrace mental and emotional aspects (Xie et al., 2020). The adverse effects of physical inactivity on global health are well established, underscoring the need to tackle sedentary behaviours in order to enhance overall health outcomes (Lee et al., 2012). Zumba fitness is known for its dynamic integration of movement and music, providing a stimulating experience that encourages self-expression and activates different aspects of one's personality (Kaufmann, 2011; Studer-Lüthi & Züger, 2012). Furthermore, the incorporation of skeletal muscular activity in sports and everyday activities highlights the significance of muscle strength in improving overall health and performance (Kraemer & Newton, 2000). In the study conducted by Puspodari et al. (2022), titled "Effectiveness of Zumba Exercise on Maximum Oxygen Volume, Agility, and Muscle Power in Female Students," it was found that Zumba exercise, performed for 30 minutes at 80% of maximum heart rate (HRmax), three times per week over an 8-week period, led to significant improvements in maximum oxygen volume (VO₂max), agility, and muscle power among female students at Universitas Nusantara PGRI Kediri, East Java, Indonesia. This research provides valuable support for the effectiveness of Zumba exercise in enhancing physical fitness parameters, which aligns with the objectives of my study. Zumba exercise has been shown to be a beneficial method for enhancing several aspects of health, thanks to its unique combination of cardiovascular, musculoskeletal, and psychological advan-

tages. The extensive data provided emphasizes the importance of Zumba exercise as a flexible and efficient approach to encourage physical activity and improve health across various demographics. Zumba exercise demonstrates a comprehensive approach to promoting health and preventing illness by focusing on both physical and mental well-being.

Conclusions

The findings of this study provide compelling evidence that Zumba exercise, conducted for 30 minutes per session at 80% of maximum heart rate (HRmax), three times per week over an 8-week period, significantly enhances maximum oxygen volume (VO₂max), agility, and muscle power among students in Gwalior, Madhya Pradesh, India. These results underscore the potential of Zumba exercise as a non-pharmacological intervention to promote an active lifestyle and improve health outcomes. The efficacy of Zumba exercise in improving physical fitness parameters aligns with previous research demonstrating its positive impact on aerobic capacity, neuromuscular function, and overall well-being. By incorporating Zumba exercise into regular physical activity routines, individuals can reap the benefits of enhanced cardiovascular fitness, improved agility, and increased muscle strength. Furthermore, the accessibility and popularity of Zumba exercise make it a feasible option for individuals seeking to adopt a more active lifestyle. Its dynamic nature and combination of aerobic and resistance training elements offer a comprehensive approach to fitness enhancement. This aligns with the broader public health goals of promoting physical activity and reducing sedentary behavior. Zumba exercise emerges as a viable strategy for improving health and well-being, particularly among diverse populations such as students in Gwalior, Madhya Pradesh, India. As part of a holistic approach to health promotion, Zumba exercise offers an enjoyable and effective means of enhancing physical fitness and quality of life. Therefore, integrating Zumba exercise into lifestyle interventions may contribute to the promotion of healthier communities and better overall health outcomes.

Conflict of interest

No conflict of interest.

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Фізіологічний вплив виконання вправ із зумби на організм студентів коледжу чоловічої статі: Інтервенційне дослідження

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

Реферат. Стаття: 7 с., 3 таб., 42 джерела.

Мета дослідження. Метою дослідження була оцінка ефективності вправ із зумби з точки зору покращення фізіологічних параметрів організму студентів чоловічої статі, які займаються за програмою аеробних вправ у місті Гваліор, штат Мадх'я-Прадеш, Індія.

Матеріали та методи. У дослідженні застосовано модель перед- і післятестового аналізу за участю однієї групи, яка включала 15 студентів чоловічої статі у віці 19-24 років. Учасники займалися тренуванням із зумби під наглядом медичних працівників тричі на тиждень протягом восьми тижнів. На передтестовому та післятестовому етапах із використанням різного обладнання та методів проведено оцінку низки вимірювань, включаючи показники максимального споживання кисню, спритності та м'язової сили.

Результати. Статистичний аналіз із застосуванням програмного забезпечення SPSS версії 26 включав перевірку критерію нормальності за допомогою тесту Шапіро-Вілка та рівня значущості $p \geq 0,05$. Для порівняння показників максимального споживання кисню, спритності та м'язової сили перед початком і після закінчення тестування було застосовано метод t-критерію парних вибірок. Результати представлені як середнє значення \pm стандартне відхилення (СВ). Отримані дані свідчать про значне покращення всіх параметрів, що оцінювалися після інтервенції. Показник максимального споживання кисню підвищився з $26,5 \pm 4,5$ до $30,8 \pm 4,2$ мл/кг/хв, спритність покращилася з $15,8 \pm 1,2$ до $14,6 \pm 1,3$ секунди, сила м'язів нижніх кінцівок зросла з $394,2 \pm 66,4$ до $411,1 \pm 67,5$ джоулів, а сила м'язів рук збільшилася з $123,5 \pm 17,1$ до $138,2 \pm 13,9$ джоулів (усі показники на рівні $p \leq 0,001$). Такі результати демонструють ефективність тренувань із зумби з точки зору покращення фізичної підготовленості серед студентів коледжу чоловічої статі.

Висновки. Отримані результати дають підстави стверджувати, що виконання вправ за фітнес-програмою зумба є ефективною нефармакологічною інтервенцією з метою покращення показників тренуваності серцево-судинної системи, спритності та м'язової сили серед студентів чоловічої статі. Інтегрування вправ із зумби до комплексу регулярних фізичних навантажень може сприяти стимулюванню активного способу життя та покращенню загальних показників здоров'я.

Ключові слова: вправи із зумби, фізіологічні параметри, студенти чоловічої статі, тренуваність серцево-судинної системи, інтервенція фізичної активності.

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Determining the Effects of a 12-Week Moderate Intensity Circuit Exercise Program on Body Composition and Physical Fitness among Overweight Women of Working Age

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. The study aimed to examine the effects of a 12-week moderate-intensity circuit exercise program on body composition and physical fitness among overweight women of working age.

Materials and methods. Twenty-nine overweight women of working age were divided into two groups: the control group (CG, n = 14) had a normal daily life, and the moderate intensity circuit exercise group (MICE, n = 15) underwent training that included 3 sessions of MICE (40–50 seconds followed by 60 seconds of rest for each exercise and 90 seconds of recovery between sessions at 64–76% of maximum heart rate). The training was conducted for 60 minutes per day, three days per week. Body composition and physical fitness were measured before (2 days prior) and after (2 days post) a 12-week training period.

Results. After the 12-week training, the MICE showed a considerable improvement in a number of key health indicators, including body weight, BMI, fat mass, skeletal muscle mass, visceral adipose tissue, total energy expenditure, resting energy expenditure, waist circumference, and waist-to-hip ratio (-0.65%, -0.73%, -2.16%, 2.53%, -7.12%, 10.85%, 0.71%, -3.13%, and -2.67%, respectively, $p < 0.05$) when compared to the CG. Similarly, the MICE demonstrated a significantly larger improvement in the sit and reach test, the back extension test, the hand grip strength of the right hand, hand grip strength of the left hand, leg strength, the 60-second chair stand test (also known as sit-to-stand test), and the maximum oxygen consumption (18.98%, 16.53%, 10.69%, 7.68%, 9.97%, 26.25%, and 8.87%) compared to the CG (-4.10%, -1.19%, -0.26%, -1.53%, -1.44%, 0.24%, and -0.70%), respectively.

Conclusions. Moderate-intensity circuit exercise has been found to have positive effects on improving body composition and physical fitness in overweight working women. Thus, the implementation of MICE with appropriate sessions, resting, duration, and training periods can achieve maximum benefit.

Keywords: body composition, moderate intensity circuit exercise, overweight, physical fitness, women of working age.

Introduction

The epidemic of overweight continues to increase among the adult population, especially working-age women (Sadali et al., 2023), which may affect daily life or result in the risk of various non-communicable diseases (NCDs) and come with behaviors that have a negative effect on health conditions such as smoking and alcohol drinking (Farhat et al., 2010). It also increases the risk of diabetes, coronary heart disease, and cancer by 58%, 21%, and 42%, respectively (WHO,

2020), and leads to breast cancer among women (Hu, 2003). Sarcopenia also occurs during adulthood and decreases even more in the elderly, leading to various chronic diseases and impaired adipose tissue that affect the cardiometabolic risk (Bosy-Westphal & Müller, 2021).

Exercise plays an important role in preventing and treating overweight and obesity. Proper exercise training will help develop physical fitness and lead to changes in good health behaviors (Bandura, 1977). Changes in body composition and the proportion between fat mass and muscle mass, improved resting blood pressure and heart rate, and increased cardiorespiratory fitness are generally found (Irene-Chrysovalanto et al., 2021). The intensity of exercise is determined by the force required to perform the physical

activity. The American College of Sports Medicine (ACSM) defines moderate exercise intensity at 64-76% of maximum heart rate (MHR) (Medicine, 2018), 46-64% of maximum oxygen consumption ($VO_2\max$), and the Borg's scale at the levels of 12-13 and 50-70% of repetition maximum (RM) (Thompson et al., 2013). Moderate-intensity exercise also improves aerobic capacity, develops emotions, or has a positive effect on psychology (Lox et al., 2019).

Circuit exercise consists of 9-12 exercise stations, focusing on improving muscle strength, muscular endurance, and stimulating cardiorespiratory endurance simultaneously (Adamson, 1959). Moreover, circuit exercise saves on exercise time but is highly effective in improving physical fitness. When combined with body weight exercise, it will use less equipment, which is easy and convenient to start exercising (Klika & Jordan, 2013). A previous study by Paoli et al. (2013) compared three types of training: high-intensity circuit training, low-intensity circuit training, and endurance training, which were performed 3 times/week for 50 minutes each. After a 12-week training, it was found that the high-intensity circuit training can improve diastolic blood pressure. The reductions in fat mass and arterial cholesterol were significantly different. The low-intensity circuit training group experienced the greatest changes in systolic blood pressure. Also, all these three training programs had a significant effect on body weight changes. It was effective in improving BMI and body composition in adults (Paoli et al., 2013). Irene-Chrysovalanto et al. (2021) used a moderate-intensity intermittent circuit training program among obese and overweight individuals, with the intensity at 50-60% of maximum heart rate, 2 times/week. A total of 10 exercise stations were repeated for a total of 2 circuits. After the 8-week training, significant improvements were found in body weight, body mass index, body fat, lean body mass, systolic blood pressure, resting heart rate, and cardiorespiratory fitness. It can be concluded that moderate intensity circuit training is as effective in improving physical fitness as high intensity circuit training (Irene-Chrysovalanto et al., 2021). Furthermore, a moderate-to-high-intensity circuit training program can affect changes in muscle performance. In particular, there is an increase in upper and lower muscular strength (Marcos-Pardo et al., 2019). These basic strengths are important indicators for working-age women to maintain their muscular fitness to prevent muscular disorders and the risk of injury to bones and joints (Nelson et al., 2007). Moderate-intensity exercise can help reduce cell damage or inflammation compared to high intensity exercise over a long period of time, which has a greater negative effect on cellular inflammation (Cerqueira et al., 2020). A systematic review by Ramos-Campo et al. (2021) revealed that resistance circuit-based training can improve body mass index, fat mass, and muscle mass significantly among middle-aged and elderly women. $VO_2\max$, maximum aerobic speed, and the strength of the upper and lower extremities also significantly improved (Ramos-Campo et al., 2021). Previous studies reported beneficial effects of circuit training among women of working age and other age groups, as it can improve the cardiorespiratory system and prevent cardiovascular diseases (Ballesta-García et al., 2020; Beqa Ahmeti et al., 2020). In this study, the researchers considered the safety during the training of the samples, who were working-age women with sedentary behavior. If

they begin to practice a high-intensity circuit exercise program, they may be at risk of injury during exercise training. Therefore, the exercise intensity was set at a moderate level of 64-76 % MHR throughout the 12-week exercise training period. The researchers have recognized the importance of applying a moderate-intensity exercise program to improve body composition and enhance physical fitness, which can be the guidelines for health care, prevention, and treatment among overweight working-age women.

Materials and Methods

Study Participants

Twenty-nine working-age participants, overweight women from Ubon Ratchathani Rajabhat University (mean age 42.66 ± 4.19 years), volunteered for this study. The inclusion criteria were as follows: participants measured and reported as overweight ($BMI = 25.0-29.0 \text{ kg/m}^2$), likely to be untrained, no training for aerobic and resistance exercise programs within the past 3 months, and no contraindication for circuit exercise. The exclusion criteria included having tendons, joints, and muscle injuries or other complications, such as heart disease, and participating in the research project for less than 80% of the training. Participants provided written informed consent after being informed about the study's details, objectives, risks, and potential of a moderate-intensity circuit exercise program. The research received approval from the Human Ethics Committee (HE662039) at Ubon Ratchathani Rajabhat University.

Study Organization

The participants were randomly divided into two groups: the control group (CG, $n = 14$) and the moderate intensity circuit exercise group (MICE, $n = 15$). The control group did not exercise and had a normal daily life. Baseline measurements were taken for all participants before the start of the training program. After twelve weeks of training, measurements were taken again, namely between two days before and after the final training session (Fig. 1).

Training Program

The moderate-intensity circuit exercise program consisted of workouts that lasted for 60 minutes per day, 3 days per week, on non-consecutive days, for a total of 12 weeks. The program was scheduled every Monday, Wednesday, and Friday, with two sessions available from 3:00 p.m. to 4:00 p.m. and 5:00 p.m. to 6:00 p.m. The exercise sessions took place at UBRU Fitness, located at Ubon Ratchathani Rajabhat University. The circuit exercises comprised nine body weight-based exercises, including jumping jacks, triceps dips, sit-ups, knee-hops, Russian twists, lunges, planks, squats, and jogging. These exercises were followed by a moderate intensity circuit exercise, during which participants wore HR monitors (Rhythm+2.0; Scosche Industries P.R.C.) on their upper forearms to monitor heart rate. The target pulse range was set at 64% to 76% of maximum heart rate (MHR) (Cerqueira et al., 2020) throughout the training period.

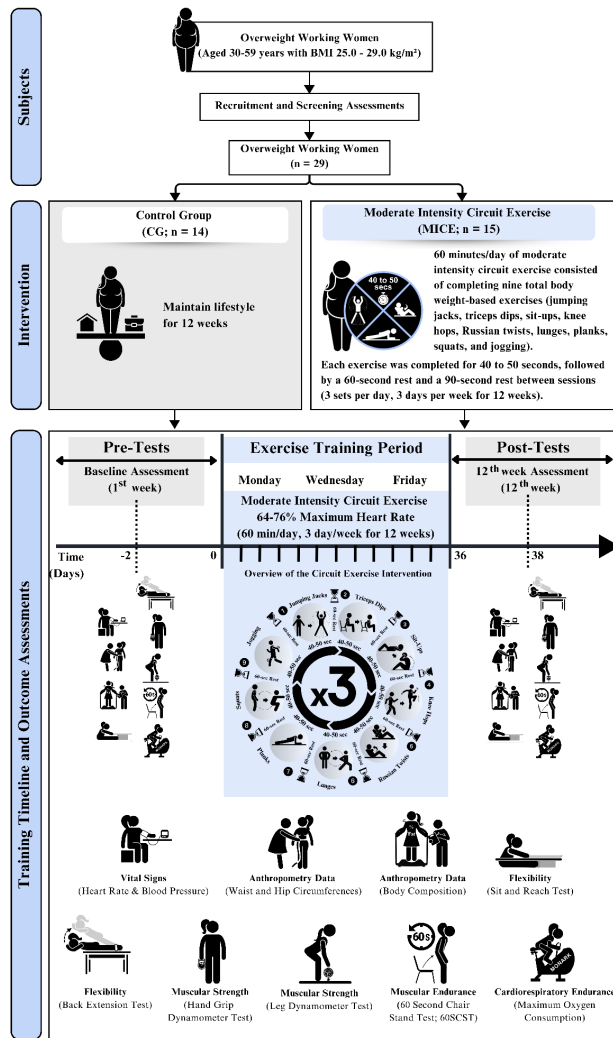


Fig. 1. Outline of the training and testing schedule



Fig. 2. Circuit exercise training protocol

Measurements

Body Composition Measurement

A bioelectrical impedance analysis device (Seca mBCA, Hamburg, Germany) measured weight, body mass index (BMI), fat-free mass, skeletal muscle mass (whole body, right arm, left arm, torso, right leg, and left leg), visceral adipose

tissue, total energy expenditure, and resting metabolic expenditure while each participant stood barefoot for 5 minutes.

Anthropometric Measurement

Waist circumference (WC) and hip circumference (HC) were assessed by measuring the distance between the lower rib border and the iliac crest, as well as the level of the greater trochanter, using a flexible inch tape. The waist-to-hip ratio (WHR) was calculated using the provided measurements and the designated formula. The waist-to-hip ratio (WHR) is calculated by dividing the waist circumference (WC) by the hip circumference (HC), both measured in centimeters (cm).

Flexibility Measurement

The flexibility of the hamstring and lower back muscles was assessed using a standing trunk flexion meter (Flexion-D Takei physical fitness test; T.K.K. 5403, Japan), while the trunk muscles were evaluated using a trunk extension meter (Extension-D Takei physical fitness test; T.K.K. 5404, Japan).

Muscular Strength Measurement

The arm muscles were assessed for strength using a grip strength dynamometer (Grip-D Takei physical fitness test; T.K.K. 5401, Japan), while the leg muscles were evaluated for strength using a back strength dynamometer (Back-A Takei physical fitness test; T.K.K. 5002, Japan).

Muscular Endurance Measurement

The 60-seconds chair stand test (60SCST) was conducted to assess muscular endurance. Upon receiving the “Start” signal, the individual was required to rise from the chair, assume an upright posture with legs fully extended, and then return to the initial seated position. This was recorded as a single iteration. The frequency of repeats was documented for a duration of 60 seconds, during which the participants executed the action of standing up and sitting down on a chair with accuracy, striving to achieve the maximum number of repetitions.

Cardiorespiratory Endurance Measurement

A maximum oxygen consumption test (VO₂max) was conducted to assess cardiorespiratory endurance or aerobic capacity. Cardiorespiratory endurance was indirectly assessed using the Astrand method - rhyming, which included utilizing a cycle ergometer (Monark Ergonomic 828E, Vansbro, Sweden). The evaluation was completed under the researcher’s observation.

Statistical Analysis

The statistical analyses were conducted using SPSS 25 (IBM Corp., IBM SPSS Statistics for Windows, Version 25.0; Armonk, NY: IBM Corp). The data are reported as the mean ± standard deviation (SD). The normality of the data was assessed using the Shapiro-Wilk test. The study used

paired t-tests to compare data acquired before and after a 12-week training period. Additionally, independent t-tests were used to compare the variations from baseline across different groups. A P value less than 0.05 was deemed to be statistically significant.

Results

The participant's baseline characteristics of cardiovascular parameters in the control and moderate-intensity circuit exercise groups are presented in Table 1. No significant differences existed among the groups (CG and MICE) for any variable.

Table 1. Baseline characteristics of cardiovascular parameters in the control and moderate-intensity circuit exercise groups

Parameters	CG (n = 14)	MICE (n = 15)	t	p-value
Age (y)	41.86 ± 3.76	43.40 ± 4.55	0.992	0.165
Weight (kg)	72.95 ± 8.63	69.87 ± 10.16	-0.259	0.399
Height (cm)	159.15 ± 5.08	159.00 ± 5.46	-0.074	0.471
BMI (kg/m ²)	28.61 ± 3.29	27.65 ± 3.65	-0.265	0.397
Resting heart rate (b/m)	82.23 ± 12.43	81.50 ± 9.47	-0.164	0.436
SBP (mm Hg)	121.31 ± 9.12	126.75 ± 11.49	1.317	0.101
DBP (mm Hg)	81.91 ± 9.12	83.08 ± 6.84	0.351	0.365

Description: CG = control group, MICE = moderate-intensity circuit exercise group; BMI; body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure. Values are mean ± SD. $p > 0.05$ No significant difference was found between the two groups for any variable

After 12 weeks, the body weight, BMI, fat mass, skeletal muscle mass (whole body, right arm, left arm, right leg, and left leg), visceral adipose tissue, TEE, REE, WC, and WHR were reduced in MICE by -0.65%, -0.73%, -2.16%, 2.53% (2.54%, 3.17%, 3.59%, 3.13%, and 3.35%), -7.12%, 10.85%, 0.71%, -3.13%, and 2.67%, respectively, $p < 0.05$) when compared to CG. Likewise, this increase in the MICE, changes in body composition, and anthropometrics as a result of training (baseline to post-intervention) were not significantly different in the CG (Table 2).

In particular, after 12 weeks of training, the sit and reach test, back extension test, hand grip strength of the right hand, hand grip strength of the left hand, leg strength, 60SCST, and VO_2 max were significantly increased in the MICE (18.98%, 16.53%, 10.69%, 7.68%, 9.97%, 26.25%, and 8.87%) compared with the CG (-4.10%, -1.19%, -0.26%, -1.53%, -1.44%, 0.24%, and -0.70%), respectively (Table 3). Despite this increase in the moderate-intensity circuit exercise group, changes in physical fitness as a result of training (baseline to post-intervention) were not significantly different in the control group.

Discussion

The findings revealed significant changes in body composition and physical fitness over a 12-week period of moderate-intensity circuit exercise programs among

overweight women of working age. Changes in body weight and BMI after the training may be due to the fact that the samples received an exercise program that changed the energy balance or caused energy expenditure affecting changes in body weight and BMI (Weinsier et al., 2002). Berge et al. (2021) compared the effects of a moderate-intensity continuous training (MICT) program and a combined MICT with high-intensity interval training (HIIT/MICT) program. After 24 weeks of training, both groups had a significant increase in energy expenditure during exercise (EED). The HIIT/MICT group showed greater reductions in body weight and BMI (Berge et al., 2021). This is similar to the present study's findings that the total energy expenditure (TEE) and the resting energy expenditure (REE) of the experimental group significantly increased and were significantly different between groups after the training. In other words, the circuit or interval exercise can influence changes in energy expenditure, affecting changes in body composition.

In addition, in this research, the waist circumference, waist-to-hip ratio, visceral fat, and body fat mass of the MICE group decreased. Similarly, a study by Berge et al. (2021) found the decrease in fat mass in the HIIT/MICT group that was different from that in the MICT group after 24 weeks of training. Changes in waist circumference after the experiment in the HIIT/MICT group were also found (Berge et al., 2021). A study of high- and low-intensity circuit training programs also revealed changes in body fat mass (Paoli et al., 2013). It can be concluded that if circuit exercise is done continuously, it will cause changes in body fat mass. The hip circumference that was not changed after the training may be because the training program in this study added exercises for the hip muscles. Therefore, the muscles in these areas may have developed, resulting in no change in hip circumference. However, changes in the waist-to-hip ratio were found. The mean waist circumference of the experimental group decreased due to exercise in the overweight and obese groups (Khan et al., 2022).

Also, an increase in muscle mass was found in all muscles of the body. This is consistent with the study of Irene-Chrysovalanto et al. (2021), which investing the effects of a moderate-intensity intermittent circuit training program among obese and overweight individuals. It was found that the leg muscles (L. Hamstring and L. Quadriceps) of the experimental group increased significantly compared to the control group after 8 weeks of training (Irene-Chrysovalanto et al., 2021). Likewise, a study by Paoli et al., (2013) found changes in fat-free mass in the group that trained with the circuit training program (Paoli et al., 2013). The present study also found that the body's muscle mass increased by 2.53%. It is possibly because the training program used body weight exercise as resistance, causing muscle development. Resistance circuit-based exercise can help improve muscle performance (Klika & Jordan, 2013).

Muscle flexibility in the MICE group increased by 18.98%, indicating an improvement in muscle performance in terms of flexibility. In the training program, resistance from body weight was used as the main exercise. Both major and minor muscles were used together through repetitions a number of times, resulting in the stretching of muscles during the movement periods. If the exercise is practiced correctly and appropriately, it will help increase muscle

Table 2. Body composition and anthropometric variables of participants in all 2 groups after 12-week training

Variables	CG (n = 14)					MICE (n = 15)				
	Pre-test	Post-test	% change	t	p-value	Pre-test	Post-test	% change	t	p-value
Body composition										
Weight (kg)	70.86 ± 9.75	71.86 ± 10.17	0.71	-1.978	0.069	69.87 ± 10.16	69.42 ± 9.96	-0.65	-2.408	0.012†
BMI (kg/m ²)	28.01 ± 3.43	28.19 ± 3.63	0.65	-1.753	0.103	27.65 ± 3.65	27.44 ± 3.64	-0.73*	-2.634	0.007†
Fat-Free mass (kg)	42.31 ± 4.51	42.73 ± 4.87	0.98	-1.909	0.083	45.49 ± 5.61	46.10 ± 5.75	1.35*	0.557	0.292
Fat mass (%)	39.35 ± 3.43	39.25 ± 3.63	-0.25	0.443	0.667	39.14 ± 3.71	38.30 ± 3.81	-2.16*	-2.539	0.009†
Skeletal muscle mass (kg)	19.31 ± 2.88	19.25 ± 2.90	-0.32	1.199	0.216	19.37 ± 3.32	19.86 ± 3.32	2.53*	4.710	0.001†
Whole body (kg)	19.31 ± 2.89	19.13 ± 2.95	-0.91	1.696	0.118	20.06 ± 4.06	20.57 ± 4.06	2.54*	4.433	0.001†
Right arm (kg)	1.06 ± 0.17	1.05 ± 0.18	-0.73	0.932	0.370	1.07 ± 0.20	1.10 ± 0.20	3.17*	3.439	0.001†
Left arm (kg)	0.97 ± 0.16	0.96 ± 0.16	-1.41	2.096	0.062	1.00 ± 0.20	1.04 ± 0.20	3.59*	4.166	0.001†
Torso (kg)	7.89 ± 1.54	7.9 ± 1.63	0.63	-0.432	0.674	7.54 ± 1.09	7.82 ± 1.06	3.65*	1.828	0.041†
Right leg (kg)	4.71 ± 0.59	4.71 ± 0.58	0.14	-0.210	0.838	4.70 ± 0.70	4.85 ± 0.79	3.13*	2.662	0.007†
Left leg (kg)	4.62 ± 0.65	4.64 ± 0.67	0.37	-0.338	0.741	4.62 ± 0.70	4.77 ± 0.79	3.35*	2.125	0.022†
Visceral adipose tissue (L)	2.29 ± 0.51	2.34 ± 0.56	1.98	-1.336	0.211	2.05 ± 0.61	1.91 ± 0.63	-7.12*	-3.490	0.001†
TEE (kcal/day)	2012.29 ± 177.65	2000.93 ± 273.97	-0.56	0.183	0.857	2130.46 ± 331.48	2361.69 ± 225.08	10.85*	2.867	0.004†
REE (kcal/day)	1418.50 ± 112.55	1419.30 ± 113.61	0.06	-0.371	0.720	1383.25 ± 79.93	1393.08 ± 84.11	0.71*	3.026	0.004†
Anthropometrics										
WC (cm)	90.67 ± 8.23	91.00 ± 8.60	0.37	-1.301	0.220	88.38 ± 8.82	85.62 ± 0.51	-3.13*	-4.206	0.001†
HC (cm)	103.27 ± 4.27	103.91 ± 4.91	0.62	-1.750	0.111	102.08 ± 5.82	101.92 ± 5.33	-0.15	-1.125	0.137
WHR	0.78 ± 0.26	0.78 ± 0.26	-0.01	0.001	1.000	0.86 ± 0.06	0.84 ± 0.06	-2.67*	-2.257	0.029†

Description: TEE = Total energy expenditure; REE = Resting energy expenditure; WC = Waist circumference; HC = Hip circumference; WHC = Waist-to-hip ratio. *Significant p<0.05 (pre vs post), †Significant p<0.05 (CG vs MICE)

Table 3. Physical fitness of participants in all 2 groups after 12-week training

Variables	CG (n = 14)					MICE (n = 15)				
	Pre-test	Post-test	% change	t	p-value	Pre-test	Post-test	% change	t	p-value
Flexibility										
Sit and reach test (cm)	11.44 ± 6.36	10.97 ± 5.74	-4.10	1.304	0.217	12.99 ± 5.10	15.45 ± 5.81	18.98*	3.602	0.001†
Back extension test (cm)	34.28 ± 6.41	33.87 ± 6.91	-1.19	0.992	0.342	33.92 ± 5.44	39.53 ± 6.88	16.53*	4.130	0.001†
Muscular strength										
Hand grip strength of right hand (kg/weight)	0.35 ± 0.07	0.35 ± 0.07	-0.26	0.199	0.846	0.40 ± 0.08	0.45 ± 0.08	10.69*	3.531	0.001†
Hand grip strength of left hand (kg/weight)	0.33 ± 0.05	0.32 ± 0.05	-1.53	1.342	0.213	0.37 ± 0.07	0.40 ± 0.07	7.68*	4.389	0.001†
Leg strength (kg/weight)	1.20 ± 0.31	1.18 ± 0.29	-1.44	1.035	0.325	1.32 ± 0.30	1.45 ± 0.27	9.97*	3.757	0.002†
Muscular endurance										
60SCST (reps)	32.15 ± 6.01	32.23 ± 5.48	0.24	-0.132	0.897	32.93 ± 9.33	41.57 ± 9.15	9.97*	4.319	0.003†
Cardiorespiratory endurance										
VO ₂ max (ml/kg/min)	26.04 ± 4.78	25.83 ± 4.32	-0.70	0.635	0.559	26.48 ± 7.01	28.82 ± 6.79	8.87*	5.050	0.001†

Description: 60SCST = 60 seconds chair strand test; VO₂max = Maximum oxygen consumption. *Significant p<0.05 (pre vs post),

†Significant p<0.05 (CG vs MICE)

flexibility (Alizadeh et al., 2023). In the present study, sit and reach and back extension were used to test muscle flexibility, so the core and lower limb muscles were used. The training program consisted of the exercises that helped develop these muscles properly. Doing resistance training that allows muscles to work their full range of motion at least three times per week can improve flexibility (Rinaldo et al., 2017).

Changes in muscle strength performance were also found in every test result (Handgrip: L&R, Leg strength). A study by Marcos-Pardo et al. (2019) also pointed out that a 12-week resistance circuit training program can improve muscle strength in both elderly men and women (Marcos-Pardo et al., 2019). A study by Irene-Chrysovalanto et al. (2021) found changes in muscle strength in hamstring and quadriceps muscles after doing moderate-intensity circuit training (Irene-Chrysovalanto et al., 2021). Previous studies have shown the effectiveness of the circuit training program. The improvement in handgrip strength may be caused by the poses that primarily use the arm muscles. The triceps dip or other poses that use the muscles in the forearm may help develop the strength of these muscles among working-age women who tend to lack this type of exercise. The increase in leg muscle strength may be due to the fact that most training exercises involve using these muscles for movement or resistance, causing the muscles to develop strength (Marcos-Pardo et al., 2019).

Muscular endurance increased by 9.97%. Similarly, a study by Myers et al. (2015) examined the effects of circuit training on a group of young women who were physically inactive. The study revealed a significant improvement in muscular endurance after 5 weeks of training, conducted three times per week. After training, the muscular endurance of the hamstring muscles increased by 23.3% (Myers et al., 2015). In contrast to this research, the sample consisted of working-age women, potentially leading to a smaller increase in the magnitude of the change. However, the age factor may influence the change. Circuit training, on the other hand, has

the potential to improve muscular endurance performance if the training program is appropriate for the subjects (Jung et al., 2019; Rinaldo et al., 2017).

The change in VO₂max in this study may be caused by the combined resistance and rest periods. As a result, the exercise had an appropriate intensity (moderate) for the samples. It was a combination of the aerobic and anaerobic energy systems in the exercise. After the training, VO₂max changed by 8.87%. It is considered to have a positive effect on the prevention of cardiovascular diseases because every 1 ml/kg/min increase in VO₂max is associated with a 9% reduction in the risk of cardiovascular diseases (Reljic et al., 2021). A study by Irene-Chrysovalanto et al. (2021) also showed an approximately 10% change in VO₂max after 8 weeks of circuit training (Irene-Chrysovalanto et al., 2021). That is, moderate-intensity circuit training can help improve cardiovascular endurance. Therefore, it can be said that a 12-week moderate intensity circuit exercise program in this study was possible to cause changes in body composition and overall physical fitness in overweight women of working age. However, the interpretation of such results needs confirmation from subsequent studies because the volunteers in this study were not restricted or controlled in their diet. Therefore, training combined with controlled or restricted food intake compared with training alone will make it possible to draw clear conclusions about these results.

Conclusions

After 12 weeks of training, moderate-intensity circuit exercise using body weight as resistance can improve body composition and physical fitness in overweight women of working age. It is an appropriate, convenient, safe, and effective exercise program that can be recommended to women with physical inactivity and those who are obese. Moreover, we recommend combining MICE with food

restriction to see clear results of change, as this approach yields better results than exercising alone.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Визначення впливу 12-тижневої програми кругових вправ помірної інтенсивності на показники композиції тіла та фізичної підготовленості жінок працездатного віку з надмірною масою тіла

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

Реферат. Стаття: 9 с., 3 табл., 2 рис., 27 джерел.

Мета дослідження. Дослідження мало на меті вивчити вплив 12-тижневої програми кругових вправ помірної інтенсивності на показники композиції тіла та фізичної підготовленості жінок працездатного віку з надмірною масою тіла.

Матеріали та методи. Двадцять дев'ять жінок працездатного віку з надмірною вагою були розділені на дві групи: контрольна група (КГ, n = 14) дотримувалася звичайного повсякденного способу життя, та група, що виконувала кругові вправи помірної інтенсивності (КВПІ, n = 15) і проходила тренування, що включали 3 сеанси КВПІ (40-50 секунд з наступним 60-секундним відпочинком на кожну вправу і 90-секундним відновленням між сеансами на рівні 64-76% максимальної частоти серцевих скорочень). Тренування проводилися впродовж 60 хвилин на день, три дні на тиждень. Показники композиції тіла та фізичної підготовленості вимірювали до початку (за 2 дні до) та після (через 2 дні після) 12-тижневого періоду тренувань.

Результати. Після 12-тижневого тренування в групі, що займалася КВПІ спостерігалось значне покращення низки ключових показників стану здоров'я, включаючи масу тіла, ІМТ, жирову масу, масу скелетних м'язів, вісцеральну жирову тканину, загальні енерговитрати, енерговитрати у стані спокою, окружність талії та співвідношення талії до стегон (-0,65%, -0,73%, -2,16%, 2,53%, -7,12%, 10,85%, 0,71%, -3,13% та -2,67%, відповідно, p < 0,05) порівняно з результатами контрольної групи. Аналогічним чином, група КВПІ також продемонструвала суттєвіше поліпшення показників у виконанні тесту на гнучкість (спосіб вимірювання загальної гнучкості тіла при згинанні тулуба вперед, сидячи на підлозі з витягнутими вперед руками), тесту на розгинання спини, сили кистьового хвату правої руки, сили кистьового хвату лівої руки, сили нижніх кінцівок, 60-секундного тесту на оцінку сили та витривалості нижніх кінцівок, що передбачає вимірювання кількості рухів з положення сидячи та встаючи зі стандартного стільця, а також максимального споживання кисню (18,98%, 16,53%, 10,69%, 7,68%, 9,97%, 26,25% та 8,87%) порівняно з КГ (-4,10%, -1,19%, -0,26%, -1,53%, -1,44%, 0,24% та -0,70%) відповідно.

Висновки. Встановлено, що кругові вправи помірної інтенсивності позитивно впливають на покращення показників композиції тіла та фізичної підготовленості працюючих жінок з надмірною масою тіла. Таким чином, впровадження КВПІ з відповідними сеансами, режимом відпочинку, тривалістю та періодами тренувань може досягти максимальної користі.

Ключові слова: композиція тіла, кругові вправи помірної інтенсивності, надмірна маса тіла, фізична підготовленість, жінки працездатного віку.

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Evaluating Cardiorespiratory Fitness Level of College Students: A Comparative Analysis Between Basketball and Football Classes

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Abstract

Objectives. The study aimed to compare the cardiorespiratory fitness levels among male students majoring in football and basketball.

Materials and methods. A cross-sectional study was conducted with a sample size of 60 students, divided into two groups: 30 students from the basketball class and 30 students from the football class. The average age of students in the football class was 22.03 ± 0.81 , while in the basketball class, it was 22.07 ± 0.74 . All participants were male and active strata 1 students in semesters 4 and 6, equivalent to second and third-year students. The cardiorespiratory fitness level was assessed using the Cooper 1.5 mile or 2.4 km Run Test. The data analysis was performed using a two-tailed independent sample t-test to determine differences between the two groups at a significance level of less than 5% ($p < 0.05$). Prior to the t-test, normality was assessed using the Shapiro-Wilk test, and homogeneity was assessed using Levene's statistics, with a significance level higher than 5% ($p > 0.05$).

Results. The findings revealed that students in the football class showed a higher VO_{2max} (42.54 ± 5.40) compared to those in the basketball class (37.86 ± 5.62), demonstrating a statistically significant difference ($p = 0.002$).

Conclusions. The study found a significant disparity in cardiorespiratory fitness levels between the football and basketball student groups within the campus setting.

Keywords: college students, football, basketball, cardiorespiratory fitness.

Introduction

Physical fitness, as highlighted by Farley et al. (2020), Puchalska-Sarna et al. (2022), Xiao et al. (2021), stands out as a crucial factor influencing sports performance. This concept is commonly categorized into two distinct components: fitness pertaining to overall health and fitness specific to sports skills, as discussed by Kariyawasam et al. (2019) and Zheng et al. (2023). The foundation of health-related fitness is essential for individuals across the spectrum (Xiang et al., 2017), encompassing both the general populace and athletes, including basketball and football players. Optimal physical fitness is imperative to underpin daily activities and accomplishments. Therefore, it can be inferred that health-related physical fitness serves as the cornerstone that athletes must establish before honing skill-related physical abilities

to attain peak performance. Bompa (2012) emphasizes that physical fitness linked to health represents a fundamental biomotor element that every athlete should possess.

The fitness components associated with health encompass body composition, cardiorespiratory fitness, flexibility, muscle strength, and muscle endurance, as highlighted by Blair et al. (2001), Janssen and Leblanc (2010), and Ross et al. (2016). Among these elements, cardiorespiratory fitness assumes paramount importance due to its direct correlation with vital human systems, specifically the lungs and heart. Raghuvver et al., (2020) describe cardiorespiratory fitness as the synergy between the cardiovascular system (comprising the heart and blood vessels) and the respiratory system (involving the lungs and respiratory tract) in facilitating oxygen distribution throughout the body and eliminating carbon dioxide generated during metabolic processes.

In the realm of student demographics, the levels of cardiorespiratory fitness emerge as a significant focal point as they wield the potential to impact academic performance, overall well-being, and quality of life, as noted by Chang & Jui-Fu (2011) and Singh et al. (2012). This notion aligns with

findings from Sardinha et al. (2016), underscoring that higher levels of cardiorespiratory fitness and sustained enhancements in fitness are linked to enhanced academic outcomes. Essentially, individuals with elevated and progressively advancing cardiopulmonary fitness levels tend to exhibit improved academic achievements. Studies concerning cardiorespiratory fitness among college students often underscore the role of regular physical activity in enhancing lung and heart health. Nevertheless, within educational settings, particularly campuses, other variables such as engagement in competitive sports can also impact cardiorespiratory fitness levels.

The participants in this study consisted of students who were enrolled in basketball and football coaching programs. It was essential to note that not all students in these classes were necessarily athletes. Among the students were individuals with a keen interest in basketball or football, aiming to delve deeper into these sports, including former athletes and enthusiasts aspiring to pursue coaching roles. Thus, the primary objective of this study was to meticulously evaluate and compare the cardiorespiratory fitness levels of students engaged in basketball and football classes. Through this comparative analysis, we aimed to enhance our comprehension of how the nature of sporting activities could impact cardiorespiratory fitness levels within the college student cohort.

This research offers valuable insights not only into the significance of sports education in upholding student health but also into the specific impact of certain sports on enhancing cardiorespiratory fitness. Therefore, the objectives of this research carry significant practical implications for the advancement of health and fitness programs tailored for students within the campus setting.

Materials and Methods

Participants

This research is a cross-sectional and observational study that examines data collected from a specific population at a single time point (Capili, 2021; Kesmodel, 2018; Wang & Cheng, 2020). The sample for this study comprised 60 male students, with 30 students from the basketball sports coaching class and 30 from the football sports coaching class. These participants were active undergraduate students in their fourth and sixth semesters, corresponding to the second and third years of study. Essentially, these students possessed significant prior experience in practicing basketball or football. For further details regarding the sample characteristics in this study, please refer to Table 1.

Data Collection Technique

In this research, data collection employed tests and measurements. Participants were required to be in good health, free from injuries, and instructed to refrain from engaging in strenuous exercise for a minimum of 48 hours,

as well as abstain from consuming food prior to the test. Prior to the testing procedure, participants were recommended to engage in a 10-minute warm-up and stretching session.

The Cooper 1.5 mile or 2.4 km Run Test was the instrument utilized to evaluate cardiorespiratory fitness levels in this study. This 2.4 km running test serves as a straightforward aerobic fitness assessment, necessitating solely a running track, stopwatch, and a recording sheet to document the participant's overall score. Subsequent to the test, calculations and standards for cardiorespiratory fitness levels were analyzed utilizing the formula outlined by Wood (2008).

Statistical Analysis

The data analysis was conducted utilizing SPSS version 27.0. The data presentation format adopted was mean \pm SD. The data analysis technique employed a two-tailed independent sample t-test to assess variations in the means of the two groups, with a significance threshold set below 5% ($p < 0.05$). Prior to conducting the t-test, prerequisite tests were performed, namely: (1) normality testing using Shapiro-Wilk; and (2) homogeneity testing using Levene Statistics. The prerequisite or assumption tests utilized a significance level exceeding 5% ($p > 0.05$).

Results

Normality Test

Table 2. Normality Test Results

Variable	Class	Shapiro-Wilk		
		Statistic	df	Sig.
VO ₂ max (ml/kg/min)	Football	0.959	30	0.284
	Basketball	0.960	30	0.311

The table above displays the outcomes of the Shapiro-Wilk test. The p-value for the Shapiro-Wilk test in the football class is 0.284 (> 0.05), and in the basketball class, it is 0.311 (> 0.05). As both values are greater than 0.05, it indicates that both groups exhibit a normal distribution according to the Shapiro-Wilk test.

Homogeneity Test

Table 3. Homogeneity Test Result

Variable	Levene Statistic	df1	df2	Sig.
Based on Mean	0.328	1	58	0.569
Based on Median	0.236	1	58	0.629
VO ₂ max (ml/kg/min)	0.236	1	57.867	0.629
Based on trimmed mean	0.324	1	58	0.571

Table 1. Participant's physical characteristics (mean \pm SD)

Group	N	Age	Height (m)	Weight (kg)	BMI	HB (g/dl)
Basketball	30	22.07 \pm 0.74	1.70 \pm 0.52	60.61 \pm 8.32	20.78 \pm 2.22	15.45 \pm 1.77
Football	30	22.03 \pm 0.81	1.66 \pm 0.56	57.63 \pm 7.48	20.84 \pm 2.23	16.30 \pm 1.72

The table above presents the outcomes of the homogeneity test conducted using Levene's Test method. The Levene's value displayed in the row based on the Mean is 0.328, with a p-value (sig) of 0.569, indicating that the value is > 0.05. This result suggests that there is equal variance between the groups, signifying homogeneity.

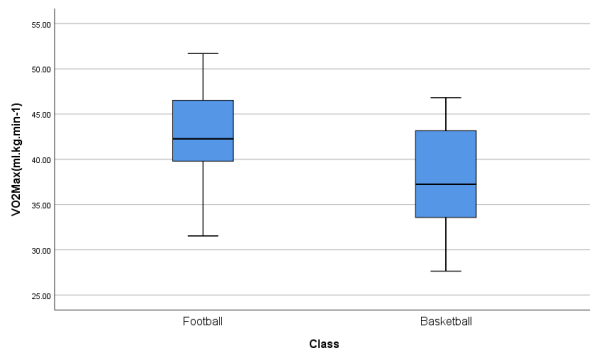


Fig. 1. Boxplot independent t-test

The box plot above reveals no outliers above or below the boxplot, indicating the absence of any outliers. With all assumptions met, we have proceeded to the next test, namely the Independent T-Test.

Hypothesis Test

Prior to testing the hypothesis, the cardiorespiratory fitness level results were classified within each class. Below is the data from this categorization:

Table 4. Data Category Results of Cardiorespiratory Fitness Level of Basketball and Football Class

Group	Category					Total
	Very Poor	Poor	Fair	Good	Excellent	
Class Football	2	3	15	5	5	30
Basketball	8	9	9	4	0	30
Total	10	12	24	9	5	60

Upon reviewing the categorized data of cardiorespiratory fitness levels for the basketball and football classes, a comparison of the analysis results conducted by the researchers is presented in Table 5. The mean ± standard deviation is greater in the football class than in basketball, with a significant p-value of 0.002 (p < 0.005), indicating a notable difference.

Table 5. Comparison Cardiorespiratory Fitness Level Basketball and Football Class

Variable	Basketball Class	Football Class	p value
Cardiorespiratory Fitness [VO ₂ max (ml/kg/min)]	37.86±5.62	42.54±5.40	0.002*

Mean±Standard deviation; *Statistically significance

Discussion

In the soccer class, the average age was 22.03 ± 0.81, while in the basketball class, it was 22.07 ± 0.74. It is important to note that the research samples in both groups included not only athletes but also former athletes, amateur players, or individuals studying the sport to pursue coaching roles.

The study uncovered notable variances in cardiorespiratory fitness levels among college students enrolled in basketball and football classes. This distinction was supported by a significance level of p = 0.002, indicating a value below 0.05. These results offer valuable insights into the factors impacting cardiorespiratory fitness levels within the student community and may have implications for designing programs in higher education.

Students enrolled in soccer classes exhibited superior levels of cardiorespiratory fitness in comparison to their counterparts in basketball classes in this study. This disparity could be attributed to variations in the intensity and nature of exercises practiced in each sport.

Drawing on research by Stojanović et al. (2018), the average VO₂max of elite male basketball athletes ranges from 50 to 61 ml/kg/min. In comparison, student athletes typically exhibit an average VO₂max of 50 to 58 ml/kg/min, engaging in approximately 21 to 57 movements per minute during gameplay. Further, the average distance covered by players in a basketball game spans from 4,400 to 7,500 meters over a 40-minute match (excluding breaks).

Basketball is classified as an intermittent sport, as highlighted by Koryahin, (2022) and Salafi et al. (2023), characterized predominantly by high-intensity activities where the average heart rate surpasses 85% of HRmax during gameplay. In contrast, elite male soccer players, as reported by Turner & Stewart (2014), typically exhibit an average VO₂max ranging from 50.3 to 65.3 ml/kg/min. Moreover, the average distance covered in a football match typically ranges between 10 to 13 kilometers per game.

Football is a high intensity intermittent sport, featuring critical events completed at high/maximal intensity which is superimposed onto an aerobic base of lower intensity activities and rest (Hulton et al., 2022). The aerobic energy system is highly taxed during a football game, with average and peak heart rates around 85% and 98% of maximal values, respectively, corresponding to average oxygen uptake of around 70% of maximum (Bangsbo, 2014). In summary, during a soccer match, the body predominantly utilizes the aerobic energy system at high intensity, leading to elevated heart rates and oxygen consumption. This underscores the crucial role of cardiorespiratory fitness in determining athletes' performance levels during soccer matches.

Based on the findings of cardiorespiratory fitness research, students in football classes exhibit a VO₂max of 42.54 ± 5.40, whereas those in basketball classes show 37.86 ± 5.62. These results suggest that the intensity and duration of training in basketball classes may not be sufficient to achieve the same level of cardiorespiratory fitness as observed in soccer classes.

Not only physical performance but also biological conditions can significantly influence performance optimization. For instance, hematological parameters are crucial for predicting optimal physical performance as hemoglobin and red blood cells are essential for oxygen transport (Schum-

acher et al., 2002). According to Table 1, the average Hemoglobin (HB) levels are 16.30 ± 1.72 for students in football classes and 15.45 ± 1.77 for those in basketball classes.

According to Walker et al. (1990), the typical Hb levels for males range from 14 to 18 g/dl, while for females, the range is 12 to 16 g/dl, indicating that the HB results for each class fall within the normal range. However, the soccer class showed the highest improvement. The levels of hemoglobin and cardiorespiratory fitness are closely linked. It is well-established that endurance training leads to adaptations in blood levels, characterized by an increase in blood volume due to heightened plasma volume and an increase in the red blood cell count (Schumacher et al., 2002). The study revealed that players residing at moderate altitudes exhibited higher hemoglobin concentrations (16.2 ± 0.2 g/dl) compared to those living at sea level locations (14.4 ± 0.7 g/dl). Additionally, the average VO_2 max value of players at medium altitude (54.1 ml/kg/min) significantly surpassed that of players at low altitude (49 ml/kg/min). A review indicates that elevated hemoglobin concentrations are linked to enhanced physical performance, with improvements ranging between 5% and 10% (Wilber, 2002).

It is essential to note that while adequate hemoglobin levels in the blood are crucial, enhancing VO_2 max remains a key consideration. Factors like lung capacity, heart efficiency, and the muscles' capacity to utilize oxygen all impact an individual's VO_2 max. Thus, although elevated hemoglobin levels can enhance VO_2 max, a holistic grasp of the various elements influencing aerobic capacity is vital for optimizing athletic performance and overall physical fitness.

Various factors, including motivation, effective rest time management, and lifestyle choices, can impact cardiorespiratory fitness outcomes (Noriega de la Colina et al., 2024; Thapa et al., 2023). Students in the football class might exhibit higher motivation levels towards enhancing their cardiorespiratory fitness. Moreover, maintaining a healthy lifestyle and efficiently managing time to strike a balance between academic responsibilities and sports engagements can further enhance cardiorespiratory fitness levels.

The level of cardiorespiratory fitness in this study can also be influenced by factors such as the content covered in the lecture, the duration of the lecture, and the frequency of meeting sessions conducted.

The findings emphasize the significance of considering the type and intensity of cardiorespiratory fitness programs developed within the campus setting. The discrepancy in results between basketball and football classes could possibly be attributed to the frequency of lectures. This aspect warrants careful consideration to optimize outcomes.

This research offers recommendations for enhancing current lecture programs, such as incorporating training techniques from other sports to enhance the cardiorespiratory fitness of students in basketball classes. Strategies may involve integrating intense cardiorespiratory training components and emphasizing targeted aerobic exercises to elevate fitness levels. Additionally, students can benefit from insights gained from lectures in other classes to inspire ongoing skill and knowledge development, thereby preventing monotony in a single sport discipline.

This study has several limitations that need to be acknowledged. Firstly, the relatively small sample size might restrict the applicability of the findings to the broader student

population. Moreover, factors like genetic predispositions and stress levels, not accounted for in this study, could impact cardiorespiratory fitness outcomes, warranting consideration in future research endeavors. Furthermore, a limitation arises from the predominant use of athlete data in related studies, highlighting the scarcity of research focused on the student demographic.

Nevertheless, this study can provide strong evidence about the differences in cardiorespiratory fitness levels between basketball and football students in a college setting.

Conclusions

The study findings revealed that students in the soccer class exhibited a higher VO_2 max (42.54 ± 5.40) in comparison to those in the basketball class (37.86 ± 5.62), indicating a statistically significant distinction ($p = 0.002$). Therefore, it can be concluded that there exists a notable variance in cardiorespiratory fitness levels between the two student groups within the campus setting.

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Conflict of interest

The authors guarantee that no conflicts of interest exist.

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Оцінка рівня кардіореспіраторної підготовленості студентів коледжу: Порівняльний аналіз груп, які займаються баскетболом та футболом

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

Реферат. Стаття: 6 с., 5 табл., 1 рис., 29 джерел.

Мета дослідження. Метою цього дослідження було проведення порівняльного аналізу показників кардіореспіраторної підготовленості серед студентів чоловічої статі, які займаються футболом та баскетболом.

Матеріали та методи. Проведено поперечне дослідження з обсягом вибірки 60 студентів, розділених на дві групи: 30 студентів з баскетбольного класу та 30 студентів з футбольного класу. Середній вік студентів у футбольному класі становив $22,03 \pm 0,81$ роки, тоді як у баскетбольному — $22,07 \pm 0,74$. Усі учасники дослідження були чоловічої статі з категорії активного прошарку та навчалися на 4 і 6 семестрах, що еквівалентно студентам другого і третього курсів. Рівень кардіореспіраторної підготовленості оцінювали за допомогою бігового тесту Купера на 1,5 милі або 2,4 км. Аналіз даних проведено із застосуванням двостороннього критерію для незалежних вибірок з метою визначення відмінностей між двома групами на рівні значущості менше 5% ($p < 0,05$). Перед застосуванням t-критерію, було оцінено перевірку даних на нормальність (критерій нормальності) за допомогою тесту Шапіро-Вілка, а однорідність визначено із використанням статистики Левене, з рівнем значущості вище 5% ($p > 0,05$).

Результати. Результати дослідження свідчать про те, що студенти футбольного класу мали вищий показник VO_{2max} (максимальне споживання кисню) ($42,54 \pm 5,40$) порівняно зі студентами баскетбольного класу ($37,86 \pm 5,62$), демонструючи статистично значущу різницю ($p = 0,002$).

Висновки. В ході дослідження встановлено значну різницю в рівнях кардіореспіраторної підготовленості між групами студентів, які займаються футболом і баскетболом у межах студентського містечка.

Ключові слова: студенти коледжу, футбол, баскетбол, кардіореспіраторна підготовленість.

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Implementing Complex Training Method: Its Effects on Endurance, Speed, Power, and Agility of Adolescent Basketball Players

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Abstract

Objectives. This study aimed to examine the effectiveness of complex training on aerobic endurance, speed, power, and agility in adolescent basketball players.

Materials and methods. Field testing experimental research method was used in the study. Purposive sampling was conducted, with participants meeting the following criteria: (1) basketball players training at one club, (2) males, (3) having daily training at one club, and (4) being in good health. A total of 16 participants were involved with a body weight of \pm 60-80 kg, and a height of 170-190 cm. Observation data collection techniques, review of relevant articles, and tests were used in order to obtain the required material. To ensure the assessment of physical aspects, the following tests and instruments were applied: Jump DF instrument, Multistage fitness test, 20-meter sprint, lane agility test. The Friedman test data analysis technique was performed using the statistical software program SPSS 23.

Results. The average score for the first endurance test was 48.53, with the second and third tests demonstrated the results of 50.01 and 52.47, respectively. Similarly, the average speed test score achieved in the first was 3.20, the second was 3.18, and the third – 2.97. The average score for the first agility test was found to be 11.66, the second showed 11.70, and the third – 10.57. The average for the first leg muscle strength test was 66, while the second and third tests were found to be 65 and 69, respectively. The Friedman test variables were used to determine differences in aerobic endurance, speed, power, and agility, the overall significance value was $0.000 < 0.05$.

Conclusions. The implementation of a complex training method for 24 sessions provided a significant increase in aerobic endurance, speed, power, and agility of youth basketball players.

Keywords: weight training, plyometrics, complex training, adolescent basketball players.

Introduction

Basketball is a highly dynamic sport with rapid speed changes and a lot of jumping, thus all of the muscles in the body play an active role (Aksovic et al., 2021). This sports scores to put the ball into the ring repeatedly to win the match, which necessitates strong physical aspects (Amaro et al., 2023). Basketball is a sport played by five persons on one team against each other which means that this sport involves physical contact (Deepika, 2021). The physical aspect becomes important when sports require fast, strong movements and physical contact (Yudhistira, Suherman, et al., 2021). Basketball, like other sports, is a sport that combines aerobic and anaerobic energy system activities such as metabolism, as well as intermittent and explosive

movements (Freitas et al., 2019). These movements are characterized as jumping on one leg, jumping on two legs, running fast, and changing direction repeatedly over a relatively long duration (Freitas et al., 2019; Yudhistira & Tomoliyus, 2020). In this case, the foundation of basketball strength training is extremely important to offer optimal contributions to movements linked to running speed, agility, leg muscle power, and aerobic endurance (Freitas et al., 2019; Neal et al., 2018).

Sports training programs must be specifically designed to optimize athlete performance (Alvar et al., 2017; Hartono et al., 2024). As a result, training programming as provided in training methods is one of the keys to optimizing physical performance. A good training program improves numerous essential components of a sport (Saifu et al., 2021; Sulistiyono et al., 2021; Yulianto & Yudhistira, 2021). Aside from that, good training approaches have undoubtedly been used in prior studies with a consistent level of effectiveness

(Purnawan et al., 2022; Yulianto & Yudhistira, 2021). The complex training method is an appropriate option for enhancing physical condition in basketball (Nikolic et al., 2017). One variation of the complex training method is a combination of plyometrics and weight training (Cavaco et al., 2014).

Several studies have highlighted the effectiveness of complex training methods, including a study by Freitas et al comparing optimal load vs modified complex training methods on dynamic upper and lower body strength, 10-meter speed, countermovement jump, standing long jump, and change of direction (Freitas et al., 2019). In this study, the effectiveness of complex training on vertical jump performance (Dan et al., 2014), and the short-term effects of complex training on agility performance of soccer players (Cavaco et al., 2014). Complex training exercises for ten weeks twice a week have a significant influence on the leg muscle power of basketball players (Dejan, 2012).

The effect of a constant resistance training complex versus a variable resistance training complex on physical performance (Shi et al., 2022), boosting physical performance with a complex training intervention for three weeks (Šebić et al., 2023), and improving sprinting with complex training methods in young basketball players (Nikolic et al., 2017). Several studies have shown that delivering interventions utilizing complex training methods has a positive effect on physical performance in sports games.

The author carefully examined the research listed above, which concentrated on improving power, maximum strength, and speed while not measuring aerobic endurance. Naturally, this raises the concern of whether complex training may improve aerobic endurance. Aside from that, the intervention was relatively short-term, with only three weeks of training and sixteen meetings. According to recent studies, the suggested duration of training to develop power using plyometrics is 8 to 12 weeks; anything less than that is not considered desirable (Kumar et al., 2023). Furthermore, past research did not include consecutive and periodic testing. The samples utilized in some of the research above were not controlled in a single mesh. When athletes are not controlled in one mesh, external influences can impact the outcomes of physical performance. In this case, the author considers that additional empirical studies are needed to investigate the impact of complex training on the physical performance of adolescent basketball players.

As material for rationalizing the problem, the author gives observational and interview evidence that the physical training methods that have been devised are being implemented successfully. However, the author argues that various factors are critical, such as the use of training dosages that are not optimal in terms of intensity and volume. For example, the use of strength exercises aimed at developing speed and strength does not meet the parameters of intensity. Of course, when they are not well organized, the results are less than optimal. Furthermore, movement characteristics are naturally used to calculate the intensity of plyometric training, and the number of foot contacts made during landing is used to calculate volume as a parameter for establishing the training dose (Pramono et al., 2023). However, in practice, this type of regulation is not followed. According to studies, the exercise dose is related to a drug dose: if given more than the dose, it will result in an overdose,

and if given less, it will not affect the body (Gronwald et al., 2020; Maslov et al., 2018; Yudhistira, 2023). The same is true for physical training; if the training dose exceeds capacity and there is no recovery setting, overtraining will occur, but supplying a lower training dose will not result in training adaptation (Gronwald et al., 2020; Maslov et al., 2018). As a result, physical exercise must be carried out regularly, with an appropriate training load and the principle of individuality (Gronwald et al., 2020).

In this context, the author's goal is to cover the gap left by earlier studies by carrying out a more comprehensive study into the use of complex training methods to enhance the physical performance of adolescent basketball players. The purpose of this study is to determine the effectiveness of the complex training method increases running speed, leg muscle power, agility, and aerobic endurance. The author conducted three tests in this study. The first test is a pretest, which is completed before the intervention is administered. The second test takes place after the intervention has been running for 16 meetings, to assess progress and evaluate training. The final test, or the post-test, is administered after the intervention is completed or after 24 meetings. Testing is carried out separately from administering the intervention. The authors hypothesize that the complex training method will improve adolescent basketball players' aerobic endurance, running speed, leg muscle power, and agility. It is intended that this study will make a significant contribution by providing the most recent empirical data on the efficiency of complex training methods for adolescent basketball players.

Materials and Methods

Study Participants

This study is a field testing experiment using a one-group pretest-posttest design. The study included 16 adolescent basketball players from the Generasi Muda Cirebon Basketball Club in West Java, Indonesia, between the ages of 17 and 20, weighing between 60 and 80 kilograms and standing between ± 170 -190 centimeters tall. The collection of data techniques includes observations to identify phenomena in the training area, physical measurement tests, and document analysis in the form of articles in relevant journals as material for rationalizing problems. The sampling technique was purposive, with the following criteria: (1) basketball players who train at the Generasi Muda Cirebon Club, (2) male, (3) attending the Generasi Muda Cirebon Club daily, and (4) being in good health or not incurred an injury. Aerobic endurance, short running speed, agility, and leg muscular power are the physical aspects tested. The instruments used were the Multistage fitness test, 20-meter sprint acceleration, lane agility, and jump DF.

Study Organization

The authors conducted an observational study at the Generasi Muda Cirebon basketball club, with a thorough analysis focusing on the physical aspects. Several problems have been uncovered in various physical aspects that are significant in basketball matches. Aside from that, the author analyzed various journal-based articles that focused on experimental investigations with complex training program

Table 1. Complex training program

Week	Meeting	Exercise	Intensity	Rep/Jump	NC	NS	PC	PI	RS
1-4	1-8	WT	60-70% (1RM)	8-12 rep	4	4	30 s	0-10 s	3 min
		Plyo	Maximal	84-92 jumps					
5-8	9-16	WT	70-75% (1RM)	8-10 rep	4	4	30 s	0-10 s	3 min
		Plyo	Maximal	92-100 jumps					
9-12	17-24	WT	75-80% (1RM)	5-8 rep	4	4	30 s	0-10 s	3 min
		Plyo	Maximal	100-112 jumps					

Description: WT-weight training, Plyo-Plyometrics, NC-Number of Complexes, NS-Number of Sets, PC-Pause between Complexes, PI-Pause between items, RS-Rest between Sets

interventions on team and game athletes to boost the authors' research. To make it clearer, the program is presented in Table 1 as follows:

The training program lasted 12 weeks with a total of 24 meetings. The frequency of training in one week is 2 times to optimize the recovery process. Complex training is conducted during the initial special preparation stage to prepare for matches against national clubs. This signifies that the previous stage, which included general preparation for training in areas such as maximum strength, hypertrophy, muscle endurance, and aerobic and anaerobic endurance, has been completed previously. As a result, this specific period serves as the conversion phase for power training. This training sequence lasts about 90 minutes and consists of three parts: dynamic static stretching (15 minutes), core complex training (60 minutes), and cool-down (15 minutes). One training complex consists of one weight training exercise item and one plyometrics exercise, administered with a 10- to 30-second break. In one weight training activity, there is a 0-10 second break followed by plyometric exercises. One series consists of completing four complexes, resulting in a three-minute break. The intensity of weight training exercises begins at 60% and gradually increases to 80%. The repetitions at 60% intensity are 10-12, 70%-75% are 8-10, and 80% are 5-8. Weight-training exercises include barbell squats, leg presses, leg extensions, leg curls, and standing barbell calf raises. The intensity of plyometric training is determined by the movements utilized; for example, bilateral movements in the ladder box are classified as low-level plyometrics, whereas jumping one leg from the ladder box is classified as intense plyometrics (Davies, 2015). In this case, the plyometrics used are high intensity plyometrics training items used are tuck jump, box jump, hurdle jump, reactive depth jump box, depth jump with sprint. In this case, the plyometrics are performed at a high intensity. Tuck jumps, box jumps, hurdle jumps, reactive depth jump boxes, and depth jumps with sprints are examples of plyometric training exercises used. In terms of determining the volume of plyometrics training in one session, if the number of jumps is 60, it is included in the low-volume category, and more than 200 jumps are included in the high-volume category (Chu & Myer, 2013).

Statistical Analysis

The training program was carried out in 24 meetings. The test was carried out three times. Before carrying out the

training program, a pretest was carried out, after meeting 16 a second test was carried out, after meeting 24 a posttest was carried out. This means that by running these three tests, it will be discovered the comprehensive effectiveness of the programming of the training complex.

The data analysis technique employed was quantitative descriptive analysis, which presents minimum, maximum, mean, and standard deviation values. To compare the pretest and posttest results from the first, second, and third tests, an alternative nonparametric test using Friedman analysis from Anova was utilized, which was assisted by the SPSS version 23 application (Hadi & Yudhistira, 2023; Sulistiyono et al., 2021; Yudanto, Suherman, et al., 2022; Yudanto, Yudhistira, et al., 2022).

Results

Table 2. Results of data descriptions of endurance, speed, agility, and power

Variable	Min	Max	Mean	Std. Dev
Aerobic Endurance Test 1	47.01	57.04	48.53	3.29336
Aerobic Endurance Test 2	47.09	62.02	50.01	4.20972
Aerobic Endurance Test 3	49.01	63.01	52.47	4.37947
Speed Test 1	2.96	3.45	3.20	0.14098
Speed Test 2	2.96	3.42	3.18	0.12990
Speed Test 3	2.08	3.21	2.97	0.33097
Agility Test 1	11.31	12.26	11.66	0.25591
Agility Test 2	11.27	12.58	11.70	0.42556
Agility Test 3	10.09	11.41	10.57	0.43995
Leg Power Test 1	60	72	66	4.143
Leg Power Test 2	60	72	65	3.594
Leg Power Test 3	64	76	69	3.715

According to the results of the descriptive analysis presented in Table 2, the average score for the first endurance test is 48.53, the second is 50.01, and the third is 52.47. The average speed test score for the first is 3.20, the second is 3.18, and the third is 2.97. The first agility test yielded an average of 11.66, the second 11.70, and the third 10.57. The first leg muscle power test resulted in an average of 66, followed by 65 and 69. The mean values obtained from the first, second, and third tests for endurance, speed, agility, and leg muscular power showed a tendency to increase.

Table 3. Results of Friedman Test Analysis

Test	Mean Rank	Asymp.Sig	Information
Aerobic Endurance Test 1	1.00		Significant differences were found
Aerobic Endurance Test 2	2.00	0.000	
Aerobic Endurance Test 3	3.00		
Speed Test 1	2.88		Significant differences were found
Speed Test 2	2.09	0.000	
Speed Test 3	1.03		
Agility Test 1	2.47		Significant differences were found
Agility Test 2	2.53	0.000	
Agility Test 3	1.00		
Leg Power Test 1	1.56		Significant differences were found
Leg Power Test 2	1.44	0.000	
Leg Power Test 3	3.00		

Based on the results of Friedman's analysis presented in Table 3, the Asymp.sig scores for endurance, speed, agility, and power are all less than 0.05. As a result, it would be feasible to explain why the average increase varies between the three measurement interval groups. In other words, complex training programs can improve physical aspects such as endurance, speed, agility, and leg muscular power in adolescent basketball players.

Discussion

The Friedman analysis results show that the endurance aspect has an Asymp.sig value of $0.000 < 0.05$, followed by speed, agility, and power at $0.000 < 0.05$. These findings demonstrate that the average score in the physical aspects such as endurance, speed, agility, and leg power varies between the three measurement time interval groups. The key finding was that 24 meetings of complex training increased physical aspects such as endurance, speed, agility, and leg muscle power. If we look attentively, the physical aspects of the first, second, and third tests differ significantly. The first test in this study was a pretest. The second test, which involved intervention across 16 meetings, revealed a significant improvement, particularly in agility and leg muscular power. However, it does not end there; after 24 intervention meetings, these three physical aspects showed greater improvement than the second test. In other words, even in the second test, there was an improvement, but the rise could not be considered permanent. Previous studies revealed that intervention over 8 meetings can alter performance, either increasing or decreasing, whereas intervention over 16 meetings or more has a permanent change impact (Faizal et al., 2019; Yudhistira, 2023). In addition, the novelty of the study was obtained, namely the novelty of the measurement test method which previously only carried out pretests and posttests in this study using three tests to see the improvement. Then previous studies focused on increasing power, but in this study the authors added an independent variable, namely endurance.

Basketball players require physical skills such as running movements to attack. Meanwhile, to survive fast, speed is required, which is associated with running. Furthermore,

agility and leg muscular power are vital when running simultaneously while shooting and jumping into the ring or running past the opponent in front of him (Hadi et al., 2022). Aside from that, endurance is essential when performing these movements repeatedly. As a result, the role of physical conditioning in basketball is very complex (Hadi et al., 2022; Hidayah & Akhiruyanto, 2023) In this case, different complexity training is required to optimize the physical condition. This is, of course, extremely important for sports practitioners and academics; earlier research reported a large reduction in adolescent basketball players during the competition season, implying that complex training is an alternative method for enhancing good physical aspects (Freitas et al., 2019).

Complex training is a physical training method for basketball players that aims to optimize physical condition to the maximum extent feasible (Aksovic et al., 2021). Complex training is high-intensity exercise training that includes maximum strength and explosive strength training (Aksovic et al., 2021). Complex training is distinguished by weight training exercises that are subsequently channeled into plyometric exercises (Aksovic et al., 2021). Furthermore, from a biomechanical perspective, complex training exercises must be adjusted to include muscle and joint involvement between weight training and plyometrics exercises to achieve optimal results (Mansur, 2016). For example, we can do complex training exercises for the lower extremity muscles with squats for 3-6 repetitions, followed by plyometrics tuck jump exercises for 8-12 repetitions, and then complex training exercises for the upper extremities, such as bench press 2-5 repetitions followed by plyometrics push up for 8 repetition (Mansur, 2016).

Complex training affects physical performance in team and individual sports, including power, speed, and agility (Mansur, 2016). According to studies, variable-resistance complex training is as effective as standard complex training in developing power and sprint speed in rugby (Scott et al., 2023). Variable resistance complex training, in particular, increased relative strength more than traditional complex training, which increased 10 and 20-meter sprint speed. According to other studies, complex training improves sprint performance, making it one of the training options for game sports (Scott et al., 2023). A comparable study attempted to assess optimal load training methods with modified complex training in basketball players, and the results showed that both methods were equally effective in building lower-extremity strength and power (Freitas et al., 2019). In this situation, complex training significantly improves the vertical jumping capacity of adolescent basketball players (Dan et al., 2014). The enthusiasm of sports academics, particularly for improving the physical condition of basketball players, does not end here. This is supported by the most recent research on complex training methods that are modified in the form of speed, agility, and quickness training by monitoring individual training doses during the three-week intervention, which shows that there is an improvement in the physical condition of speed endurance, aerobic endurance, speed acceleration, agility, and leg muscle power (Šebić et al., 2023).

However, in this situation, the use of the complex method of training must be tailored to the training stages. Complex training focuses on strength and power training

using external loads, as well as power training employing plyometric training methods. This suggests that strength is essential for developing power, speed, and agility (Nasrulloh et al., 2023). Furthermore, basketball players can improve their aerobics endurance with complicated exercises. Of course, basketball players have previously completed general and anaerobic endurance training. In line with previous studies, the initial part of complex training is used as basic preparation, and development of general endurance and strength endurance so that basketball players are ready to practice complex training with high intensity (Nikolic et al., 2017).

Therefore, when a basketball player begins to train utilizing a complex training method, they must first establish a solid foundation, keeping in mind that strength training affects the optimization of gaining power. Trainers must pay particular focus to maximum strength data when determining the intensity of weight training exercises to be paired with plyometric training. The basic requirement for high-impact plyometrics training is that the athlete should meet some criteria, including the ability to perform a barbell back squat weighing 1.5 of the athlete's body weight (Pramono et al., 2023). In this study, all basketball players who received intervention with complex training met the criteria by completing maximum strength and aerobic endurance training in the previous stage. Thus, it can be concluded that giving a complex training program is a safe way to optimize the physique of young basketball players. But by paying attention to the periodization of exercise and the right dose of exercise.

Developing basketball players is more complicated than just twisting our hands. Coaches must comprehend the characteristics of individual athletes and teams. As a result, the coaching principle is how athletes can learn in all areas of education, both at and outside of school (Armour, 2013). According to the study, this is related to pedagogical principles, namely guidelines and procedures for learning sports-specific abilities (Lee et al., 2014). Furthermore, the most important rule is how to properly implement learning so that athletes benefit individually, as a team, socially, and in good health (Armour, 2013)

Conclusions

Mean scores varied between the first, second, and third tests in all physical aspects, including aerobic endurance, speed, power, and agility. The Asymp. sig (2-tailed) value for all aspects was $0.000 < 0.05$, indicating a significant difference. Based on the findings and discussion, it is possible to infer that the sequential complex training method used in the first, second, and third tests resulted in significant differences in aerobic endurance, speed, leg muscle power, and agility among adolescent basketball players. However, this study has limitations for its sample size which was only 16 male athletes, with no comparison group. It is thus expected that more studies could fill this research gap and generate more comprehensive results.

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Conflict of interest

All authors declare no conflict of interest.

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Впровадження комплексного методу тренування: Вплив на показники витривалості, швидкості, сили та спритності баскетболістів підліткового віку

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

Реферат. Стаття: 7 с., 3 табл., 37 джерел.

Мета дослідження. Метою цього дослідження було вивчити вплив ефективності комплексного тренування на показники аеробної витривалості, швидкості, сили та спритності у баскетболістів підліткового віку.

Матеріали та методи. У дослідженні застосовано метод польового експериментального спостереження. Була проведена цілеспрямована вибірка, учасники якої відповідали наступним критеріям: (1) баскетболісти, які тренувалися в одному клубі, (2) чоловічої статі, (3) проводили щоденні тренування в одному клубі, (4) мали добрий стан здоров'я. Загалом було залучено 16 учасників з масою тіла 60-80 кг і зростом 170-190 см. Для отримання необхідного матеріалу використовувалися методики збору даних спостережень, огляд відповідних статей і тести. З метою забезпечення оцінки фізичних аспектів були застосовані наступні тести та інструменти: цифровий вимірювач, що розраховує висоту вертикального стрибка, човниковий біг, спринтерський біг на 20 метрів, тест на спритність на доріжці. Методика аналізу даних за критерієм Фрідмана була проведена шляхом застосування статистичного програмного забезпечення SPSS 23.

Результати. Середній бал першого тесту на витривалість склав 48,53, другий і третій тести продемонстрували результати 50,01 і 52,47, відповідно. Аналогічним чином, середній бал за перший тест на швидкість становив 3,20, другий був на рівні 3,18, а третій – 2,97. Середній бал першого тесту на спритність склав 11,66, другого показав 11,70, а третього – 10,57. Середній бал першого тесту на визначення сили м'язів нижніх кінцівок склав 66, а другого і третього тестів – 65 і 69, відповідно. Для визначення відмінностей в показниках аеробної витривалості, швидкості, потужності та спритності використовували змінні критерію Фрідмана, загальний рівень значущості становив $0,000 < 0,05$.

Висновки. Впровадження комплексної методики тренування протягом 24 тренувальних сесій забезпечило значне підвищення показників аеробної витривалості, швидкості, сили та спритності юних баскетболістів.

Ключові слова: силове тренування, пліометрика, комплексне тренування, баскетболісти підліткового віку.

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Using Programmable Device Installations to Control Students with Disabilities after Blast Traumatic Brain Injury in 10 Meter Walking Test

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Abstract

Objectives. This study aimed to determine the degree of authenticity for the test implemented using a programmable installation for monitoring the functions of functional mobility, gait, and the state of the vestibular apparatus in students with disabilities who have sustained a blast traumatic brain injury.

Material and methods. The study included a total of 39 first-year students with disabilities after an explosive brain injury. The following methods were used: theoretical analysis of scientific and methodological literature, the method of technical modelling, pedagogical testing, pedagogical experiment, and methods of mathematical statistics. In order to ascertain the efficacy of the proposed intervention, a 10-meter walking test was conducted.

Results. The result of our study was the development using information systems and networks of a programmable device for the implementation of the 10-meter walking test, which is used to monitor the recovery of functional mobility, gait, and the state of the vestibular apparatus in students with disabilities after an explosive brain injury. The installation was based on a network of sensors organized according to the Arduino microcontroller platform. Acoustic, optical sensors, distance sensors, proximity sensors, presence sensors, and spatial position sensors have been placed to record the results of the test distance. The sensors, having received an information signal about the student passing the test, transmit it to the controller. In the controller, information is identified, processed, calculated and transferred to a personal computer, where it is displayed on the screen and reproduced graphically. The software ensures maintainability throughout the test, as well as efficiency of data processing, calculation of required parameters and their storage. Data processing is implemented using image analysis systems based on neural networks. According to the findings of testing and correlation analysis, indicators' authenticity degree for the used tests were established, which differed by the means of measuring the results. The level of correlation coefficient between the values for test reliability and validity in the case of fixing the test results using a stopwatch was not found to fall within the "low" and "acceptable" limits, while in the second case, when the results were fixed by a programmed control unit, it reached the "high" level.

Conclusions. The use of the developed programmable device in the practical work of inclusive PE provides convenience, functionality, objectivity and reliability of control in the process of rehabilitation of students with disabilities after an explosive craniocerebral injury. What is confirmed by the values of the test authenticity measure obtained during the experiment when fixing the results by the developed installation.

Keywords: students with disabilities, blast traumatic brain injury, physical education, testing, inclusion, control, authenticity.

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Introduction

From February 24, 2022, Russia's full-scale aggression against Ukraine continues. In addition to protracted hostilities, the aggressor's army is shelling the civilian population daily. As a result, the number of people, including military personnel, children, and civilians, affected by the aggression of the Russian Federation with war injuries is permanently increasing (Dzyak et al., 2023).

Despite the lack of accurate statistical data for the period of the war in Ukraine, Ukraine has not yet encountered such a large number of complex injuries. Injuries as a result of war are characterized by considerable diversity, but according to data, 99% of victims have mine-explosive injuries, among which brain injuries are considered the most complex – blast traumatic brain injury (TBI) (U.S. Department of Veterans Affairs. Office of Research and Development, Veterans Health Administration, 2007).

According to (Chapman & Diaz-Arrastia, 2014), the number of blast TBI from blast wave action, which has no analogs in the clinic of peacetime diseases, is astounding. According to evidence (Mac Donald et al., 2014), among all injuries received during the war: 35-40% are head injuries, of which 80 % is blast TBI. According to data (VA research on Traumatic Brain Injury, 2019), the majority of blast TBIs associated with military actions and received by civilians are classified as mild.

Due to the fact that individuals with disabilities due to blast TBI are becoming students in increasing numbers, the higher school has found itself at the epicenter of serious challenges. The need to provide conditions for the restoration of the health status of students with disabilities after blast TBI in the process of education is growing due to the challenges of the long war, which determines the relevance of scientific intelligence.

The problem of improving the health status of students with disabilities after blast TBI becomes especially urgent given the fact that the timely restoration of the functions is a factor in preventing physical maladaptation of such students and ensuring the further ability to effectively perform their professional activities (Blavt & Gurtova, 2023; Hellweg & Johannes, 2008).

In higher education, the rehabilitation function of students with disabilities is considered in the context of inclusive PE (Rekaa, Hanisch, & Ytterhus, 2019). It has been studied (Haarbauer-Krupa et al., 2021) that the effectiveness of recovery after blast TBI depends on expertise, timeliness, qualified approaches, and a list of rehabilitation measures (Bramlett & Dietrich, 2015; Hellweg & Johannes, 2008). After analyzing the scientific literature, it was found that physical activity is considered an important means of rehabilitation after a blast TBI (Wise et al., 2012; Physical Activity Guidelines for Traumatic Brain Injury; Fulk & Nirider, 2014).

It should be noted that scientists have a common belief (Kuntjoro et al., 2022; Page et al., 2021) that the main thing in the process of inclusive PE is compliance with the requirements of time (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023). It has been studied that in the presence of modern technologies and equipment, the learning and PE process becomes more applied, motivating, actionable and diverse (Pellerin, Wilson, & Haegele, 2022; Blavt, Chaplinskyi et al., 2023).

There is a large list of studies on the feasibility and necessity (given the need to eliminate the influence of the human factor) of using information systems and networks, created on the basis of electronic technologies that are used in the PE process (Mykytyuk, Blavt et al., 2022; Varga & Révész, 2023; Gupta, 2021).

Purpose of the research is a determination of the degree of authenticity of the test implemented using a programmable installation for monitoring the functions of functional mobility, gait, and the state of the vestibular apparatus in students with disabilities after blast TBI.

Materials and Methods

Research Methods

The conducted research belongs to the randomized controlled type of empirical research. The experiment was implemented in two stages. The following methods were used: theoretical analysis of scientific and methodological literature, the method of technical modeling, pedagogical testing, pedagogical experiment, and methods of mathematical statistics.

The first stage consisted in the development of a programmable control unit using information systems and networks. For this, the method of technical modeling was used.

The second stage involved the implementation of a pedagogical experiment. The experiment consisted in the implementation of pedagogical testing, during which the control of functional mobility, gait, and the state of the vestibular apparatus (to determine functional mobility, gait, and vestibular function) was implemented in students of the studied sample.

The 10 Meter Walk Test was used in the study (Gafner, & Bruyneel, 2022). The appropriateness of choosing this test was that its use provides ease of control and assessment of measuring locomotor capacity in clinical and research settings (to measure locomotor capacity in clinical and research settings (de Baptista et al., 2020) which are recommended for monitoring the rehabilitation process for various diseases (Unver et al. 2017).

It is considered (Physiopedia), the scale properties (time in seconds or m/s) of the 10 Meter Walk Test make it a responsive test well suited to evaluating clinical interventions.

Test procedure. Equipment Required: a clear pathway with a set distance (6, 8, or 10 meters in length depending on distance tested). The student must walk 10 meters unaided, with the intervening 6 meters timed to account for acceleration and deceleration (Fig. 1). The time is recorded (to the nearest second) and the walking speed is calculated.

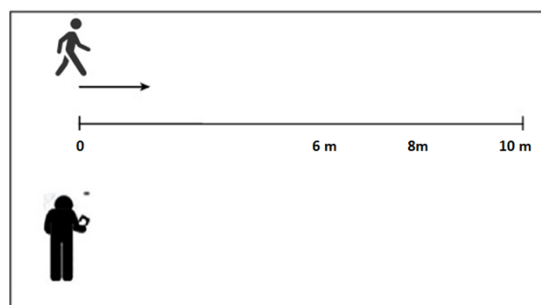


Fig. 1. Scheme of the test

The student walks without assistance for 10 meters, with the time measured for the intermediate 6 meters to allow for acceleration and deceleration. Perform three trials and calculate the average of three trials. Scoring: The time (to the nearest second) is fixed.

Study Participants

39 students in the 1st year of studies with disabilities as a result of the blast TBI, were involved in the study from Lviv Polytechnic National University, Kamianets-Podilskyi Ivan Ohiienko National University, Lviv State University of Physical Culture named after Ivan Boberskyj and Lutsk National Technical University.

To implement the empirical part of the study, a research sample was formed. The selection of students for the experiment was randomized, taking into account personal consent to the collection and systematization of control information in an anonymized form for further statistical analysis. The gender factor was not taken into account, since no evidence of the influence of gender has been found on the quality indicators of the test.

The criteria for inclusion in the studied sample were the presence of the anamnesis of students with mild blast TBI disability, obtained as a result of the war, and being in a state of restoration of lost functions. The criteria that did not allow students with disabilities after blast TBI to participate in the study were the presence in the anamnesis of deformities and diseases affecting walking, the inability to move without aids (crutches, walking sticks), the presence of chronic health conditions and combined injuries.

The study was planned and carried out following the principles of bioethics set forth by the World Medical Association (WMA-2013) in the Helsinki Declaration "Ethical Principles of Medical Research Involving Humans" and UNESCO in the "General Declaration on Bioethics and Human Rights".

Research Organization

A comparative pedagogical experiment was carried out to determine the effectiveness of the means of control. As an experimental factor, a means of registering the results was used. In the first case, the registration of the results took place using a stopwatch and was carried out by the teacher.

Average time and speed of the walk (10 m) and mid-walk (6 m) obtained at a self-selected fast pace were analyzed. Participants were tested on the 10MWT twice: at baseline (test) and after seven days (retest). The outcome variable was mean speed. The results of the average arithmetic value of three attempts were used in the conclusions.

On the contrary, in the second case, the registration of the results took place using the programmable installation developed during the research, which ensured the calculation of all the necessary parameters automatically.

Statistical Analysis

Statistical analysis was used as a data analysis tool in our study. The obtained data from such an analysis became the basis of substantiated conclusions of the study of the degree of authenticity of the used test. In our case, such data served

as the intraclass correlation coefficient, which is an indicator of the quality characteristics of the test as a measurement tool, namely its reliability and validity values. Intraclass correlation coefficient determined by correlation analysis.

All statistical analyses were performed using SPSS Version 22.0 (IBM Corporation).

Results

First of all, our experiment is based on the characteristics of blast TBI and the consequences for the body that accompanies it. It should be taken into account that BI, which occurs as a result of the action of a mine blast wave and has received the name blast TBI, is significantly different from that which occurs as a result of the action of other factors (impact, sports injuries, etc.) (Denby et al., 2020; Capizzi Woo & Verduzco-Gutierrez 2020).

Understanding the mechanisms of blast overpressure injury is important to finding ways to repair it (Nelson, Davenport, Sponheim, & Anderson, 2015). Therefore, in the PE process, it is necessary to take into account the impact of blast TBI on numerous vital functions, which can have a significant long-term impact on health (Bryden, Tilghman, & Hinds, 2019), since blast TBI is described as a chronic health condition (Haarbauer-Krupa, Pugh, Prager, Harmon, Wolfe, & Yaffe, 2021).

The peculiarity of blast TBI is that it can be accompanied by damage to the auditory and vestibular apparatus (Denby et al., 2020) and lead to a persistent vegetative state of disturbance in the activity of the central nervous system (Mac Donald et al., 2014). The result of such lesions is a motor deficit, consisting of a violation of body balance (DePalma, 2015), and a long-term motor deficit (Bramlett, & Dietrich, 2015). The result is a loss of stability and balance during walking and other locomotor movements (getting out of bed, chair, etc.) (Corwin et al., 2015).

Therefore, to ensure the efficiency and speed of recovery, specialists (Briskin, Odinet & Pityn, 2015) focus their attention on finding ways to effectively control this process, as a result of which tests become more and more diverse and complex to implement best practices for timeliness of intervention, monitoring and evaluation states after blast TBI (Haarbauer-Krupa et al., 2021).

The result of our research was the development, using information systems and networks, of a programmable installation for monitoring the restoration of functional mobility functions, gait, and the condition of the vestibular apparatus in students with disabilities after blast TBI.

The basis of the installation (Fig. 2) (Mykytyuk et al., 2024) was a sensor network organized based on the

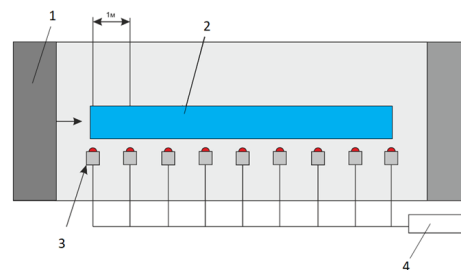


Fig. 2. Scheme programmable installation (1 – start, 2 – track for passing the test, 3 – a system of sensors, 4 – data processing system)

Arduino microcontroller platform. Acoustic, optical, range, proximity, presence, and spatial position sensors are placed to record the test distance results (Mykytyuk, Blavt et al., 2022), which have different purposes in our installation. However, all sensors are assembled in a set, united by a common program for storing, processing, and displaying test data on a personal computer.

Sensors are placed at control points to record the beginning of the test process, the intermediate 6 meters, and the end of the test. In this way, it is possible to record whether a student walks 10 meters, without outside help, without losing balance, and at a constant speed. The determination of the time of movement between points is provided by the developed software.

A “smart system” with optical sensors is built into the device to measure the student’s position in space when performing a test exercise that assesses the state of functional mobility and balance while walking. Such a system, with the help of a neural network, analyzes the position and movements of the student during the test and automatically records all the studied parameters and the presence of deviations from the norm.

In the developed installation, sensors are placed directly on the student’s body. In this way, we ensure the reliability of the measurement of all parameters of coordination, balance, and functional mobility. A feature of the developed software installation is that such measurements can be carried out without sensors located at control points of the test distance.

The sensors, having received an information signal about the student passing the test, transmit it to the controller. In the controller, information is identified, processed, calculated, and transferred to the personal computer (PC). On a PC, the test results are displayed on the screen and reproduced graphically.

The software implements maintainability throughout the test, efficiency of data processing, calculation of necessary parameters, and storage. Data processing is implemented using image analysis systems based on neural networks.

The second stage involved the implementation of a comparative pedagogical experiment. According to the results of testing and correlation analysis (Table 1), indicators of the degree of authenticity of the used tests were established, which differed in the means of measuring the results.

Table 1. Degree of authenticity of the 10 Meter Walk Test for students with disabilities after blast TBI (n = 39)

	r _{tt}	S	PI	S	PI	S	PI	S	PI
reliability	0.588	0.891	0.611	0.922	0.594	0.912	0.591	0.933	
validity	0.215	0.218	0.616	0.609	0.220	0.618	0.223	0.601	

* Note: S – fixing the results with a stopwatch, PI – fixing the results with a programmable installation

The level of the correlation coefficient of the values of test reliability and validity in the first case (fixing the results with a stopwatch) was not at the limit of “low” and “acceptable”, in the second case (fixing the results with a programmable installation for monitoring) it reached the level of “high”.

Discussion

Before the war, the issue of inclusion attracted considerable attention, however, as a result of the war, the issue of inclusive PE in higher education, given the humanitarian trends during emergencies (Congressional Research Service, 2019), gained special importance. The research conducted extends the data of previous studies (Blavt, Bodnar et al., 2023; Blavt, Iedynak et al., 2023) that the evolution of inclusive PE to meet the challenges of today, which are caused by Russia’s long-term aggression against Ukraine requires the search for innovative solutions to ensure proper conditions for recovery after injuries of students with disabilities.

Researchers see the solution to this issue in constructive and technological solutions based on the use of modern information technologies (Varga & Révész, 2023; Gupta, 2021; Cuthbert et al., 2014), which is currently is the most dynamic segment of software engineering development.

The effects of blast TBI remain a serious source of injury for armed forces and civilians in combat zones worldwide (Xiang et al., 2022). Blast injuries have been identified as a new entity with specific characteristics. Blast injuries have been identified as a novel entity with specific characteristics (Maas et al., 2008; Merritt et al., 2015). Physical activity is considered by experts as a powerful means of non-pharmacological recovery after blast TBI (Physical Activity Guidelines for Traumatic Brain Injury; Fulk & Nirider, 2014;

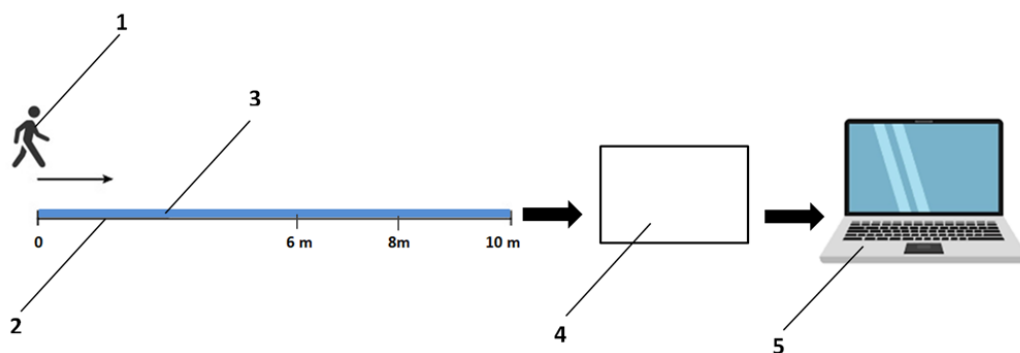


Fig. 3. Scheme using a programmable installation for 10 Meter Walk Test (1 – student, 2 – track for passing the test, 3 – a system of sensors that determine the time of passage of each section of the system to determine the speed and its changes during walking, 4 – controller, 5 – PC)

Johnson et al., 2023), control, as proven (Bland et al., 2011; Fure et al., 2021), having an exploratory and evaluative nature, is the basis of evidence-based rehabilitation. The need for such studies is due to the lack of randomized trials establishing the effectiveness of rehabilitation after blast TBI (Xiang et al., 2022).

Tests that use the function of walking are quite widespread in the practice of monitoring the rehabilitation process in persons with amputations (Brooks et al., 2001), cardiovascular diseases (Bellet et al., 2012; Hanson et al., 2012; Casillas et al., 2013), with total hip arthroplasty (Yuksel, Unver, Kalkan, & Karatosun, 2021), brain injuries (SCIRE-PROJECT), in muscular dystrophy (Pizzato et al., 2016), in neurological diseases (Tyson & Connell, 2009) and even in children, during their development (de Baptista, et al., 2020).

A certain list of works is devoted to the determination of quality indicators of tests using walking for a certain distance in relation to various studied contingents. In particular, young healthy adults (Smith-Turchyn et al., 2021), persons with total hip arthroplasty (Yuksel et al., 2021), in typically developing children (de Baptista et al., 2020), persons with lower limb prostheses (Sawers et al., 2020). However, studies on the use of distance walking tests for students with disabilities after blast TBI have not yet been conducted.

On the other hand, we agree with our research on the use of test results to monitor the progression of disability. This was confirmed by previous studies (Pizzato et al., 2016).

The results of our previous research on the expediency of using technical means in the implementation of the control process in inclusive PE have been supplemented. Considering that specialists recommend repeating the test after certain periods (Pizzato et al., 2016), the developed setup makes it possible to implement such control with the least loss of time.

Conclusions

Inclusive PE in times of war faces new challenges. As a result of the armed aggression of the Russian Federation, due to shelling and explosions, the structure of the contingent of students with disabilities was significantly affected: now students with disabilities after blast TBI are the largest contingent.

Blast TBI is considered a problem that goes beyond the scope of BI and is positioned as a multiple injuries, which is included in the concept of mine-explosive injury and requires a comprehensive approach in the implementation of the recovery process.

Developed with the use of information systems and networks, the programmable device for monitoring functional mobility, gait, and the state of the vestibular apparatus in students with disabilities after blast TBI integrates modern electronic technologies and a package of system application programs.

The use of the developed programmable installation in the practical work of inclusive PE provides convenience, functionality, objectivity, and reliability of control in the process of rehabilitation of students with disabilities after blast TBI. What is confirmed by the values of the measure of authenticity of the test obtained during the experiment in the case of fixing the results by the developed setup: The calculated values of the coefficients reach the "high" level,

which allows us to assert the objectivity of the control of the studied parameters.

Conflicts of Interest

No conflicts of interest exist.

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Застосування здобувачами вищої освіти з інвалідністю після вибухової черепно-мозкової травми установки для контролю у 10-метровому тесті ходьби

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

Реферат. Стаття: 9 с., 1 табл., 3 рис., 55 джерел.

Мета дослідження – визначити ступінь автентичності у 10-метровому тесті ходьби, реалізованого з використанням розробленої програмованої установки контролю відновлення функцій функціональної рухливості, ходи та стану вестибулярного апарату у здобувачів вищої освіти з інвалідністю після вибухової черепно-мозкової травми.

Матеріал та методи. 39 студентів I курсу з інвалідністю після вибухової черепно-мозкової травми. Використано такі методи: теоретичний аналіз науково-методичної літератури, метод технічного моделювання, педагогічне тестування, педагогічний експеримент, методи математичної статистики. У дослідженні застосовано 10-метровий тест ходьби.

Результати. Результатом нашого дослідження стала розробка з використанням інформаційних систем та мереж програмованої установки для реалізації 10-метрового тесту ходьби, який застосовується для контролю відновлення функцій функціональної рухливості, ходи та стану вестибулярного апарату у студентів з інвалідністю після вибухової черепно-мозкової травми. Основою установки стала мережа сенсорів, яку організували на базі мікроконтролерної платформи Arduino. Для фіксації результатів по дистанції проходження тесту було розміщено акустичні, оптичні датчики, датчики дальності, наближення, присутності та положення у просторі. Датчики, отримавши інформаційний сигнал про проходження тесту передають його на контролер. У контролері інформація індифікується, обробляється, обчислюється та передається на персональний комп'ютер, де відображаються на екрані та відтворюються графічно. Програмне забезпечення реалізує супроводження впродовж усього тесту, ефективність обробки даних, обчислення необхідних параметрів та їхнє зберігання. Обробка даних здійснюється з використанням систем аналізу зображень на основі нейромереж. За результатами тестування та кореляційного аналізу було встановлено показники міри автентичності використаних тестів, які відрізнялись засобами вимірювання результатів. Рівень коефіцієнта кореляції значень тестової надійності та валідності у разі фіксації результатів тестування з використанням секундоміра перебував не межі "низької" та "прийнятної", у другому, коли фіксували результати програмованою установкою контролю, – досягав рівня "високий".

Висновки. Використання у практичній роботі інклюзивного фізичного виховання розробленої програмованої установки контролю забезпечують зручність, функціональність, об'єктивність та достовірність контролю у процесі реабілітації здобувачів вищої освіти з інвалідністю після вибухової черепно-мозкової травми. Що підтверджується отриманими в процесі експерименту значень міри автентичності тесту у разі фіксації результатів розробленою програмованою установкою.

Ключові слова: здобувачі вищої освіти з інвалідністю, вибухова черепно-мозкова травма, фізичне виховання, тестування, інклюзія, контроль, автентичність.

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Assessing the Effect of Traditional Games on Manipulative Movements in Elementary School Students Based on Gender

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Abstract

Background. Manipulative movements are essential for children's development, which can be found in traditional games, representing manifestation of local wisdom that has been passed down from generation to generation.

Objectives. This study aimed to examine the effect of traditional games on the manipulative movements of elementary school students based on gender.

Materials and methods. This experimental study comprised two pretest-posttest groups without control variables. Data collection on pretest and posttest was carried out using three types of tests, namely throwing, catching, and kicking. A total of 60 students aged between 9 and 12 years were selected to participate in this study. The sample consisted of 30 male students (height 140.21 ± 6.2 cm, and weight 35.77 ± 5.6 kg), and 30 female students (height 138.4 ± 6.8 cm and weight 34 ± 4.1 kg).

Results. The t-test analysis showed that the test results for male students were as follows: throwing $0.011 < 0.05$, catching $0.007 < 0.05$, and kicking $0.003 < 0.05$. Then, the test results for the female students were: throwing $0.013 < 0.05$, catching $0.017 < 0.05$, and kicking $0.012 < 0.05$. The results of the independent t-test indicated that the throwing, catching, and kicking tests revealed a statistical significance ($p < 0.05$) in both male and female students.

Conclusions. The implementation of traditional games has been found to enhance the manipulative movements of elementary school students, as evidenced by positive changes observed in the pretest and posttest results. The improvement was achieved, among others, through the adaptation of traditional games following the characteristics of students' development. Therefore, the conceptualization of physical learning within the framework of traditional games proved to be applicable and practical.

Keywords: traditional games, manipulative movement, elementary school, children's games.

Introduction

Motor development in elementary school-aged children is an important aspect that influences various aspects of their lives, including learning abilities and social interactions (Samodra et al., 2023). Three types of movements that are important in children's motor development are locomotor movements, non-locomotor movements, and manipulative movements. Locomotor motion refers to physical displacement from one place to another, such as walking,

running, jumping, and crawling. In contrast, non-locomotor motion involves changes in body position without significant physical displacement, such as bending, bending, and twisting (Siregar et al., 2021; Sunanto et al., 2022). On the other hand, manipulative motion is concerned with the use of hands and fingers to control, manipulate, and interact with objects or the surrounding environment, such as grasping, throwing, catching, and cutting (Setyawan et al., 2024).

Traditional games have become an integral part of the culture and history of Indonesian society (Maulidiyyah & Purwoko, 2023). However, with technological advancements and lifestyle changes, traditional games are often marginalized by more passive modern games. It raises concerns about the potential impact on children's motor development of

incredibly manipulative movements (Yilmaz & Griffiths, 2023). Games have a significant impact on the development of manipulative movements in children. The results of previous studies have shown that children who engage in varied physical activities, such as throwing and kicking a ball, crawling around a playground, or holding a pencil while colouring, can strengthen the muscles of their hands and fingers, as well as their legs (Samsudin et al., 2022). Traditional games also provide opportunities for children to engage in sensory exploration by touching, smelling, or sensing different objects, so they help increasing their sensory sensitivity and developing the ability to control movement with more precision (Hartanto et al., 2021; Mujriah et al., 2022).

In addition, games often require strategic thinking and fast movements that require the use of manipulative motions, such as sodor carts, fish nets, and balloon racing games (Septianto et al., 2024). The social interactions that occur during play also contribute to the development of manipulative motions, as children learn to share, communicate, and collaborate with peers or family members through activities involving ball, such as sepak tekong (Anggraini et al., 2023; Mensa et al., 2023). Games provide a fun and engaging context for children to practice manipulative movements without feeling like doing a tedious task or exercise, as they can enjoy playtime while learning and developing. Thus, games are a rich and beneficial means for children to practice and develop their manipulative motor skills in a natural and enjoyable way (Rejeki et al., 2022).

The results of further studies show that traditional games have a significant impact on academic achievement through increasing students' manipulative movements (Nasution et al., 2022). Active participation in traditional games allows students to develop their fine motor skills in a fun and natural way (Hafeez, 2022). This ability is essential in performing academic tasks such as writing, drawing, and colouring. Furthermore, traditional games often involve elements of problem-solving strategy. When students engage in such games, they must think of appropriate steps and manipulate objects or situations according to the rules or objectives of the game (Milenia & Nurharini, 2024). These abilities build the cognitive skills necessary to solve academic problems, such as understanding instructions, planning solutions, and evaluating outcomes. Then traditional games also have story elements or cultural contexts. Through these traditional games, students can expand their knowledge of specific cultures, histories, and traditions (Wibowo et al., 2023). This knowledge can increase students' interest and understanding of history, language, or cultural arts.

Although scientific literature has provided sufficient understanding of the importance of manipulative

movements on children's development, research examining the direct influence of traditional games on this aspect is limited. Therefore, this study aims to explore in more depth the influence of traditional games in increasing manipulative movements of elementary school students. Through an experimental approach, this study seeks to make a significant contribution to the understanding of the role of traditional games in supporting children's motor development, especially in the context of manipulative movements. The results of this study are expected to provide a more vigorous basis for developing more holistic and sustainable educational strategies for elementary school-age children.

Materials and Methods

Study Participants

The sample of this study were elementary school students from SD Negeri 3 Bantul, SD Negeri 1 Bantul and SD Muhammadiyah Serut. Those students were in grades 4, 5, and 6 with a total of 130 students, but the sample was selected through random sampling. Thus, the selected students were 60 students aged 9-12 years. The characteristics of students were analyzed based on age, height and weight (mean \pm SD). The sample consisted of 30 male students (height 140.21 \pm 6.2 cm, and weight 35.77 \pm 5.6 kg), and 30 female students (height 138.4 \pm 6.8 cm and weight 34 \pm 4.1 kg). In addition, this study has received approval from parents.

Study Organization

The type of this research is an experiment with two pretest-posttest groups without control variables. Data collection on pretest and posttest was carried out with three types of tests, namely throwing, catching, and kicking (Setyawan et al., 2024). The traditional games done were gobak sodor, fish nets, engklek and balloon racing. The treatment was carried out for six weeks with three weeks of training. Training was conducted on Monday, Wednesday, and Friday from 08.00-09.00, with the duration of one game was 30 minutes. The following is the traditional game treatment program in Table 1.

Statistical Analysis

Analysis of this study was done using a t-test and paired sample t-test with a significance value ($p < 0.05$). The t-test was carried out to test for differences before and after treatment. At the same time, the paired sample t-test was used to test the difference in training results of male and female

Table 1. Traditional games program (FN: Fish Nets, GS: Gobak Sodor, EK: Engklek, BR: Balloon Racing)

1 st Week			2 nd Week			3 rd Week		
Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
FN	EK	GS	BR	GS	FN	GS	EK	GS
GS	BR	EK	FN	BR	EK	FN	BR	EK
4 th Week			5 th Week			6 th Week		
Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
BR	GS	FN	GS	EK	GS	BR	GS	FN
FN	BR	EK	FN	BR	EK	FN	BR	EK

students. Before conducting the t-test and paired sample t-test, it will first pass the normality test and homogeneity test. Data analysis of this study used the help of SPSS 26.

Results

The following is a data analysis based on statistical analysis to test the purpose of this study. The first analysis is to conduct an assumption test through a normality test.

Table 2. Normality test results

Gender	Test	Test Type	Shapiro-Wilk		
			Statistic	df	Sig.
Male	Pretest	Throwing	0.074	29	0.091
		Catching	0.144	29	0.127
		Kicking	0.246	29	0.174
	Posttest	Throwing	0.067	29	0.103
		Catching	0.139	29	0.158
		Kicking	0.253	29	0.131
Female	Pretest	Throwing	0.082	29	0.145
		Catching	0.125	29	0.147
		Kicking	0.239	29	0.112
	Posttest	Throwing	0.073	29	0.186
		Catching	0.129	29	0.181
		Kicking	0.233	29	0.193

Based on the results of Table 2, the normality test using Shapiro-Wilk from the pretest-posttest results on male and female students showed a significance value (> 0.05), meaning that the data were normally distributed. The second analysis is a homogeneity test to test whether the sample comes from the same population.

Table 3. Hypothesis test results

Gender	Test	Test Type	Levene Statistic	df1	df2	Sig.
Male	Pretest-Posttest	Throwing	0.798	1	59	0.379
		Catching	0.867	2	58	0.386
		Kicking	0.394	1	59	0.551
Female	Pretest-Posttest	Throwing	0.582	1	59	0.483
		Catching	0.822	2	58	0.231
		Kicking	0.441	1	59	0.428

Based on the results of Table 3, the homogeneity test of the pretest-posttest results in male and female students came from the same population. Therefore, from the results of the assumption test through the normality test and homogeneity test, the research data is feasible to do t t-test and independent sample t-test.

Based on the results on Table 4, male students showed pretest-posttest results on the throwing test $0.011 < 0.05$, the catching test $0.007 < 0.05$, and the kicking test $0.003 < 0.05$. Then, the female students showed pretest-posttest results on the throwing test $0.013 < 0.05$, the catching test $0.017 < 0.05$, and the kicking test $0.012 < 0.05$. Thus, it can be explained

Table 4. T-test results

Gender	Test	Test Type	t	df	Sig. (2-tailed)
Male	Pretest-Posttest	Throwing	2.605	59	0.011
		Catching	2.932	59	0.007
		Kicking	3.144	59	0.003
Female	Pretest-Posttest	Throwing	2.274	59	0.013
		Catching	2.119	59	0.017
		Kicking	2.645	59	0.012

that traditional games affect the manipulative movements of male and female students at the elementary school level. Subsequent analysis by comparing test results in the male and female student groups aimed to analyze the effect of traditional games on the two groups.

Table 5. Independent sample t-test results

Male – Female Test Differences		t	df	Sig. (2-tailed)
Throwing	Equal variances assumed	1.854	59	0.071
	Equal variances not assumed	1.854	7.867	0.071
Catching	Equal variances assumed	1.770	59	0.083
	Equal variances not assumed	1.770	7.188	0.083
Kicking	Equal variances assumed	1.812	59	0.077
	Equal variances not assumed	1.812	7.312	0.077

Based on the results of Table 5, regarding the throwing test results of the male and female students, the significance value showed $0.071 > 0.05$. The results of catching tests of the male and female students showed a significance value of $0.083 > 0.05$. The results of the kicking test of the male and female students showed a significance value of $0.077 > 0.05$. Based on the results of Table 5, there were no differences in throwing test, catching test, and kicking test of the male and female student groups, so traditional games were effective in improving the manipulative movements of male and female elementary school students.

Discussion

This study aims to explore the effect of traditional games on manipulative movements of elementary school students based on gender. The results showed that traditional games can affect manipulative movements in elementary school students based on gender. It can be seen from the difference in increasing values from pretest and posttest tests. In addition, the results showed a significant increase after being given traditional game materials. The results of this study are supported by previous studies that explain that traditional games can improve body skills and balance and build a fit physique (Kusuma et al., 2021). The increase also occurs because traditional games provide opportunities for children to play in groups, the equipment used is simple, contains cultural values, and is carried out with pleasure without pressure (Suryadi, Nasrulloh, et al., 2024) Other research results also show that traditional games serve as an element of education that encourages the development of fundamental movement skills (Suherman et al., 2019).

Based on this foundation, the movement activities included in the modified traditional games include basic movements. Modification of traditional games in accordance with the principle of development has contributed to the improvement of students' movement skills (Suryadi, Nasrulloh, et al., 2024). The games are arranged in a straightforward manner, ensuring that students can easily engage and understand the gameplay. The game is designed not only to improve and foster students' manipulative movement abilities but also to encourage decision-making during gameplay and encourage students' motor skills. Achieve and advance game goals and align with learning principles.

The result of the research is to improve manipulative movements through traditional games for elementary school students based on gender. In addition, traditional games contribute to improving students' movement skills so as to help students develop their motor skills (Harianto et al., 2023). This statement is reinforced by research that reveals that modified traditional games are able to encourage students' level of understanding and motor skills (Gustian, 2021). Motor skills also improve students' academic achievement because improvements influence their cognitive abilities (Tandon et al., 2016), as well as improving fitness, psychological and mental health (Lobstein et al., 2015).

Throwing is essential because it is a complex movement (Stodden et al., 2006) and will determine the involvement of children's sports (Johnson et al., 2019; Maselli et al., 2019), water polo, javelin throwing (Chi, 2010) as well as handball and baseball. Based on this statement, traditional sports have included aspects of manipulative motion, such as throwing and catching kicks. If throwing skills are not taught well, it can be ascertained that children's involvement in sports and physical activities will not occur well. If the community is not physically active, it can be ascertained that the level of fitness will be low (Mashud et al., 2024; Rubiyatno et al., 2023; Septianto et al., 2024; Suryadi et al., 2023). It will have an impact on a person's physical health-child productivity in learning new things. If the child is fit, it will contribute to academic ability (Hermassi et al., 2021). Mastery of basic throwing movements will develop if learning interventions are carried out.

Furthermore, the ability to catch is also a critical skill stated by (Drost et al., 2015), stating that if the skill of catching is mature, it will have a significant role in other skills in the future of children. It is proven that throwing and catching skills will be the most influential if the child is visually impaired (Wagner, Haibach, and Lieberman 2013). There is an era relationship between throwing ability and catching ability (Dirksen et al. 2016). In another study, it was stated that there was a relationship between motor skills, fitness, and academic skills (Syväoja et al., 2021). Based on this finding, guided motor activities in schools are effective in improving children's motor fitness and competence (Huhtiniemi et al., 2023). In an experiment with children aged 4-5 years regarding one of the skills, which is catching skill, the results show that the scores for boys were higher (Navarro-Patón et al., 2021).

Conclusions

Traditional games increase the manipulative movements of elementary school students, as evidenced by

positive changes in the results of the pretest and posttest. The improvement was carried out, among others, through the adaptation of traditional games in accordance with the characteristics of students' development. These games combine a fun approach, tailoring activities to students' movement skills. Furthermore, game modification adheres to the principles and aspects that are conducive to the learning experience of elementary school students. The results contribute valuable insights in the field of physical education for elementary school students. To further enhance the study findings, future researchers may consider or evaluate the appropriateness of different methods of adjusting demographics.

Conflicts of Interest

No conflicts of interest exist.

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Оцінка впливу традиційних ігор на розвиток маніпуляційних рухів учнів початкової школи з урахуванням статевої приналежності

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

Реферат. Стаття: 7 с., 5 табл., 38 джерел.

Історія питання. Маніпуляційні рухи є важливим компонентом в процесі розвитку дітей, які можна зустріти в традиційних іграх, представляючи втілення місцевої мудрості, що передається з покоління в покоління.

Мета дослідження. Метою цього дослідження було вивчення впливу традиційних ігор на розвиток маніпуляційних рухів учнів початкових класів з урахуванням статевої приналежності.

Матеріали та методи. Експериментальне дослідження складалося з двох передтестових і післятестових груп за відсутності контрольних змінних. Збирання даних на етапах передтестового та післятестового дослідження було проведено за допомогою трьох типів тестів, а саме: виконання кидка, ловіння предмета та удару ногою. Для участі в дослідженні було відібрано 60 учнів віком від 9 до 12 років. Вибірка складалася з 30 хлопців (зріст – 140,21 ± 6,2 см, вага – 35,77 ± 5,6 кг) та 30 дівчат (зріст 138,4 ± 6,8 см і вага 34 ± 4,1 кг).

Результати. Аналіз t-критерію показав наступні результати для учнів чоловічої статі: виконання кидка 0,011 < 0,05, ловіння предмета 0,007 < 0,05 і удар ногою 0,003 < 0,05. Тоді як результати тесту для дівчат були представлені наступним чином: виконання кидка 0,013 < 0,05, ловіння предмета 0,017 < 0,05 і удар ногою 0,012 < 0,05. Отримані результати t-критерію для незалежних вибірок свідчать про те, що показники тестів на виконання кидків, ловіння предмета та ударів ногою мають статистичну значущість (p < 0,05) як у дітей чоловічої, так і жіночої статі.

Висновки. Встановлено, що впровадження традиційних ігор сприяє підвищенню рівня розвитку маніпуляційних рухів в учнів початкових класів, про що свідчать позитивні зміни, які спостерігаються в результатах передтестового та післятестового етапів дослідження. Покращення показників було досягнуто, зокрема, шляхом адаптації традиційних ігор відповідно до особливостей розвитку учнів. Таким чином, концептуалізація фізичного навчання в рамках застосування традиційних ігор довела свою доцільність і практичну значущість.

Ключові слова: традиційні ігри, маніпуляційні рухи, початкова школа, ігри для дітей.

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Enhancing Respiratory Function and Cardiovascular Endurance through Intensive Yogic Intervention: A Comprehensive Study

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Abstract

Background. Optimal respiratory function and cardiovascular endurance are integral to overall health and athletic performance. Yogic interventions have emerged as potential strategies to enhance physiological and physical parameters. These metrics not only unlock the human body's potential but also play a vital role in increasing sports performance.

Objectives. This study aimed to evaluate the effectiveness of a structured yogic regimen in improving respiratory function and cardiovascular endurance in young male adults, shedding light on yoga's role as a complementary approach to physical fitness enhancement.

Materials and methods. Forty (N = 40) male undergraduate university students (aged 18 to 25 years) were randomly assigned to the experimental (n = 20) and control group (n = 20). The experimental investigation centered on vital capacity (VC), both positive and negative breath holding times (PBHT and NBHT), peak flow rate (PFR), and cardiovascular endurance (CVE). Using an analytical research approach, a randomized pre-test – post-test – controlled group design was implemented. The experimental group engaged in daily yoga sessions supervised by certified instructors, incorporating various asanas, pranayama techniques, and meditation, while the control group maintained their regular lifestyle. Pre-and post-intervention assessments of respiratory parameters and cardiovascular endurance were conducted using standardized tests. Statistical analyses, including Levene's test for normality, and paired t-tests for intra-group comparisons, were performed using SPSS software (IBM, version 25, Chicago). The experiment lasted for six weeks, with a significance level set at $\alpha = 0.05$.

Results. The paired t-test analyses demonstrated significant improvements in VC $t_{(19)} = 4.96$, and $p < 0.000$; PBHT $t_{(19)} = 6.34$, and $p < 0.000$; NBHT $t_{(19)} = 4.18$, and $p < 0.001$; PFR $t_{(19)} = 7.02$, and $p < 0.000$; as well as CVE $t_{(19)} = 3.96$, and $p < 0.001$, within the experimental group. Conversely, no significant changes were observed in the control group.

Conclusions. The findings underscore the effectiveness of a six-week yogic intervention in enhancing respiratory function and cardiovascular endurance among young male adults. Integrating yoga into exercise routines may yield substantial benefits for physical fitness improvement.

Keywords: yogic intervention, respiratory function, cardiovascular endurance, physical fitness, undergraduate students.

Introduction

Air pollution is a major health hazard, exposing individuals to fine particles that infiltrate the lungs and

cardiovascular system, leading to conditions such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases, and respiratory infections (WHO, n.d.). It is the biggest environmental risk to public health in the world, thought to be the reason for 7 million preventable deaths every year (UNEP, 2021). Specifically, indoor air pollution contributes to 4-6% of India's national disease burden. In response to these health challenges, yoga has

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been recognized as an effective way to boost respiratory efficiency and strengthen the immune system against environmental hazards (Balaguru et al., 2022). Regular yoga practice significantly improves respiratory function and cardiovascular endurance, enhancing breathing, lung function, and oxygen delivery to muscles during exercise (Beutler et al., 2016; Kothari et al., 2023; Selmann et al., 2020). Moreover, yoga has been shown to increase cardiovascular endurance by boosting cardiac stroke volume and lowering blood pressure (Kothari et al., 2023; Santaella et al., 2011). Yoga, originating in ancient India millennia ago, is a holistic practice uniting the body, mind, and spirit, as the term “yoga” means to yoke or unite (Cameron, 2023). In recent years, yoga has surged in global popularity, evolving from a physical exercise to a holistic method for enhancing mental health benefit and physical well-being (Pramanic et al., 2024). It comprises physical postures (asanas), breathwork (pranayama), meditation, and ethical principles, aiming to improve overall health, mental clarity, emotional stability, and spiritual harmony (Cameron, 2023). Patanjali’s holistic approach to yogic practices encompasses both mental mastery and stress regulation (Sonwane & Mishra, 2016). Notably, Pranayama breathing exercises in yoga significantly boost oxygen intake, enriching the blood for essential organs like the brain, heart, and lungs, thereby enhancing their function. This improved oxygenation leads to better cardiorespiratory fitness by enhancing oxygen flow to the brain, regulating breathing, and reducing strain on the heart, resulting in enhanced endurance and cardiovascular fitness (Kothari et al., 2023).

The human respiratory system, encompassing both the upper and lower tracts, serves as the conduit for essential gas exchange between the body and the environment, a process vital for overall health. Additionally, it plays a pivotal role in evaluating lung function and efficiency (Islam et al., 2020). This system’s impact on sports performance is multifaceted. For example, improving lung capacity and respiratory health can augment endurance by facilitating increased oxygen delivery to muscles during physical activity (Ardejani & Saleem, 2022). Furthermore, the respiratory system’s ability to adapt to altitude and temperature variations is crucial for athletic prowess (Ardejani & Saleem, 2022). Key respiratory parameters such as vital capacity, respiratory rate, and breath-holding capabilities significantly contribute to enhanced endurance and improved cardiovascular fitness.

Vital capacity (VC), a crucial measure of lung function, is often assessed through spirometry, with a typical range of 3.5-4.5 liters (David & Sharma, 2023). Comprising inspiratory reserve volume, tidal volume, and expiratory reserve volume, VC tends to be greater in taller individuals and declines with age (Bhatti et al., 2014). Restrictive lung diseases significantly reduce VC due to decreased lung volumes and hindered expansion (Lutfi, 2017; Martinez-Pitre et al., 2023). Crucial for respiratory health, VC significantly impacts physical performance, especially in sports, facilitating better oxygen distribution to muscles during exercise (Taneja & Bose, 2019). Athletes with larger VC often excel due to their ability to intake more air, sustaining high-performance levels (Taneja & Bose, 2019; Mazic et al., 2015). Research indicates that yoga practices, including SN, asanas, and pranayama, can enhance VC, as demonstrated in college students (Birkel & Edgren, 2000).

Additionally, a study published in the *National Journal of Physiology, Pharmacy, and Pharmacology* affirms yoga’s positive impact on respiratory function and VC (Kondam et al., 2015). These findings emphasize the beneficial role of yoga in promoting lung health and enhancing vital capacity.

Respiratory rate, or the frequency of breaths per minute, is a critical indicator of health, with norms ranging from 12 to 20 breaths per minute for adults and varying by age in children (Rowden, 2023). Measurement methods encompass manual counting via observing chest movements and automated devices tracking breathing patterns (Singh et al., 2020). Various factors including age, activity level, and environmental conditions influence respiratory rate, which can also be elevated due to allergic reactions, anxiety, fever, or cardiac issues (Rowden, 2023). Furthermore, respiratory rate significantly impacts sports performance, encompassing physical, physiological, and mental aspects (Migliaccio et al., 2023). Employing proper breathing techniques, such as deep, slow breathing, aids athletes in managing stress and anxiety by inducing a calming effect on the nervous system, particularly beneficial during pre-game jitters or competitive situations. Moreover, yogic practices like Suryanamaskar, asanas, and pranayama have been documented to positively influence respiratory rates. A study highlighted in the *International Journal of Economic Perspectives* (Kumar & Tak, 2021) underscored the beneficial impact of these practices on respiratory rates.

Positive breath-holding times (PBHT) and negative breath-holding times (NBHT) measure breath duration after inhaling and exhaling. Breath-holding time, a metric measuring respiratory endurance and lung efficiency, has been widely explored in various contexts. Ideguchi et al. (2021) and Hedhli et al. (2021) found that individuals with chronic obstructive pulmonary disease exhibit shorter breath-holding times compared to healthy counterparts. Additionally, studies such as Yildiz et al. (2020) have utilized breath-holding time to investigate the impact of stroke and aging on lung function. Moreover, breath-holding exercises have emerged as a promising avenue for improving respiratory capacity and oxygen utilization, particularly beneficial for endurance athletes engaged in activities like running, cycling, or swimming (Fernández et al., 2022). Notably, practices such as yoga, particularly Pranayama, have shown significant potential in enhancing breath-holding capacity. Singh et al. (2022) demonstrated that a six-week Pranayama training program notably improved breath-holding among soccer players compared to control groups. This suggests a tangible link between breath-holding exercises, such as Pranayama, and enhanced respiratory endurance, which can be advantageous for athletes seeking to optimize their performance.

Peak flow rate (PFR), measures the maximum exhaling speed in L/min and helps assess lung function and respiratory disease severity (DeVrieze et al., 2023). PFR are crucial indicators of respiratory health, varying based on factors like age, height, sex, and race. While adults typically range between 400-700 L/min, children usually fall between 150-450 L/min. The research underscores the significance of PFR in sports performance, particularly in activities requiring endurance and efficient breathing. Studies have consistently shown that higher PFR values, indicative of superior respiratory function, directly correlate with enhanced

athletic abilities (Mackala et al., 2019; Kurtoğlu et al., 2024; Lydia & Latha, 2019). Furthermore, yoga has emerged as a promising avenue for improving PFR and overall lung function. Agnihotri et al. (2016) demonstrated that yoga significantly enhanced peak expiratory flow rate in patients with mild to moderate persistent chronic bronchial asthma. Similarly, a study published by Abel et al. (2013) found that regular yoga practice led to notable improvements in pulmonary function, as assessed by peak expiratory flow rate. These findings underscore the potential of yoga as a complementary approach to enhance respiratory health and athletic performance.

Furthermore, cardiovascular endurance (CVE), a cornerstone of health-related fitness, is essential for overall well-being and also has an impact on game performance (Reza et al., 2024). It encompasses the coordinated functioning of the heart, lungs, and circulation to deliver oxygen during physical exertion. Through regular training, the heart becomes stronger, thereby reducing the risk of heart disease. Moreover, enhancing cardiovascular endurance not only contributes to better health but also elevates athletic performance by enabling athletes to sustain high-intensity activities over prolonged periods. Interestingly, recent research underscores the efficacy of yoga in augmenting cardiovascular endurance, surpassing conventional aerobic exercises recommended for cardiovascular health (Sovová et al., 2015). Specifically, a study by Satheesh and Bindu (2020) unveiled that consistent pranayama practice enhances cardiovascular efficiency and physical endurance among young, healthy individuals. This evidence underscores the multifaceted benefits of incorporating yoga, particularly pranayama, into fitness routines for promoting cardiovascular health and endurance.

This study aims to assess how a structured six-week yoga program impacts vital parameters including VC, PBHT, NBHT, PFR, and CVE. By analysing these changes, it seeks to offer empirical evidence of yoga's effectiveness in enhancing respiratory function and cardiovascular endurance. This research contributes to our understanding of yoga's physiological benefits and its potential as a non-invasive health intervention.

Materials and Methods

Selection of Subjects

Forty (N = 40) male undergraduate university students, aged 18 to 25 years, were enlisted from University of Delhi, India. They were randomly divided into two groups: the control group (n=20) and the experimental group (n=20). The study was conducted at the yoga laboratory of the Indira

Table 1. Demographic data of the initially randomized sample (Mean ± SD)

Sl. No.	Baseline characteristics	Experimental Group (n = 20)	Control Group (n = 20)
1	Age (yrs.)	21.20 ± 2.14	22.32 ± 1.59
2	Weight (kg)	57.56 ± 5.62	63.00 ± 4.71
3	Height (m)	1.66 ± 0.07	1.67 ± 0.08
4	BMI (kg/m ²)	21.87 ± 1.74	22.58 ± 1.81

Gandhi Institute of Physical Education and Sports Sciences, University of Delhi. Throughout the testing, the participants did not smoke or use alcohol, and they did not have any acute or chronic diseases or medication use. Their vision was also normal. Participants provided written informed consent after being informed about the study's details.

Experimental Design

The study employed an analytical research approach, utilizing an experimental method known as the randomized pre-test – post-test – controlled group design, also recognized as the True experimental design. It aimed to investigate whether a six-week yogic intervention could effectively enhance specific respiratory parameters and cardiovascular endurance. The sample selection process involved utilizing probability sampling methods from the population.

Experimental protocol

The experimental group underwent a structured yoga intervention comprising Yogic Prayer, Suryanamaskar, and a variety of yoga asanas including Ardha-Halāsana, Sarvangāsana, Matsyāsana, Halāsana, Chakrasana, Bhujangāsana, Shalvhasana, Naukasana, Dhanurasana, ArdhaMatsyendrasana (Left and Right), Paschimottanasana, Vajrasana, Yogamudra, Ushtrasana, Padmasana, Utkatasana, Trikonasana, Vrikkhasana, Tadasana, and Shavasana. Additionally, Pranayama techniques such as AnulomVilom Pranayama and Bhastrika Pranayama, along with meditation, were included. This regimen was conducted daily from 7:30 am to 8:30 am at the yoga lab, IGIPES, University of Delhi, supervised by certified yoga instructors. The control group, on the other hand, continued with their regular activities without any additional intervention. All participants' metrics were assessed both before the intervention and after six weeks for comparison. The specifics of the intervention are summarized in Table 2.

Table 2. Brief yoga intervention module

Sequence	List Yoga Practices	Time duration (60 min)	Schedule
1	Yogic prayer	5 min	
2	Surya Namaskar	10 min	Monday, Tuesday
3	Asanas	25 min	Wednesday,
4	Pranayama	15 min	Thursday, Friday,
5	Meditation	5 min	and Saturday

Instrument and Tools

A wet spirometer was used to measure vital capacity, which was recorded in liters. Breath-holding time, encompassing both inhalation (positive breath-hold time) and exhalation (negative breath-hold time) phases, was timed to the nearest second with a stopwatch. Peak expiratory flow rate was determined using a Wright Peak Flow Mini-meter (ARMED, Clement Clarke Int. Ltd, England) and recorded in liters per minute (L/min). Cardiovascular endurance was evaluated through the Harvard Step Test, utilizing equipment such as a stopwatch, a bench (20 inches high

for boys and 16 inches high for girls), and a metronome. The Physical Fitness Index (PFI), as delineated by Fox et al. (1973), was computed using the following formula: Physical Fitness Index = Duration of exercise period in seconds \times 100 / ($2 \times$ Sum of three pulse counts after exercise).

Test Administration

To measure vital capacity, participants were seated comfortably and instructed to follow a demonstrated procedure. They took a deep breath, held it, and then exhaled forcefully into a spirometer. The highest value from three trials, with less than a ten percent variance, was recorded (Balaguru et al., 2022). Breath-holding time was assessed by timing how long participants could hold their breath after inhaling fully (positive) or exhaling completely (negative), and this was done to ensure no hyperventilation or movement during the test, and participants used a nose clip (Bagade et al., 2018). The peak flow rate was determined using a Mini-Wright peak flow meter. Participants exhaled through a mouthpiece to measure the maximum airflow (Oza et al., 2019). The respiratory rate was calculated by counting breaths for one minute while participants were at rest. Cardiovascular endurance was evaluated with the Harvard Step Test. Participants stepped in sync with a metronome for five minutes, and their pulse was recorded at specific intervals post-exercise to calculate a fitness index (Kaur & Mithlesh, 2023).

Statistical Analysis

In this study, statistical analyses were conducted using SPSS software (IBM, version 22, Chicago). The normality of the data was verified through Levene's test, confirming adherence to a normal distribution. Paired sample t-tests were employed to analyse respiratory functions and cardiovascular endurance. A significance level of 0.05 was set for this research. Given the normal distribution of the data, results are presented as mean (M) and standard deviation (SD).

Results

In Table 3, the descriptive statistics for the EG and CG illustrate changes across five variables from pre-test to post-test. In the EG, the mean values for VC increased from 2.22 to 2.28, while in the CG, the values increased slightly from 2.20 to 2.23. PBHT showed a notable increase in the EG from 28.59 to 31.45, whereas the CG only increased marginally from 34.02 to 34.68. NBHT also improved in the EG from 24.11 to 26.61, compared to a smaller increase in the CG from 23.01 to 24.96. For PFR, the EG saw a rise from 3.96 to 4.63, while the CG had a slight decline from 3.79 to 3.71. CVE improved significantly in the EG from 55.61 to 60.38, contrasted with a moderate increase in the CG from 53.28 to 55.93. These statistics indicate that the intervention had a more substantial positive impact on the EG compared to the CG across all measured health variables, suggesting its effectiveness in improving respiratory and cardiovascular health metrics.

Table 3. Descriptive statistics for the five variables between the pre-test and post-test of the experimental and control groups

Variables	Group	Test	N	Mean	Std. Deviation	Std. Error Mean
VC	EG	Pre-test	20	2.22	0.21	0.05
		Post-test	20	2.28	0.20	0.05
	CG	Pre-test	20	2.20	0.33	0.08
		Post-test	20	2.23	0.32	0.07
PBHT	EG	Pre-test	20	28.59	9.47	2.12
		Post-test	20	31.45	9.42	2.10
	CG	Pre-test	20	34.02	11.95	2.67
		Post-test	20	34.68	11.51	2.57
NBHT	EG	Pre-test	20	24.11	7.06	1.58
		Post-test	20	26.61	7.38	1.65
	CG	Pre-test	20	23.01	8.66	1.94
		Post-test	20	24.96	5.77	1.29
PFR	EG	Pre-test	20	3.96	1.06	0.24
		Post-test	20	4.63	1.09	0.24
	CG	Pre-test	20	3.79	0.82	0.18
		Post-test	20	3.71	0.93	0.21
CVE	EG	Pre-test	20	55.61	7.75	1.73
		Post-test	20	60.38	8.26	1.85
	CG	Pre-test	20	53.28	11.90	2.66
		Post-test	20	55.93	14.06	3.14

Key: VC: Vital Capacity; PBHT: Positive Breath Holding Time; NBHT: Negative Breath Holding Time; PFR: Peak Flow Rate; CVE: Cardiovascular Endurance; EG: Experimental Group; CG: Control Group

Table 4. Paired sample t-test for the five variables between the pre-test and post-test of the experimental and control groups

Variables	Group	Test	Mean Difference	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
VC	EG	Pre-test	0.07	0.06	0.01	4.96	19	0.000*
		Post-test						
	CG	Pre-test	0.04	0.22	0.05	0.72	19	0.482
		Post-test						
PBHT	EG	Pre-test	2.85	2.01	0.45	6.34	19	0.000*
		Post-test						
	CG	Pre-test	0.66	1.70	0.38	1.73	19	0.099
		Post-test						
NBHT	EG	Pre-test	2.50	2.68	0.60	4.18	19	0.001*
		Post-test						
	CG	Pre-test	1.94	6.23	1.39	1.40	19	0.179
		Post-test						
PFR	EG	Pre-test	0.68	0.43	0.10	7.02	19	0.000*
		Post-test						
	CG	Pre-test	0.08	0.32	0.07	1.06	19	0.302
		Post-test						
CVE	EG	Pre-test	4.77	5.39	1.20	3.96	19	0.001*
		Post-test						
	CG	Pre-test	2.65	6.80	1.52	1.74	19	0.098
		Post-test						

*Significant at 0.05 level

In Table 4, the paired t-test analysis results indicate significant differences in several physiological and physical fitness parameters between the pre-test and post-test within the EG, but not in the CG. For the VC variable, the EG showed a significant increase, $t_{(19)} = 4.96$, and $p < 0.000$, whereas the CG did not show a significant change, $t_{(19)} = 0.72$, and $p > 0.482$. Similarly, the PBHT in the EG had a significant improvement, $t_{(19)} = 6.34$, and $p < 0.000$, with no significant change in the CG, $t_{(19)} = 1.73$, and $p > 0.099$. For the NBHT, the EG also exhibited significant improvement, $t_{(19)} = 4.18$, and $p < 0.001$, while the CG did not change, $t_{(19)} = 1.40$, and $p > 0.179$. PFR significantly increased in the EG, $t_{(19)} = 7.02$, and $p < 0.000$, but not in the CG, $t_{(19)} = 1.06$, and $p > 0.302$. Lastly, CVE showed a significant increase in the EG, $t_{(19)} = 3.96$, and $p < 0.001$, with no significant change in the CG, $t_{(19)} = 1.74$, and $p > 0.098$. These results suggest that the experimental intervention was effective in improving the measured physiological and physical fitness parameters in the experimental group.

Discussion

The paired sample t-test results presented in Table 4 indicate significant differences in the five measured variables between the pre-test and post-test for the experimental group (EG), but not significant differences in the control group (CG). These findings provide insights into the effects of the intervention on various physiological parameters.

In the conducted study, it was observed that the experimental group exhibited a notable enhancement in VC from the initial assessment to the subsequent one. This observed increase strongly suggests that the intervention administered had a beneficial impact on the VC levels of the participants. This finding aligns with several prior studies which have also highlighted the positive influence of yogic practices on VC. For instance, a study reported a significant improvement in vital capacity among students participating in a yogic practices program (Jothipriya & Thanigaikoumarane, 2013). Similarly, another study documented that yogic exercises notably augmented both vital capacity in healthy subjects (Yadav & Das, 2001). Furthermore, 2-month regimen of pranayama and suryanamaskar practices led to a significant increase in vital capacity among medical students. The study concluded that such practices enhance respiratory breathing capacity by promoting chest wall expansion and augmenting forced expiratory lung volumes (Karthik et al., 2014).

The intervention group demonstrated a noteworthy enhancement in both PBHT and NBHT, underscoring the effectiveness of the intervention in augmenting these parameters. Conversely, the control group exhibited no significant variation in PBHT and NBHT from the pre-test to the post-test. Various scientific inquiries into yogic practices consistently affirm their beneficial impact on breath-holding times. For example, a study focusing on Pranayama revealed substantial increases in breath-holding time among

participants who engaged in this technique for 45 minutes, five days a week, over six weeks (Sivapriya & Veerapandian, 2017). Similarly, research on Anulom Vilom demonstrated improved lung function and endurance among competitive swimmers, potentially contributing to heightened breath-holding capacities. Moreover, yogic breathing exercises, including Pranayama, boosted negative breath-holding time in individuals coping with chronic respiratory ailments (Baghel & Shamkuwar, 2017).

The study revealed a significant improvement in the PFR of participants in the experimental group, indicating the effectiveness of the intervention in enhancing respiratory function. In contrast, the control group exhibited no significant change in PFR, emphasizing the importance of the intervention for meaningful improvement. These findings are reinforced by several other studies. A study examined the impact of yoga on respiratory functions in middle-aged individuals who were previously inactive. It found that both yoga asanas and pranayama led to improvements in overall respiratory function, including PFR (Yamamoto-Morimoto et al., 2019). Similarly, research by Arumugam and Anuja demonstrated a significant increase in peak expiratory flow values following yoga pranayama exercises (Arumugam & Anuja, 2016). Another study highlighted the positive effects of pranayama on the respiratory system, including improved PFR and respiratory muscle strength (Arulmozhi et al., 2018). Furthermore, a comparison between yogic practitioners and sedentary individuals revealed notably higher PFR values among those who practiced yoga (Vedala et al., 2014), suggesting the benefits of yoga for lung function even in healthy individuals without respiratory conditions. Additionally, a study concluded that a six-week yogic intervention could lead to significant enhancements in pulmonary function, including PFR, in physically fit individuals (Bhagel et al., 2022).

The intervention yielded a notable increase in CVE within the experimental group, affirming its positive impact. This improvement in CVE can be attributed primarily to the intervention, as evidenced by several studies highlighting the beneficial effects of yogic practices. For instance, a significant enhancement in cardiovascular endurance among college students following yogic practices (Vallimurugan & Vidhya, 2024). Similarly, another study conducted by Malik and Goel in 2015 revealed that yogic practices led to significant improvements in cardiovascular endurance and body composition within the experimental group when compared to the control group. Furthermore, a study featured in the *Preventive Cardiology* journal demonstrated that yoga practice substantially enhances various health-related aspects of physical fitness, including cardiovascular endurance, particularly among young, healthy individuals (Tran et al., 2001). These findings collectively highlight the positive influence of yogic practices on cardiovascular endurance.

Conclusions

Overall, the results from the paired sample t-tests indicate that the intervention was effective in significantly improving all measured variables (VC, PBHT, NBHT, PFR, and CVE) in the experimental group. These improvements were not observed in the control group, which did not undergo the intervention. This suggests that the intervention

had a substantial and positive impact on the participants' respiratory capacities and cardiovascular endurance, as evidenced by the statistically significant changes in the experimental group's pre-test and post-test scores across all variables. Future research should explore the long-term effects of yoga across diverse populations and refine intervention protocols for maximal efficacy.

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Conflicts of interest

The authors declare no conflicts of interest.

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Покращення показників дихальної функції та витривалості серцево-судинної системи за допомогою інтервенції з інтенсивної практики йоги: Комплексне дослідження

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

Реферат. Стаття: 9 с., 4 табл., 55 джерел.

Історія питання. Оптимальні показники дихальної функції та витривалості серцево-судинної системи є невід'ємною частиною загального стану здоров'я та спортивної продуктивності. Інтервенції з практики йоги розглядаються як потенційна стратегія для поліпшення фізіологічних і фізичних параметрів. Такі показники не лише розкривають потенціал людського організму, але й відіграють ключову роль у досягненні високих спортивних результатів.

Мета дослідження. Метою цього дослідження була оцінка ефективності структурованого режиму занять йогою щодо покращення показників дихальної функції та витривалості серцево-судинної системи у молодих чоловіків, а також висвітлення ролі йоги як додаткового підходу до підвищення рівня фізичної підготовленості.

Матеріали та методи. Сорок (N = 40) студентів бакалаврату чоловічої статі (віком від 18 до 25 років) були розподілені методом рандомізації на експериментальну (n = 20) та контрольну (n = 20) групи. Експериментальне дослідження було зосереджено на оцінці показників життєвої ємності легень (ЖЕЛ), часу затримки дихання на позитивному та негативному рівнях (ПЧЗД та НЧЗД), пікфлоуметрії (ПФМ) — методика діагностики функції зовнішнього дихання, яка визначає пікову об'ємну швидкість видиху, а також витривалості серцево-судинної системи (ВССС). Застосовуючи аналітичний дослідницький підхід, було впроваджено модель рандомізованого передтестового та післятестового контрольованого дослідження в групах. Експериментальна група щоденно займалась йогою під наглядом сертифікованих інструкторів, включаючи виконання різних типів асан, технік пранаями та медитації, тоді як контрольна група дотримувалась свого звичного способу життя. Оцінка параметрів дихання та витривалості серцево-судинної системи до і після інтервенції проводилася шляхом застосування стандартизованих тестів. Статистичні методи аналізу, включаючи тест Левене на визначення критерію нормальності та використання t-критерію парних вибірок для внутрішньогрупових порівнянь, проведено за допомогою програмного забезпечення SPSS (IBM, версія 25, Чикаго). Експеримент тривав шість тижнів, рівень значущості був встановлений на рівні $\alpha = 0,05$.

Результати. Аналіз із використанням t-критерію парних вибірок продемонстрував значні покращення показників в експериментальній групі: ЖЕЛ $t_{(19)} = 4,96$, $p < 0,000$; ПЧЗД $t_{(19)} = 6,34$, $p < 0,000$; НЧЗД $t_{(19)} = 4,18$, $p < 0,001$; ПФМ $t_{(19)} = 7,02$, $p < 0,000$; а також ВССС $t_{(19)} = 3,96$, $p < 0,001$. Натомість у контрольній групі суттєвих змін не спостерігалось.

Висновки. Результати дослідження підкреслюють ефективність інтервенції з виконання шеститижневих занять йогою з метою зміцнення дихальної функції та витривалості серцево-судинної системи серед молодих чоловіків. Інтеграція йоги до режиму щоденних фізичних вправ має значні переваги щодо покращення показників фізичної підготовленості.

Ключові слова: інтервенція з практики йоги, дихальна функція, витривалість серцево-судинної системи, фізична підготовленість, студенти бакалаврату.

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Selenomethionine Supplementation Contributes to Reducing Oxidative Stress and Inflammation Markers following Exercise-Induced Muscle Damage

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Abstract

Background. Exercise-induced muscle damage (EIMD) is a temporary response to intense or prolonged exercise that can cause muscle pain, inflammation, and impaired muscle function. Antioxidant supplementation is a proposed strategy to reduce EIMD symptoms by targeting reactive oxygen and nitrogen species (RONS) involved in the process.

Objective. The study aimed to investigate the effect of Selenomethionine supplementation on malondialdehyde (MDA) and C-reactive protein (CRP) levels resulting from Exercise-Induced Muscle Damage (EIMD).

Materials and methods. This study used a randomized pretest-posttest control group design, involving a total of 32 male recreational students from the Universitas Negeri Surabaya, (age 19.25 ± 0.76 years, body mass 63.16 ± 3.38 kg, height 167.28 ± 4.54 cm, body fat $19.60\% \pm 4.57\%$). The participants were randomly assigned to the selenomethionine group (SEM, 100 $\mu\text{g}/\text{day}$) or placebo group (PLA, corn starch 100 mg/day) for a period of 28 days (4 weeks). On days 1 (baseline) and 29, participants underwent a single bout of EIMD. Blood samples were collected 24 hours post-EIMD to measure MDA and CRP concentrations in plasma. The statistical analysis was conducted using paired sample t-test.

Results. The placebo group experienced a significant increase in plasma MDA and CRP concentrations after EIMD compared with baseline values ($p < 0.05$). However, the SeMet group showed lower plasma MDA and CRP levels than the placebo group.

Conclusions. Daily Selenomethionine supplementation for 28 days has been found to reduce oxidative stress by lowering MDA levels in the blood and to decrease inflammation by reducing CRP levels post-exercise-induced muscle damage. This indicates a lower risk of EIMD due to reduced oxidative stress and inflammation.

Keywords: exercise, oxidative stress, inflammation, immune function.

Introduction

There have been numerous reports indicating that exercise-induced muscle damage (EIMD) commonly occurs following strenuous unaccustomed exercise, especially when the activity involves a high frequency of eccentric contractions (Irawan et al., 2021; Irawan et al., 2024). This condition is frequently observed in exercises like running, plyometrics, strength training, and other high-

intensity activities that involve eccentric muscle actions, such as movements that involve lengthening, braking, or deceleration. The harm caused by EIMD can result in muscle tenderness, soreness, and reduced functionality. This condition can result in impaired immune function by marking an increase in IL-6 concentrations (Fernández-Lázaro et al., 2020; Irawan et al., 2021). This confirms that intense exercise, particularly those involving high-intensity eccentric muscle contractions, can increase the risk of muscle damage (Fernández-Lázaro et al., 2020; Kong et al., 2018). There are several indicators of direct and indirect muscle damage, including ultrastructural disturbances, delayed-onset muscle soreness, continued decline in muscle

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function, and changes in many serum markers such as creatine kinase (CK) and lactate dehydrogenase (LDH), anti and pro-inflammatory cytokines (IL-6, IL-2, IL-10, and TNF- α), and superoxide dismutase (SOD) (Nanavati et al., 2022; Souissi et al., 2020; Suzuki et al., 2020).

One study revealed that both strenuous exercise and intensive exercise can result in a decrease in the ability of mitochondrial membranes and an increase in lipid peroxidation (Bazzucchi et al., 2019; Del Giudice & Gangestad, 2018). The study by Souissi (Souissi et al., 2020), which aimed to examine the modality of running exercise against oxidative stress, concluded that intermittent or 15/15 intermittent exercise caused less radical damage compared to intermittent 30/30 exercise. This proves that high-intensity exercise can result in oxidative stress characterized by increased activity of oxidative stress markers including malondialdehyde (MDA), advanced oxidation protein products (AOPP), SOD, and glutathione peroxidase (GPX) (Ammar et al., 2020; Matta et al., 2021; Souissi et al., 2020). Another study concluded the association of muscle damage with oxidative stress (O'Connor et al., 2022; Suzuki, 2018).

The mechanism of immune function disorders and muscle damage due to exercise has not been widely explained, although there are clinical symptoms due to exercise, including swelling, muscle pain, and increased circulating cytokines as markers of inflammation (Arazi et al., 2021; Cicchella et al., 2021; Tidball & Villalta, 2010). Inflammatory response serves as a marker of damage to both muscle fibers and other body parts, along with mechanical disturbances that occur during high-intensity exercise (Ruhe et al., 2020; Wadley et al., 2019). Disruption due to exercise-induced muscle damage could lead to a decrease in the athlete's performance, with muscle ability decreasing between 20-50%, requiring 2-7 days for full recovery (Kyriakidou et al., 2021; Lee et al., 2021). This damage is associated with an inflammatory response that involves many mediators, one of which is an increase in circulating IL-6 cytokines and inflammation (Ellingsgaard et al., 2019; Irawan et al., 2022).

Some studies suggest that the increased risk of muscle damage and inflammation during exercise is caused by free radicals (He et al., 2018; Martinez-Ferran et al., 2020). Therefore, the use of antioxidants may help reduce the risk of muscle damage and inflammation. Several studies have focused on efforts to reduce the risk of muscle damage using drugs (Brendler et al., 2021), antioxidant supplements (Righi et al., 2020; Wang et al., 2019), and other potential agents (He et al., 2018; Lima et al., 2019; Massaro et al., 2019). These studies yield varying results, indicating the need for further research to reduce the risk of impaired immune function and inflammation.

Many studies have been conducted regarding the effectiveness of antioxidant supplements against oxidative stress and inflammation due to EIMD. However, research on the effects of Selenomethionine (SeMet) on EIMD is very limited. Therefore, the present study was designed to primarily investigate the effect of Selenomethionine supplementation on MDA and CRP resulting from Exercise-Induced Muscle Damage (EIMD) in students from the Sports Science Department at Universitas Negeri Surabaya.

Materials and Methods

Study Participants

Thirty-two male students from the Sports Science Department at Universitas Negeri Surabaya were included in the study. They were healthy, had a normal BMI, and were non-smokers. Participants were randomly assigned to either the SeMet Group (SEM, $n = 16$) or the Placebo Group (PLA, $n = 16$). All participants had the same body weight, and there were no significant differences in anthropometric parameters between groups. Before recruiting participants, the research team carefully explained the purpose and procedures of the experiment to participants, and all participants filled out an informed consent form before participating.

Study Organization

This study was an experiment with a pretest-posttest control group design. The design was developed to investigate the effectiveness of 100 μ g Selenomethionine (SeMet) capsule supplementation for 28 days (4 weeks) against changes in MDA and inflammation (CRP).

The research was conducted for one month with an initial screening on the first day to determine the participants' condition. All participants were not allowed to do sports or heavy physical activity for 30 days until the end of the study; only experimental exercise was allowed. Data on plasma concentrations levels of MDA and CRP 24 hours post-exercise before the 28-day supplementation period served as baseline data (D2), while plasma levels of MDA and CRP 24 hours post-exercise after 28 days of SeMet supplementation became posttest data (D30). On the first day (D0), participants filled out a physical fitness capacity form that included their weekly running frequency and volume, history of injuries and illnesses, and medications used in the 2 weeks before the start of the study.

The 10 sets of 10 Countermovement Jumps (CMJs), with a recovery of 1 min between sets protocol was chosen to obtain the EIMD effect. This type of Depth Jump Protocol (DP) has been proven to induce high-intensity muscle fatigue and eccentric muscle damage, which can be useful for assessing the effectiveness of supplements or interventions on muscle recovery (Dos Reis et al., 2023). All participants performed CMJs on Day 1 (D1) and Day 29 (D29) as a damaging exercise (EIMD). The MDA and CRP were obtained 24 hours post-exercise (D2 and D30). Participants were not injured and were asked to refrain from all physical activity and avoid taking anti-inflammatory drugs, treatments, and additional dietary supplements during the 30-day period of this study. A summary of the study design is presented in Figure 1.

The supplementation consisted of capsules containing 100 μ g of SeMet (SEM), while the placebo consisted of similar capsules containing 100 mg of corn starch (PLA). The Selenomethionine capsules were manufactured by Thorne (Poland), a commercially available product that ensures quality and safety for the product. The subjects consumed one SeMet (SEM) or Placebo (PLA) capsule daily with breakfast for 28 days (4 weeks). All participants were not allowed to engage in sports or heavy physical activity for 30 days until the end of the study. Additionally, participants were prohibited from participating in any recovery

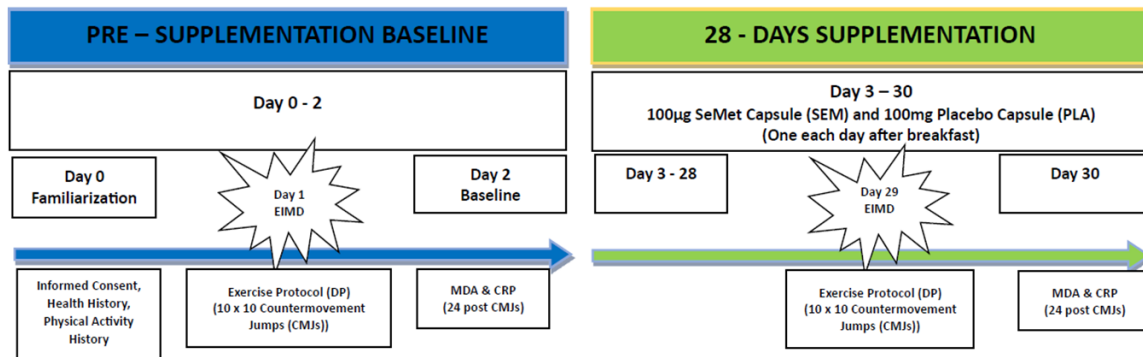


Fig 1. Study design

programs such as massage or cryotherapy. Before engaging in exercise, participants were required to be pain-free and injury-free, as confirmed by their completion of the Physical Activity Readiness Questionnaire (PAR-Q) and deemed fit for physical activity. Blood samples were taken, with up to 5 cc collected from the cubital vein and treated with EDTA. The centrifugation process was performed at 3000 rpm for 15 minutes, after which the plasma was stored in a freezer at a temperature of -20°C until analyzed. Plasma MDA and CRP levels were measured using 100 μl of plasma 24 hours post-damaging exercise before (D2) and after the 30-day supplementation period (D30). Plasma concentrations of Malondialdehyde (MDA) were determined by a high-sensitivity enzyme-linked immunosorbent assay (ELISA) kit using 96-well plates from Elabscience MDA ELISA kit, and plasma concentrations of CRP were analyzed using the DBC hs-CRP ELISA kit. The assessment of MDA and CRP plasma concentrations was conducted at the Sports Science Laboratory of Universitas Negeri Surabaya and Airlangga University Hospital Research Laboratory Installation, to obtain MDA and CRP plasma concentration data.

Statistical Analysis

The data was processed both manually and digitally to convert it into usable information. The distribution of the data was checked using the Kolmogorov-Smirnov method, and it was found that all samples had a normal distribution. With this confirmed, descriptive statistics were calculated for each measured variable. Independent t-tests were used to identify any differences between groups, and paired t-tests were used to examine changes within each group from pre-test to post-test. IBM SPSS Statistic 22.0 was used to analyze all of the data.

Results

A total of 32 male Sports Sciences Department students of Universitas Negeri Surabaya were willing to participate in this study. The participants were randomly divided into two groups: the SeMet Group (SEM, $n=16$) and the placebo group (PLA, $n=16$). The mean age of the SEM was $19.19 (\pm 0.65)$ years old, while the mean age of the PLA was $19.31 (\pm 0.87)$ years old. Tanita's Body Fat Monitor BC 730 was used to obtain data on participants' body weight and fat percentage, while the Multistage Fitness Test was used to determine individual aerobic fitness (VO_2max). The characteristics obtained from this study can be seen in Table 1.

Table 1 above shows the anthropometric characteristics of the participants, including their IPAQ level. Based on Table 1, it can be seen that the physical activity level of all participants is in the moderate category.

The next step is to carry out prerequisite tests, which include normality tests and homogeneity tests. The normality test was conducted to determine whether a given dataset follows a normal distribution or not, and homogeneity tests were used to determine whether a sample or population is homogeneous. The result of the normality test helps determine the hypothesis test. A Kolmogorov-Smirnov test for normality for MDA and CRP, whether pretest and posttest, reported a p-value of >0.05 , revealing that the distribution was normal. Likewise, with the homogeneity test using the Levene test, all variables MDA and CRP had significance values >0.05 , which means that the data can be considered homogeneous.

Based on this, the next hypothesis test used is parametric statistics, specifically the paired t-test. The pretest and posttest t-tests in the SEM group and the PLA group aim to determine whether there is a decrease in plasma levels of MDA and CRP.

Table 1. Respondent characteristic

Indicators	SEM ($n=16$)	PLA ($n=16$)	Categories
Age (years)	19.19 ± 0.65	19.31 ± 0.87	
Height (cm)	165.50 ± 4.3	168.06 ± 4.71	
Weight (kg)	62.75 ± 3.75	63.56 ± 3.24	
BMI (kg/m^2)	22.63 ± 0.66	22.50 ± 0.66	Normal
Fat Percentage (%)	20.88 ± 3.57	18.31 ± 3.55	General Fitness
IPAQ (METs-min/week)	1161.19 ± 217.22	1287.63 ± 127.87	Average
VO_2max ($\text{mL}/(\text{kg}\cdot\text{min})$)	35.67 ± 4.09	37.81 ± 3.71	Below average

Selenomethionine supplementation and changes on oxidative stress marker (MDA)

When comparing plasma concentrations of oxidative stress markers (MDA) before and after SeMet supplementation (after 4 weeks of supplementation), we found different results in both SEM and PLA (Table 2).

Table 2. Changes in MDA plasma levels between pretest and posttest

MDA	SEM (µmol/ml)	PLA (µmol/ml)	p-values
Pre	15.42 ± 0.83	16.04 ± 1.06	0.000
Post	12.99 ± 0.075	15.16 ± 1.00	0.000

Table 2 above shows changes in plasma MDA levels before (pre) and after (post) 4 weeks for both SEM and PLA. There was a significant decrease in plasma MDA levels in the SEM group ($P < 0.001$). On the other hand, in the PLA group, there was no significant change because the t-test value in the PLA group was 0.60 ($P > 0.001$). Based on this, it can be said that supplementation of SeMet caused a decrease in MDA levels, whereas in the placebo group, there was no decrease in MDA levels. Notably, the control group showed little or no change in MDA levels.

Selenomethionine supplementation and changes on inflammatory marker (CRP)

CRP is commonly used as a marker of inflammatory events following intense exercise. In a comparative analysis of plasma levels of inflammatory markers before and after SeMet supplementation (after a 4-week supplementation period), we observed a significant decrease in CRP levels in the SEM but not PLA (Table 3).

Table 3. The alterations in CRP plasma levels between pretest and posttest

CRP	SEM (mg/L)	PLA (mg/L)	p-values
Pre	6.79 ± 0.18	7.10 ± 0.19	0.000
Post	5.52 ± 0.23	6.86 ± 0.29	0.000

Table 3 above indicates the alterations in CRP plasma levels before (pre) and after (post) a 4-week supplementation period in both the SEM and PLA groups. The data reveal a significant decrease in CRP plasma levels in the SEM group ($P < 0.001$). On the other hand, the t-test value of PLA was 0.69 ($P > 0.001$), which means there were no significant changes in the placebo group. Hence, it can be deduced that SeMet supplementation results in a more substantial decrease in CRP plasma levels compared to the placebo.

Discussion

Exercise-induced muscle damage (EIMD) can occur due to unaccustomed exercise, causing a temporary decrease in muscle strength, increased passive tension, increased pain and muscle inflammation, and elevated levels of intramuscular proteins in the bloodstream (Tanabe et al., 2021). EIMD is a common symptom that occurs

when engaging in prolonged or high-intensity exercise. It is a temporary and natural part of the muscle's repair and adaptation process (Owens et al., 2019). This response can lead to a temporary decrease in muscle function, as well as symptoms such as muscle soreness, swelling, and elevated levels of proteins in the blood, which are all indicative of muscle damage (Sánchez Díaz et al., 2022).

Research has shown that muscle damage is often accompanied by oxidative stress (OS), which is characterized by an increase in reactive oxygen species (ROS), the concentration of the biomarker produced depends on the degree of fatigue or muscle damage. One of study Elevated MDA and CRP has been reported during exercise with EIMD and has similarly been attributed to a shift to more glycolytic energy production (Kruk et al., 2021; O'Connor et al., 2022; Thirupathi et al., 2021). Therefore, inflammatory processes have always been associated with OS and both are directly involved in muscle damage and should be analyzed and controlled together (Amalraj et al., 2020).

This study aimed to examine the impact of a 28-day supplementation of Selenomethionine on MDA levels as an oxidative stress marker and CRP levels as an inflammation marker following Exercise-Induced Muscle Damage. The results of this study indicate an increase in oxidative stress marker (MDA) and inflammation marker (CRP) 24 hours post a single bout of CMJs as a damaging exercise protocol, as shown in Table 2 and Table 3. Muscle contraction during exercise triggers the production of ROS in active muscle fibers, primarily originating from skeletal muscle. This generation of ROS results in oxidative damage in different tissues, such as increased protein oxidation and lipid peroxidation, accelerated muscle fatigue, and exercise-induced adaptations in muscle fiber contraction. These effects are linked to the activation of relevant biochemical signaling pathways (Ammar et al., 2020; Powers et al., 2020).

The level of cellular oxidative stress can be assessed by measuring MDA a marker of lipid peroxidation (Guerrero et al., 2021). High levels of free radicals or ROS are known to directly initiate the chain peroxidation reactions of membrane lipids (Lin et al., 2021), resulting in increased oxidative stress and damage to organs and tissues. The results of this study showed that daily intake of SeMet for 28 days effectively reduces the oxidative stress marker 24 hours post a single bout of CMJs-induced EIMD through a significant reduction in MDA plasma concentrations, as it inhibits lipid peroxidation. A possible reason for this phenomenon may lie in decreased membrane permeability and reduced leakage of components due to the inhibition of lipid peroxidation (Brendler et al., 2021; Williamson & Davison, 2020). This could be due to SeMet's potential antioxidant properties (Lior et al., 2019).

Selenium is considered the most vital micronutrient for both humans and animals. Selenium is an essential nutrient that serves as a vital cofactor for numerous enzymes, enabling them to function properly. Its antioxidant properties have been extensively researched, and it has also been found to play a significant role in the immune system's functioning and overall defense mechanisms (Mal'tseva et al., 2022). Notably, selenium can be incorporated into proteins in the body, where it can bind non-specifically to the amino acid methionine, allowing it to participate in various cellular activities (Goldsztein et al., 2022).

One of the ways selenium's antioxidant properties works is by activating glutathione peroxidase, an enzyme that contains selenium. This enzyme helps to neutralize free radicals by converting harmful compounds like hydrogen peroxide and organic hydroperoxides into harmless ones, such as water and alcohols (Bjørklund et al., 2022). Selenium-dependent enzymes, such as GPX1–4 and GPX6 and thioredoxin reductases (TrxR 1-3), directly combat oxidative stress. Cytosolic GPX4 is essential for embryonic development and cell survival. GPX1 is the most abundant selenoprotein and a critical metabolic form of selenium for combating severe oxidative stress (Weaver & Skouta, 2022).

In this study, CRP plasma concentrations in blood were measured as an inflammatory marker. As shown in the results above, there is an increase in CRP plasma concentrations 24 hours post single bout pencak silat exercise. The results of statistical analysis showed that there is a difference in CRP plasma concentrations before and after 28 days of SeMet supplementation. Recent studies have also shown a slight increase in CRP levels as an inflammatory marker after CMJs as an EIMD (Cerqueira et al., 2020; Costello et al., 2018; Kawamura & Muraoka, 2018). The presence of this inflammatory marker (CRP) is suggested to be the result of muscle cell damage as a consequence of high-intensity exercise (Boukhris et al., 2020; Mal'tseva et al., 2022). The present study showed that daily SeMet intake demonstrated to be efficient in attenuating CRP plasma concentrations 24 hours post EIMD.

Research has consistently shown that eccentric exercise, particularly when new or unfamiliar, can cause muscle damage due to the intense force exerted on the muscles (Heiss et al., 2019). This damage leads to the infiltration of inflammatory cells, destruction of cell membranes, and breakdown of the extracellular matrix. The excessive inflammatory response that follows can ultimately lead to additional tissue damage (Taherkhani et al., 2020). Previous evidence has suggested that an acute bout of exercise increases NF- κ B activity. NF- κ B is a critical regulator of various physiological and pathological processes, including inflammation and oxidative stress (Suzuki et al., 2020).

Recent studies have found that selenium can affect immune cell function and transcription pathways, such as NF- κ B (Prabhu et al., 2002). Selenium acts as an anti-inflammatory by inhibiting NF- κ B activation and regulating cytokine production at the gene expression level. NF- κ B activation triggers inflammatory markers like CRP and TNF- α (Maehira et al., 2003).

Given the scarcity of studies discussing exercise-induced muscle injury mechanisms, on the other hand, this scheme supports the need for further research to reassess the effects of long Selenomethionine supplementation on antioxidant defense systems, muscle performance, and hormonal responses to determine potential improvements in athletic performance.

Conclusions

Our research indicates that daily Selenomethionine supplementation for 28 days reduces oxidative stress by lowering MDA levels in the blood and decreases inflammation by reducing CRP levels post-exercise-induced muscle damage. Thus, it can be said that Selenomethionine

supplementation significantly attenuates exercise-induced oxidative stress and inflammatory markers, respectively, suggesting that selenium may be a valuable adjunct to optimize exercise performance and reduce muscle damage.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Приєм доіавок селенометіоніну сприяє зменшенню оксидативного стресу та маркерів запалення після пошкодження м'язів внаслідок виконання фізичних вправ

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

Реферат. Стаття: 8 с., 3 табл., 1 рис., 53 джерела.

Історія питання. Пошкодження м'язів внаслідок виконання фізичних вправ (ПМВФВ) — це тимчасова реакція на інтенсивні або тривалі фізичні навантаження, що може викликати біль у м'язах, запалення та порушення м'язової функції. Антиоксидантні доіавки є запропонованою стратегією щодо зменшення симптомів ПМВФВ шляхом впливу на реактивні форми кисню та азоту (РФКА), які беруть участь у цьому процесі.

Мета дослідження. Метою дослідження було вивчення впливу доіавок селенометіоніну на рівень малонового діалдегіду (МДА) та С-реактивного білка (СРБ), що виникають внаслідок пошкодження м'язів, спричиненого фізичними вправами.

Матеріали та методи. У цьому дослідженні використано метод рандомізованого перед- і післятестового контролю, в якому взяли участь 32 студенти чоловічої статі рекреаційного профілю навчання з Сурабайського державного університету (Індонезія), (вік $19,25 \pm 0,76$ років, маса тіла $63,16 \pm 3,38$ кг, зріст $167,28 \pm 4,54$ см, вміст жиру в організмі $19,60\% \pm 4,57\%$). Учасники були розподілені методом рандомізації до групи, яка приймала селенометіонін (СЕМ, 100 мкг/добу) або плацебо (ПЛА, кукурудзяний крохмаль 100 мкг/добу) на період 28 днів (4 тижні). На 1-й (початковий) та 29-й дні дослідження, учасники зазнали однократного впливу пошкодження м'язів внаслідок виконання фізичних вправ. Зразки крові відбирали через 24 години після ПМВФВ з метою вимірювання концентрації МДА та СРБ у плазмі. Статистичний аналіз проведено за допомогою t-критерію парних вибірок.

Результати. У групі застосування плацебо спостерігалось значне підвищення концентрації МДА та СРБ у плазмі крові після пошкодження м'язів внаслідок виконання фізичних вправ, порівняно з вихідними значеннями ($p < 0,05$). Однак в групі, яка приймала селенометіонін, рівень МДА та СРБ у плазмі крові був нижчим, ніж у групі, що отримувала плацебо.

Висновки. Встановлено, що щоденний прийом доіавок селенометіоніну протягом 28 днів зменшує оксидативний стрес шляхом зниження рівня МДА в крові та послаблює запалення шляхом зниження рівня С-реактивного білка після пошкодження м'язів внаслідок фізичних вправ. Це вказує на нижчий ризик розвитку ПМВФВ завдяки зменшенню показників оксидативного стресу та запалення.

Ключові слова: фізичні вправи, оксидативний стрес, запалення, функція імунної системи.

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Identifying the Optimal Age to learn Water Polo Tactics according to Expert Opinion: Insights through Dimensionality Reduction Analysis

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Abstract

Background. It is of great importance that the training process of youth water polo players be tailored to didactic principles and developmental characteristics. However, despite this importance, there is a dearth of pertinent studies.

Objectives. The study aimed to determine and explain the appropriate age for beginning of learning tactical elements in water polo, as stated by experts' coaches' opinion in this sport.

Materials and methods. Accordingly, 27 expert water polo coaches completed a novel questionnaire, specifically designed for this study.

Results. Test-retest reliability indicated satisfactory scores (r ranged from 0.85 to 1.00 with $p < 0.05$ for all variables). The results of the exploratory factor analysis using the Guttman-Kaiser criterion for selecting the number of factors and the Varimax raw rotation revealed the presence of six underlying factors in real-life contexts: (1) individual and group activities with a numerical advantage/disadvantage; (2) dynamic-complex collective defensive activities with an equal number of players; (3) intensive defensive activities with an equal number of players, static defensive activities with a numerical handicap and collective offensive activities with a numerical advantage; (4) static-vertical attacking activities with a numerical advantage, attacking activities with an equal number of players and dynamic defensive activities with a numerical handicap; (5) static-vertical defensive activities with an equal number of players; (6) extremely rare offensive activities which explain 19%, 16%, 17%, 11%, 11%, 6% of the manifest space variability, respectively.

Conclusions. The present findings highlight novel insight into experts' opinions regarding the learning of complex water polo movements, and offer essential guidance for key stakeholders pertaining to optimizing the training processes and curricula for all youth water polo players.

Keywords: water polo experts, tactical elements, new teaching methodology, didactic principles, early specialization.

Introduction

The training plan is mainly compiled according to certain criteria and epistemological and didactic knowledge in order to determine the technical and tactical skills. Tactics in water polo is one of the most important areas, as the outcome of the game largely depends on it. Tactics can only be decisive if a player has an excellent command of the technique of water polo and is well prepared in terms

of fitness. Tactics is the planning of how to use the available resources for the game and answers the question of how to play (Hraste, 2021). Individual tactics represent the game plan of an individual. Group tactics represent the game plan of two or more players, but not all of them. Collective tactics represent the game plan of all players. Every complex human movement takes place in a certain order; this also applies to training and development. In the training process, the areas, intensities and sequences of the training content to be taught are determined. For young water polo players, the perception of the (de)motivational style of their coaches is very important for the motivational results they report and their sporting commitment (Murillo et al., 2022). Changes

in pedagogical practice aimed to help players understand and use interventions to support the improvement of young futsal players and emphasized a new understanding of playing and coaching practices and the importance of critical player observation when thinking about how to develop supportive pedagogical practices (Ginciene et al., 2023). Research on young soccer players suggested that declarative tactical knowledge in the football team is different at different ages (Américo et al., 2016; Matos et al., 2019). The implementation of a program that included two different methods for teaching/learning football technique and tactics in young players led to improvements in participants' learning (García-Ceberino et al., 2020). The results on football tactical knowledge in the U-10, U-13 and U-16 age groups and three categories of high, medium and low competitive experience show that the improvement of declarative and procedural tactical knowledge in the early years influences the future success of individuals in football (Serra Olivares et al., 2021). A longer period of repetition and improvement is required from the beginning of learning tactical knowledge in young athletes to its application in situational conditions (de Castro Júnior et al., 2020). Coaches and athletes have been clearly identified as having difficulty recognising tactical potential, an important construct in the assessment of tactical skills (Silva et al., 2023). The acquisition and development of tactical skills in young athletes is variable and non-linear, and the need for continuous assessment during the training process across age is warranted (Praça et al., 2017; de Castro Ribeiro et al., 2021). For the first time, a study identified and explained coaches' opinions on the optimal age for learning a set of 39 water polo technique elements (Hraste et al., 2023). Unfortunately, we are not aware of any studies that have looked at expert opinion to determine the optimal age for the acquisition of tactical knowledge, either in water polo or any other sport.

The didactic principles are general norms through which the teaching-learning-assessment is put into practice, so that the functioning of the objectives/competences becomes efficient at the level of the educational dimension (Marius-Costel, 2010). When arranging the learning content, some of the basic didactic rules of gradation are usually followed, i.e. from the easier to the more difficult, from the simpler to the more complex and from the known to the unknown (Bjelica & Bilić, 2008). A top water polo player must be strong, fast and persistent as well as technically and tactically well developed. For a water polo player to achieve the highest quality, years of systematic and methodically correct training are required. In the search for an optimization of the training process according to the developmental characteristics of the children, a new teaching methodology was defined and explained (García-Angulo et al., 2019). By determining the optimal age for learning tactical skills, we can avoid early specialization. A focus on specialized training in the early stages of development has been associated with several negative consequences (Baker, 2003). Furthermore, for most sports there is no evidence that intensive training and specialization before puberty are necessary to achieve elite status (Jayanthi et al., 2013). A number of recent published studies have used objectively measurable indicators of the technical and tactical activities and efficiency of water polo (Tucher et al., 2015; Vila et al., 2011; Alcaraz et al., 2012; Lupu et al., 2014). Unfortunately, there is a relative paucity

of studies on the technical and tactical aspects of youth water polo (Hraste et al., 2014; Hraste et al., 2016; Falk et al., 2004). Water polo consists of polistructural complex movements which are performed without the ball in the phase of defence and with or without the ball in the phase of offense. From the perspective of the structural analysis of playing, there are three domains of playing: defence, offense and transition (conversion). According Hraste (2021) the phase of a set defence is the phase of play which begins with the conclusion of transition from offense to defence. The main goal of playing in a set defence is to use an appropriate tactical variant to stop the opponent's set offense and to regain the ball. In the phase of a set defence we differentiate three game systems: (1) system of press defence; (2) system of zone defence; (3) system of combined defence. The main difference between a press defence and a zone defence consists in the fact that during press defence a player guards his opponent directly and in zone defence a player guards the space in front of the opponent. Approximately 80% of movement in a press defence is performed in a horizontal and a semi-horizontal position, and around 20% is performed in a vertical and a semi-vertical position. In a zone defence approximately 70% of movement is performed in a vertical and a semi-vertical position and around 30% in a horizontal and a semi-horizontal position (Hraste, 2021). Combined defence is a system of play in which certain players play zone system and the other players do press defence at 8 meters from their own goal. The principle of this system of playing is to use press defence to guard better shooters or ball distributors while the system of zone defence guards against weaker shooters. The goal of conversion from defence to offense is a quick arrival from the area of defensive actions to the area of offensive actions after regaining the ball while the aim of conversion from offense to defence is a quick arrival to an area of defensive actions from an area of offensive actions after losing the possession of the ball (Hraste, 2021). The phase of a set offense begins in the moment when the team in a counterattack did not decide to attempt to score and the defence has transformed into set defence. In the present-day water polo game, there are following variants of the offensive systems: (1) system of positional offense with one centre forward; (2) system of positional offense with two centre forwards; (3) system of positional offense without a centre forward.

Possible problems in the methodological training of water polo players may arise due to the mismatch between biological and calendar ages, which has been reported as far back as the early 1990's (Malina & Bouchard, 1991). In practice, water polo clubs divide young players according to their calendar age, not their biological age. In such situations, it is desirable to make an exception and compromise in the execution of certain technical and tactical elements, adapting them to the individual so that the development paths are as suitable as possible. Coaches of young water polo players must monitor the psychophysical changes and know the methodology of the training process in order to fulfil the basic requirements for quality and continuous work. The main hypothesis of this research is that expert opinion on tactical elements in water polo will be ordered according to didactic principles. The aim of this paper was to determine and explain the coach opinion on the optimal age of acquiring tactical knowledge in water polo. The secondary

goal was to provide precisely structured methodological guidelines to trainers/experts for training process(es) with younger age teams.

Materials and Methods

Participants

Twenty-seven water polo coaches-experts, aged 27-61y, from Croatia volunteered to take part in this study. In Croatia, there are circa 140 licensed water polo coaches, meaning the sample used in this study comprised of ~20% of the available population. In the present study, all participants attended a water polo seminar and assured that the results would be shared; accordingly, there was a 0% dropout rate. Following a detailed description of the nature of the study, all parties provided written informed consent, prior to commencing participation.

The Sample of Variables

The sample of variables to estimate the optimal age to start learning all the tactical elements known in water polo consisted of 24 elements divided into several relatively homogeneous groups. Detailed explanation and use value of each of the listed elements can be found in Hraste (2021). All tactical water polo elements are known to water polo experts.

According to the phases of the game tactics in water polo is divided into: (1) system of 'shallow' zone defence; (2) system of 'deep' zone defence; (3) system of 'M' zone defence; (4) press defence at 8 meters from the goal; (5) press defence on the defensive half of the pool; (6) press defence across the whole court; (7) system of the combined zone defence to one player; (8) system of the combined zone defence to two players; (9) system of the combined zone defence to three players; (10) system of the combined zone defence to four players; (11) individual counterattack, known as 1:0; (12) the group counterattack 2:1; (13) the group counterattack 3:2; (14) the group counterattack 4:3; (15) the group counterattack 5:4; (16) the collective counterattack 6:5; (17) man up 4-2; (18) man up 3-3; (19) active man down with shifting from one side to another; (20) semi active man down with block and occasional shifting; (21) passive and deep man down with blocks only; (22) system of positional offense with one centre forward; (23) system of positional offense with two centre forwards; (24) system of positional offense without a centre forward.

Instruments

A novel questionnaire was used to ascertain the best age tactical aspects of water polo should be learnt. Participants were asked to select one of seven options for all tactical aspects, with reference to the best time to start. The first selection available was 10 years of age, as this pertains to the first year of water polo training for youth players.

Moreover, at this age, water polo training starts in countries with similarly developed water polo provision as Croatia (Hraste et al., 2008), including Italy (De Siati et al., 2016), Spain, Greece, Serbia, and Montenegro. The final option for starting to learn certain water polo techniques was the seventh year of playing water polo, i.e. sixteen years of age.

Statistical Analysis

Descriptive statistics, including mean (M), standard deviation (SD), median (MED), and minimum (MIN), and maximum (MAX), were calculated for each item. The test-retest method was applied to assess reliability. Between test-retest correlation coefficients were utilised taken as a measure of reliability. An exploratory strategy of factor analysis, combined with Guttman-Kaiser criterion for detection of number of real-life existing factors and Varimax Raw rotation, was utilised to assess content validity and define underlying structure. Indeed, factor analyses are conducted by examining the pattern of correlations or covariances between observed measures, where it is assumed that highly correlated variables measures are plausibly influenced by the same underlying factors (Jelaska et al., 2012). For this study, type I error was set to 5% and all statistical analysis was conducted using "Statistics for Windows" ver.13.0.

Results

After the initial validation of the instrument, consultation with four coaches took place, the final version of the questionnaire was then constructed. Test-retest reliability was high: 0.85-1.00 ($p < 0.05$). Moreover, for all variables, the arithmetic mean, standard deviation, median, mode, minimum and maximum value were additionally calculated. Table 1 shows the basic descriptive indicators for the tactic variables of all phases during water polo game.

The results in Table 1 indicate that the press defence in the defensive half of the pool, the individual counterattack and the group counterattack 2:1 are already learned at the end of the second educational year of training (M-11.96; M-11.93; M-11.96). The two other press defence tactics, known as press defines 8 meters in front of the goal and the press defines over the entire playing field, are learned at the beginning of the first half of the third educational year of training (M-12.00; M-12.15). According to the results, it can be seen that the group counterattack 3:2, the group counterattack 4:3, man up 4-2, man up 3-3, active man down with shifting, semi-active man down, offense with one centre forward and positional offense without a centre forward are learned in the third educational year of training (M-12.30; M-12.81; M-12.89; M-12.44; M-12.44; M-12.44; M-12.37; M-12.85). Table 1 details that the shallow zone defines, the deep zone defines, the combined zone defines to one player, the combined zone defines to three players, the group counterattack 5:4, the collective counterattack 6:5, the passive man down and offense with two centre forwards belong to the fourth training period (M-13.63; M-13.74; M-13.96; M-13.96; M-13.04; M-13.63; M-13.67; M-13.70). According to Table 1, coaches teach M zone defines and combined zone defines for two and four players in the fifth year of water polo training (M-14.52; M-14.00; M-14.00).

Six relatively independent latent dimensions were isolated by factor analysis and named as follows: (1) individual and group activities with numerical advantage/disadvantage; (2) dynamic-complex collective defensive activities with an equal number of players; (3) intensive defensive activities with an equal number of players, static defensive activities with a numerical handicap and collective offensive activities with a numerical advantage; (4) static-vertical attacking

Table 1. Results of descriptive statistics for all water polo tactical variables: Arithmetic mean \pm standard deviation (M \pm SD), Median (Med), modal value (Mod), Minimum value (Min), Maximum value (Max)

Tactical element	M \pm SD	Med	Mod	Min	Max
SHALZD	13.63 \pm 0.79	14.00	14.00	12.00	16.00
DEEPZD	13.74 \pm 0.81	14.00	14.00	12.00	16.00
ZONEM	14.52 \pm 0.89	15.00	15.00	13.00	16.00
PRES8M	12.00 \pm 0.78	12.00	12.00	11.00	14.00
PRESHC	11.96 \pm 0.90	12.00	12.00	11.00	15.00
PRESWC	12.15 \pm 1.13	12.00	12.00	10.00	15.00
COMZ1P	13.96 \pm 0.76	14.00	14.00	13.00	16.00
COMZ2P	14.00 \pm 0.83	14.00	14.00	13.00	16.00
COMZ3P	13.96 \pm 0.71	14.00	14.00	13.00	16.00
COMZ4P	14.00 \pm 0.96	14.00	14.00	12.00	16.00
IC1:0	11.93 \pm 0.73	12.00	12.00	10.00	13.00
GC2:1	11.96 \pm 0.71	12.00	12.00	10.00	13.00
GC3:2	12.30 \pm 0.72	12.00	12.00	11.00	14.00
GC4:3	12.81 \pm 0.68	13.00	13.00	11.00	14.00
GC5:4	13.04 \pm 0.76	13.00	13.00	12.00	15.00
CC6:5	13.63 \pm 0.79	14.00	14.00	12.00	15.00
MU4-2	12.89 \pm 1.01	13.00	13.00	11.00	15.00
MU3-3	12.44 \pm 1.01	12.00	12.00	11.00	15.00
AMDSHI	12.44 \pm 1.01	12.00	12.00	11.00	14.00
SAMDBS	12.44 \pm 0.75	14.00	13.00	12.00	16.00
PMDBLO	13.67 \pm 0.88	15.00	15.00	13.00	17.00
OF1CF	12.37 \pm 0.88	12.00	12.00	11.00	15.00
OF2CF	13.70 \pm 1.10	14.00	-	12.00	16.00
OF0CF	12.85 \pm 1.32	13.00	13.00	10.00	16.00

Legend: SHALZD – system of ‘shallow’ zone defence;
 DEEPZD – system of ‘deep’ zone defence;
 ZONEM – system of ‘M’ zone defence;
 PRES8M – press defence at 8 meters from the goal;
 PRESHC – press defence on the defensive half of the pool;
 PRESWC – press defence across the whole court;
 COMZ1P – system of the combined zone defence to one player;
 COMZ2P – system of the combined zone defence to two players;
 COMZ3P – system of the combined zone defence to three players;
 COMZ4P – system of the combined zone defence to four players;
 IC1:0 – individual counterattack, known as 1:0;
 GC2:1 – the group counterattack 2:1;
 GC3:2 – the group counterattack 3:2;
 GC4:3 – the group counterattack 4:3;
 GC5:4 – the group counterattack 5:4;
 CC6:5 – the collective counterattack 6:5;
 MU4-2 – man up 4-2;
 MU3-3 – man up 3-3;
 AMDSHI – active man down with shifting from one side to another;
 SAMDBS – semi active man down with block and occasional shifting;
 PMDBLO – passive and deep man down with blocks only;
 OF1CF – system of positional offense with one centre forward;
 OF2CF – system of positional offense with two centre forwards;
 OF0CF – system of positional offense without a centre forward

Table 2. Factor analysis of expert’s opinion of optimal beginning age for learning tactical skills in water polo (Expl.Var – variability explained by single factor; Prop.Totl – proportion of variability explained by single factor)

Variable	Factors					
	1	2	3	4	5	6
SHALZD	0.28	0.40	0.08	0.09	0.77	-0.07
DEEPZD	0.20	0.21	-0.10	0.01	0.85	-0.15
ZONEM	0.05	0.66	0.13	-0.10	0.20	-0.32
PRES8M	0.32	0.07	0.85	-0.06	-0.08	0.23
PRESHC	0.28	0.09	0.84	0.07	-0.02	0.17
PRESWC	0.43	0.06	0.59	0.30	0.26	0.02
COMZ1P	0.14	0.95	0.03	0.05	-0.04	-0.03
COMZ2P	0.11	0.93	0.04	0.07	0.10	-0.02
COMZ3P	-0.02	0.80	0.12	0.16	0.46	0.14
COMZ4P	-0.06	0.68	0.05	0.34	0.45	0.02
IC1:0	0.87	0.27	0.04	0.12	0.05	0.22
GC2:1	0.85	0.28	0.10	0.10	0.09	0.19
GC3:2	0.82	0.14	0.10	0.39	0.06	0.02
GC4:3	0.82	-0.24	0.31	0.11	0.27	-0.02
GC5:4	0.69	-0.17	0.44	-0.03	0.18	-0.12
CC6:5	0.10	-0.01	0.57	0.09	0.58	0.25
MU4-2	0.14	0.18	0.65	0.47	-0.01	-0.17
MU3-3	0.36	0.06	0.10	0.73	0.15	0.39
AMDSHI	0.41	0.17	-0.06	0.72	0.25	0.07
SAMDBS	-0.05	0.01	0.76	0.24	-0.04	-0.36
PMDBLO	-0.25	0.09	0.67	0.09	0.33	-0.26
OF1CF	0.16	0.14	0.31	0.77	-0.13	-0.04
OF2CF	-0.50	0.08	0.34	0.54	0.15	0.29
OF0CF	0.26	-0.07	0.04	0.24	-0.16	0.78
Expl.Var	4.56	3.89	4.13	2.74	2.58	1.47
Prp.Totl	0.19	0.16	0.17	0.11	0.11	0.06

Legend: SHALZD – system of ‘shallow’ zone defence;
 DEEPZD – system of ‘deep’ zone defence;
 ZONEM – system of ‘M’ zone defence;
 PRES8M – press defence at 8 meters from the goal;
 PRESHC – press defence on the defensive half of the pool;
 PRESWC – press defence across the whole court;
 COMZ1P – system of the combined zone defence to one player;
 COMZ2P – system of the combined zone defence to two players;
 COMZ3P – system of the combined zone defence to three players;
 COMZ4P – system of the combined zone defence to four players;
 IC1:0 – individual counterattack, known as 1:0;
 GC2:1 – the group counterattack 2:1;
 GC3:2 – the group counterattack 3:2;
 GC4:3 – the group counterattack 4:3;
 GC5:4 – the group counterattack 5:4;
 CC6:5 – the collective counterattack 6:5;
 MU4-2 – man up 4-2;
 MU3-3 – man up 3-3;
 AMDSHI – active man down with shifting from one side to another;
 SAMDBS – semi active man down with block and occasional shifting;
 PMDBLO – passive and deep man down with blocks only;
 OF1CF – system of positional offense with one centre forward;
 OF2CF – system of positional offense with two centre forwards;
 OF0CF – system of positional offense without a centre forward

activities with a numerical advantage, attacking activities with an equal number of players and dynamic defensive activities with a numerical handicap; (5) static-vertical defensive activities with an equal number of players; (6) extremely rare offensive activities, which explain 19%, 16%, 17%, 11%, 11%, 6% of the variability of the manifest space, respectively.

Discussion

The results of the present research confirmed that it is a reliable and valid questionnaire for determining the optimal beginning age for learning tactical skills in water polo. Furthermore, the questionnaire was successfully structured according to modelled tactical elements depending on the age of the young water polo players.

The results of the mean values indicate that the coaches probably think that it is too early to start acquiring tactical knowledge in water polo in the first year of training. In the second year of training, coaches start learning tactics in only three variables, while most of the simpler tactical solutions start to be learned in the third year of training. Most of the more complex tactical variations are only learned in the fourth and fifth year of training.

The factor named Individual and group activities with numerical advantage/disadvantage represents the first latent dimension, and it is determined by the following variables: individual counterattack, known as 1:0; the group counterattack 2:1; the group counterattack 3:2; the group counterattack 4:3; the group counterattack 5:4. The first latent dimension is responsible for 19% of the variability of the items. This latent dimension is defined by the characteristics of the variables of the simplest tactic of water polo in terms of individual and group movements with numerical advantage/disadvantage. It is plausible that the experts believed that the aforementioned variables are at the top of the hierarchical structure at the optimal start of learning the tactics of water polo. The above variables essentially provide a good basis for further training in water polo tactics.

The second latent dimension could be named as Dynamic-complex collective defensive activities with an equal number of players. The second latent dimension, which is responsible for 16% of variability of items, as being determined by variables: system of 'M' zone defence; system of the combined zone defence to one player; system of the combined zone defence to two players; system of the combined zone defence to three players; system of the combined zone defence to four players. This latent dimension is defined by the characteristic variables of zone defines with dominance of partial zone defines. The common feature of all the zone systems mentioned above is that one part of the player is in a vertical position and the other part of the player is in a horizontal position.

The third latent dimension, which is responsible for 17% of variability of items, as being determined by variables: press defence at 8 meters from the goal; press defence on the defensive half of the pool; press defence across the whole court; the collective counterattack 6:5; man up 4-2; semi active man down with block and occasional shifting; passive and deep man down with blocks only can be interpreted as Intensive defensive activities with an equal number of players, static defensive activities with a numerical handicap

and collective offensive activities with a numerical advantage. Considering the complexity of the tactical performance of the mentioned variables, the experts probably placed the mentioned variables only third in the hierarchical structure of the optimal start of learning tactical skills in water polo. The experts most likely recognised the similarity in the completion of the collective counterattack with the man up 4-2, in the variants of the man down with a pronounced block and, above all, in all three variants of pressing in the set defence phase.

The fourth latent dimension, which is responsible for 11% of variability of items, was named as a Static-vertical attacking activity with a numerical advantage, attacking activities with an equal number of players and dynamic defensive activities with a numerical handicap. The following variables mostly belong to the fourth factor: man up 4-2; man up 3-3; active man down with shifting from one side to another; system of positional offense with one centre forward; system of positional offense with two centre forwards. According to the experts, the preparation and performance of the most energy-sapping variant of the man down is probably only the fourth link in the comprehensive tactical training of young water polo players. It can be assumed that the above-mentioned performance is an integral part of the training cycle for both types of man up in water polo. In addition, positional play in attack with one and two centre forwards is considered part of the cohesive space in modern water polo.

The factor which can be named Static-vertical defensive activities with an equal number of players represents the fifth latent dimension, and it is determined by the following variables: system of 'shallow' zone defence; system of 'deep' zone defence. The fifth latent dimension is responsible for 11% of the variability of the items. This latent dimension is defined by the variables' characteristic of the most demanding defensive tactic, in which all defensive players are in a vertical position. This tactical variant requires players to have great observation skills and greater work activity, which belongs to the later age or playing age.

The sixth latent dimension could be named as Extremely rare offensive activities. The sixth latent dimension, which is responsible for 6% of variability of items, as being determined by variable: system of positional offense without a centre forward. The last latent dimension belongs to the water polo tactic, which is used extremely rarely, and it is no wonder that it is the last link in the educational cycle of water polo tactics.

This research confirms the conclusion that declarative tactical knowledge varies among young athletes at different ages (Américo et al., 2016; Matos et al., 2019). The results of this study indicate that the coaches logically believed that the tactical elements should be taught according to the didactic principles of simpler and easier to more complex and difficult (Marius-Costel, 2010; Bjelica & Bilić, 2008). By distributing tactical solutions according to complexity in four years, the possibility of injuries in young water polo players can be reduced, which is in line with the recommendations that it is very harmful to start specialization in sports early (Baker, 2003; Jayanthi et al., 2013). Apart from a higher injury rate, the risks of early sporting specialization also include increased psychological stress and giving up sport at a young age (Jayanthi et al., 2013). In general, only appropriate

periodization and methodically correct training can lead to the desired effects in young water polo players and other athletes (Hraste et al., 2016; Malina & Bouchard, 1991). As the questionnaire was completed by a sample of experienced and educated water polo coaches, it is likely that the responses were guided or at least influenced by examples of good practice, expert opinion and developmental characteristics of children (García-Angulo et al., 2019). There is a possibility that such a clearly defined tactical curriculum will provide additional motivation for young water polo players (Murillo et al., 2022).

In future research, it will be necessary to further develop a model of timely acquisition of tactical knowledge in water polo, as the acquisition and development of tactical skills in young athletes is different and non-linear, and the need for constant assessment during the training process is justified by age (de Castro Júnior et al., 2020; Praça et al., 2017). Following this research, the results could be incorporated into the training process and curricula for tactical training in water polo. Furthermore, refining these processes could help to reduce the risk of injury, increase player career longevity and promote optimal growth, development and performance.

Conclusions

The results of this research show that coaches generally agree that 24 elements of water polo tactics should be taught according to basic didactic principles, which confirms the main hypothesis of this research.

This research can inform the training plan and programme for teaching tactical skills to young water polo players.

Future research should aim to increase the number of coaches with different levels of coaching experience, playing experience and qualifications involved in this work to gain a deeper insight into the understanding and application of didactic principles in water polo.

Conflict of interest

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

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Визначення оптимального віку для опанування тактики водного поло згідно з експертною думкою: Розуміння шляхом аналізу зниження розмірності

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

Реферат. Стаття: 8 с., 2 таб., 29 джерел.

Історія питання. Процес підготовки юних ватерполістів має велике значення, оскільки він має бути адаптований до дидактичних принципів та особливостей розвитку спортсменів. Однак, незважаючи на важливість цього питання, спостерігається брак відповідних досліджень.

Мета дослідження. Метою дослідження було визначити та обґрунтувати відповідний вік для початку вивчення тактичних елементів у водному поло, згідно з думкою тренерів-експертів у цій галузі спорту.

Матеріали та методи. Відповідно до поставлених вище цілей, 27 тренерів-експертів з водного поло заповнили нову анкету, спеціально розроблену для проведення цього дослідження.

Результати. Показники ретестової надійності продемонстрували задовільні результати (значення R коливається в межах від 0,85 до 1,00 при $p < 0,05$ для всіх змінних). За результатами дослідницького факторного аналізу із застосуванням критерію Гутмана-Кайзера для відбору кількості факторів та методу обертання Варімакс вихідних даних встановлено наявність шести основних факторів в контексті реального життя: (1) індивідуальні та групові дії з чисельною перевагою/недостачею; (2) динамічно-комплексні колективні захисні дії з рівною кількістю гравців; (3) інтенсивні захисні дії з рівною

кількістю гравців, статичні захисні дії з чисельною меншістю та колективні атакуючі дії з чисельною перевагою; (4) статично-вертикальні атакуючі дії з чисельною перевагою, атакуючі дії з рівною кількістю гравців та динамічні захисні дії з чисельною меншістю; (5) статично-вертикальні захисні дії з рівною кількістю гравців; (6) вкрай рідкісні атакуючі дії, які пояснюють 19%, 16%, 17%, 11%, 11%, 11%, 6% варіабельності відкритого ігрового простору відповідно.

Висновки. Представлені результати дослідження підкреслюють нове розуміння експертних поглядів щодо вивчення комплексних рухів у водному поло та пропонують основні рекомендації для ключових зацікавлених сторін щодо оптимізації тренувальних процесів та навчальних програм для усіх юних гравців у водне поло.

Ключові слова: експерти з водного поло, тактичні елементи, нова методологія навчання, дидактичні принципи, рання спеціалізація.

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REVIEW ARTICLE

Analysing the Mental Imagery Training to Improve the Ability of Petanque Sport Shooting Game: Literature Review

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objective. The purpose of this study was to determine the role of biomechanical mental imagery training analysis in improving the ability of Petanque Sports Shooting Game.

Materials and methods. This review study was performed following the PRISMA standards for systematic reviews and meta-analyses. The studies were required to have been published within the previous four years, from January 2020 to July 2023. (1) petanque shooting; (2) mental imagery analysis were the keywords used in the search process. To conduct the study, the database Scopus and SINTA (Science and Technology Index) were used.

Results. The findings of the literature review yielded a final sample comprising 7 relevant articles. Specifically, 3 articles focused on imagery training for enhancing petanque shooting results, while 4 articles examined the effects of petanque shot improvement on the shooting game abilities of this sport.

Conclusions. This study revealed that mental imagery exercise analysis significantly improved the performance of petanque athletes in the match phase, enhancing their performance, motivation, and concentration, making it a valuable method for achieving positive effects on physical and mental performance in petanque athletes.

Keywords: training, imagery, shooting, petanque.

Introduction

The game of petanque requires good mastery of basic techniques because it is the initial capital for an athlete to develop his game (Irawan et al., 2022). There are two important basic skills which are pointing and shooting (Pelana et al., 2019). Line shooting is determined by the distance between the circle (where the athlete will shoot) and the target iron ball (Lubis et al., 2021). Shooting technique is one of the techniques that need to be mastered well because the goal of the petanque game is to keep the opponent's ball away through shots so that a team can win the match. Therefore, in carrying out training, trainers must innovate so that athletes who take part in training do not feel bored with all monotonous training programs (Nurhasan et al., 2023). Numerous research works have examined various facets of the game of petanque. creation of a shooting instruction

model with a focus on throwing accuracy for novices (Badaru, Hasmyati, et al., 2021). The findings emphasize the necessity for development and training in this sport, particularly with regard to human resources (Yahya & Haeril, 2021). The evaluation's findings assessed the athletes' shooting prowess and noted areas in which they needed to improve (Isdarianti et al., 2022). All of these studies highlight how crucial training, development, and skill improvement are to the game of petanque.

Imagery training in petanque, particularly visualization training, has shown significant potential in improving athlete performance (Mulya, 2020). Research shows that imagery training, which includes relaxation, self-talk, and anxiety management, is effective in improving shooting skills (Wahyu Perdana et al., 2022). The imagery training model, which incorporates elements of Physical, Environment, Task, Time, Learning, Emotion, and Perspective, has been effective in improving motor skills and performance in a variety of sports, including petanque (Lubis & Permadi, 2020). In addition, wrist flexibility, arm strength, and concentration training have been identified as important

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factors affecting shooting performance in petanque, further emphasizing the importance of a comprehensive training program that includes visualization techniques (Edgar & Meyer, 2017). Overall, integrating imagery exercises, including spatial views and visualizations, can significantly improve the performance and skill development of petanque athletes.

Petanque shooting is an important skill in the sport of petanque, which involves techniques to move the opponent's ball away from the target area. Various studies have highlighted the importance of different training methods and factors affecting shooting accuracy. Arm strength training by analyzing the direction of the ball has been shown to significantly improve shooting accuracy, especially at longer distances (Helmi et al., 2024). The use of specialized training tools such as modified tire hoops has proven effective in improving shot accuracy, offering a cost-effective alternative to imported equipment (Fathoni Dermawan Giaz & Nurhidayat, 2022). Studies on petanque athletes have shown that shooting practice with imagery analysis leads to better shooting results compared to those who do not use such techniques. For example, athletes who engaged in imagery training showed greater improvement in shooting scores compared to those who did not (Jannah et al., 2023).

Numerous studies in the past have improved the accuracy of petanque games and improved the shooting ability of the game through imagery training. One such study looked at the impact of imagery training on petanque game accuracy (Iskandar et al., 2023), Mental imagery and shot accuracy (Rony et al., 2021), Development of Imagery and Self-Talk Exercises to Improve Shooting Game Ability (Wahyu Perdana et al., 2022)

Analyzing imaging exercises to enhance petanque sport shooting ability is primarily done because these exercises have the potential to enhance athlete performance, lower anxiety, boost confidence, and increase concentration. An athlete needs these four items, particularly while performing precision shooting drills that call for a high degree of focus and self-assurance during aim and shooting. Additionally, the field conditions necessitate that athletes compete directly with their opponents in order to acquire points, therefore strong visualization abilities are required so that athletes are not distracted by their opponent's score while they advance to the final round.

The vast majority of professional athletes worldwide (70–90%) who claim to utilize visualization to enhance performance serve as evidence for this. Professional athletes in the sports of basketball, gymnastics, soccer, volleyball, dance, and swimming have frequently engaged in motor imagery training, yet though petanque shooting accuracy methods have not been identified employing visualization for these athletes. As a result, it is considered innovative study, and Petanque sports instructors are advised to use this activity to help athletes improve their shooting accuracy, particularly when it comes to shooting accuracy metrics.

The purpose of this study is to help develop the ability of imagination, provide detailed propositions, multisensory, and stimulus on the accuracy of shots. Mental imagery exercises performed by athletes basically aim to increase the athlete's confidence which will have an impact on improving their motor skills so that it will indirectly have an impact on

the athlete's performance. Even imagery training is a form of exercise that can help improve shot accuracy. The advantage of mental imagery training for beginners is very useful, because it can provide a stimulus that can stimulate the emergence of imagination in athletes to get a clear picture. Several studies have confirmed that mental imagery training can improve athlete performance, reduce anxiety, improve concentration and confidence.

Materials and Methods

Study Participants

The words "Mental Imagery" and "Petanque Shooting" were looked for in publications from Scopus Collections (Science Citation Index Expanded) and Sinta (Science and Technology Index). Index of Social Science Citations. Sams Humanities & Arts Citation Index) for the years 2020–2023.

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) criteria, a total sample of 7 articles was obtained from a total of 127 publications, as depicted in the flow chart (Figure 1) (Moher et al., 2015) during the identification, suitability screening, and inclusion phases.

Study Organization

The literature evaluation considered the following factors: (a) the annual trend of papers published between 2020 and 2023 (b) the first author's institution's dissemination (c) The quantity of writers (d) subject of study (health, education management, training, or other) (e) the kind of study (longitudinal, descriptive, correlational), and (1) the typical amount of citations per article.

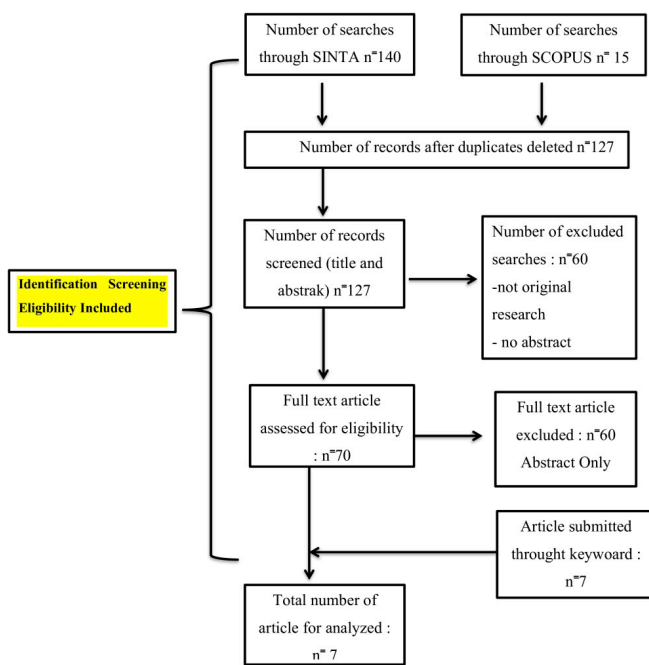


Fig. 1. Step-by-step literature search strategy process using PRISMA flow chart

Statistical analysis

Preferred were the article title abstract and keywords as this was enough to create seven reliable articles that could be used for further research. This review study only included publicly accessible articles as the authors did not want to exclude anyone who could not access their research. All relevant studies that addressed the following topics were selected based on the following inclusion and exclusion criteria.

Results

Table 1. Changes in the number of publications per year

Year of Publication	Number of Articles	Percentage
2020	50	50
2021	10	8
2022	30	20
2023	37	22
Total	127	100

The evolution of the number of publications shows different historical periods, as table 1 illustrates. The number of scholarly publications published has increased significantly since 2020 (50). Then, in 2021 there was a decline (10 articles), in 2022 there was an increase (30 articles), and in 2023 there was an increase (37 articles) in the following year.

The literature review resulted in a final sample of 7 relevant articles. Specifically, 3 articles focused on imagery training on petanque shot improvement and 4 articles on petanque shot improvement on petanque sport shooting ability.

Discussion

Based on the results of the Research These findings collectively underscore the importance of incorporating structured imagery exercises into petanque training to improve athletes' mental and physical performance, ultimately leading to better results in competition. Consistency in training is essential, as inconsistent

performance during competition has been linked to the need for a more focused shot accuracy training program, which has shown significant improvements in shooting results for both novice and professional athletes (Syahputra et al., 2021). Comparative studies show that while both precision and arm strength training have a positive impact on shooting outcomes, arm strength training tends to have more significant effects (Pelana et al., 2021). Overall, a combination of strength training, imagery, accuracy and a structured program seems to be the most effective approach to improve petanque performance especially in the shooting game.

Analysis Mental imagery training, a technique widely used in sport psychology, has been shown to improve motor performance and learning across a variety of settings and populations. Research shows that imagery training can improve motor skills in children and adolescents, with positive effect sizes, suggesting its potential in physical education and competitive sports for individuals who are more consistent in their performance (Frank, 2023). The results of other studies also prove that mental imagery training also increases athletes' self-confidence, as evidenced by futsal players who showed a significant increase in self-confidence after the training (Aikawa & Takai, 2022). Other studies have shown that mental imagery training in petanque significantly improves athletes' performance and mental resilience (Jannah et al., 2023). Research has shown that mental imagery training, which includes visual and kinesthetic elements, can improve shooting accuracy and precision in petanque athletes (Rony et al., 2021). Overall, combining these different training models and imagery techniques can provide a comprehensive method to improve petanque performance and address both the physical and mental aspects of the sport.

Different studies have investigated the variables that affect petanque shot accuracy. As eye-hand coordination, focus, and confidence are essential for shot accuracy. In addition, it has been shown that shooting drills with obstacles improve shooting ability (Saifulamri Alkhusaini et al., 2021). Another study found that modeling petanque shooting drills for beginners was the result, emphasizing the importance of drills to achieve high throwing accuracy (Badaru, Hasmyati, et al., 2021). Then the results of another study found that the effects of coordination training and

Table 2. Overview of mental imagery research characteristics

Author	Objective	Sample	Method	Results
(Jannah et al., 2023)	The research focuses on evaluating the mental aspects of athletes through mental imagery and self-talk.	9 Athletes	Descriptive Qualitative	Emphasizes the importance of utilizing imagery and self-talk techniques to help athletes improve their mentality, overcome fear, and perform optimally during competition.
(Rony et al., 2021)	The focus of the study was to find out how mental images affect shot accuracy in the sport of petanque.	A20 Athletes	One-Group Pretest-Posttest Design experimental study	This study shows that petanque athletes can use drawing as a basic cognitive process that improves motor movements and performance.
(Iskandar et al., 2023)	Knowing the effect of video imagery training on improving the pointing accuracy of novice athletes	16 Athletes	One-Group Pretest-Posttest Design experimental study	Data analysis concluded that video imagery training has a significant effect on the accuracy of shots in the sport of petanque.

Table 3. Overview of petanque shooting research characteristics

Author	Objective	Sample	Method	Results
(Badaru, Hasmyati, et al., 2021)	The purpose of this study was to develop a model of petanque shooting practice for beginners.	30 Athletes	Research & Development (R & D)	The validity of the training model was assessed through expert justification tests, ensuring that the developed model is suitable for improving shooting accuracy in the sport of petanque for beginners.
(Sutrisna et al., 2018)	Implementation of a petanque shooting skill training model for beginners and determine the effectiveness, efficiency and attractiveness of children to the model made.	330 Students	Research & Development (R & D)	The petanque sports shooting training model for beginners that has been developed, obtained evidence of this increase is shown in the results of testing the pretest and posttest data, there is a significant difference between before and after the model treatment.
(Hafizh Taajuddiin & Nurhidayat, 2022)	Aims to examine the comparison of shooting game ability	20 Athletes	Descriptive Qualitative	The shooting game ability between Surakarta city petanque athletes and Karanganyar regency petanque athletes has no significant difference.
(Ardhiyanto et al., 2021)	Analyzed the backswing and release angles in petanque shots, finding that the athlete's height and arm length affected the angles.	25 Athletes	Quantitative	Based on the analysis of several samples, it shows that the athlete's height and arm length affect the size of the backswing and release angle.

concentration training on shooting game ability were equally important, but concentration training gave better results (Lubis & Permadi, 2021). This study collectively emphasizes that concentration and mental imagery training forms are essential for improving accurate petanque shooting ability. Utilizing multiple analyses of mental imagery training forms for practice allows for intelligent training planning to get the best results quickly and safely.

In mental imagery training, athletes are asked to view a pre-recorded shooting video by themselves. This is done to store in their brain memory the shooting movements that must be done within a certain distance (Parnabas, 2015). The athlete is then given the task of imagining the shooting motion to be performed. This technique is done without the use of the ball to increase imagination, as a strong imagination produces nerve impulses similar to those produced when performing the actual movement. Once the athlete is sure the imagination is right, the ball is given for the actual shooting with various variations of obstacles and shooting distances. The imagery intervention was conducted over 8 weeks, 3 days each week, with 30 minutes of imagery practice and 60 minutes of photography practice. This was done because each athlete had not previously received a mental training program, as 24 sessions of training was sufficient to achieve the desired results (Shaari et al., 2019). Therefore, Petanque coaches are advised to implement mental imagery exercises to help their athletes shoot more accurately, especially with precision shooting numbers.

Conclusions

This study suggests that mental imagery training is necessary to improve the performance of petanque athletes in shooting. This includes structured imagery training and strength, precision and accuracy training programs. The results of another study also showed that mental imagery training significantly improved the performance and mental

endurance of petanque athletes. Petanque coaches are advised to implement mental imagery training to help athletes shoot more accurately, especially in shooting numbers. Especially, this mental imagery exercise plays an important role in improving the physical and mental performance of petanque athletes and can be a comprehensive method to improve the overall performance of petanque sports.

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Conflict of interest

The authors report no potential conflicts of interest.

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Аналіз проведення тренування із застосуванням методу ментальної візуалізації для покращення навичок виконання ударів у спортивній грі в петанк: Огляд літератури

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

Реферат. Стаття: 6 с., 2 табл., 1 рис., 29 джерел.

Мета дослідження. Метою цього дослідження було визначити роль біомеханічного аналізу проведення тренувань із застосуванням методу ментальної візуалізації щодо покращення навичок виконання ударів у спортивній грі в петанк.

Матеріали та методи. Дане оглядове дослідження проведено відповідно до стандартів PRISMA для систематичних оглядів і мета-аналізів. Дослідження мали бути опубліковані протягом попередніх чотирьох років, з січня 2020 року по липень 2023 року. (1) удари в петанку; (2) аналіз ментальної візуалізації — використовувалися як ключові слова в процесі пошуку. Для проведення дослідження використовували наукометричну базу даних Scopus та Індекс науки і технологій SINTA (Science and Technology Index).

Результати. За результатами огляду літератури було сформовано кінцеву вибірку, що включає сім релевантних статей. Зокрема, у трьох статтях розглянута методика застосування ментальної візуалізації з метою поліпшення результатів виконання ударів у петанку, тоді як у чотирьох статтях досліджено вплив вдосконалення ударів у петанку на ігрові здібності спортсменів при відпрацюванні техніки ударів у цьому виді спорту.

Висновки. Це дослідження показало, що аналіз проведення тренувань із використанням ментальної візуалізації значно покращив результати спортсменів-петанкістів у фазі матчу, підвищивши їхню продуктивність, мотивацію та концентрацію уваги, що свідчить про цінність застосування даної методики задля досягнення позитивного впливу на фізичну та розумову працездатність спортсменів з петанку.

Ключові слова: тренування, візуалізація, виконання ударів, петанк.

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REVIEW ARTICLE

Analyzing Sports Injuries of Kabaddi Players: A Systematic Review

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Abstract

Objective. This study aimed at analyzing sports injuries of kabaddi players through a systematic review.

Materials and methods. This review study adhered to the PRISMA guidelines for systematic reviews and meta-analyses. The study must have been published within the previous five years, from 2020 to 2024. The search procedure was conducted using the keywords (1) kabaddi, and (2) injuries. The Scopus search engine was used in this study.

Results. The search results in the database produced 104 articles that were adjusted to the criteria into 5 articles. Four articles summarized knee injury, one article focused on ACL tear injury, one article summarized the prevalence of traumatic orofacial injuries and traumatic episodes, two articles addressed ankle injuries and one article described and summarized shoulder injury.

Conclusions. The analysis of sports injuries in kabaddi players using a systematic review's findings leads to the conclusion that common injuries among kabaddi players are ACL tear injuries, knee injuries, prevalence of traumatic orofacial injuries, widespread presence of traumatic episodes, ankle injuries and shoulder injuries.

Keywords: kabaddi, injuries.

Introduction

Sports injuries can have a significant impact on athletes, especially in adolescent athletes, female futsal athletes, gymnasts and individuals with spinal cord injury (SCI). In adolescent athletes, pars injuries are a common cause of low back pain, with MRI being an accurate diagnostic modality (Asperti et al., 2017; Sun, 2023). Female futsal athletes showed a negative relationship between injury frequency and Adversity Quotient, emphasizing the need for psychological support during recovery (Haraldsdottir & Watson, 2021). Gymnasts frequently experience wrist injuries, with elite gymnasts facing higher injury rates, requiring proper evaluation and treatment to prevent chronic consequences. For individuals with SCI, participating in sport can positively impact physical function, quality of life, and community integration, highlighting the potential benefits of sport as an intervention to address the challenges associated with SCI (Cheung et al., 2022). Understanding the psychosocial impact of sports injuries in young athletes

is crucial to aid their management and prevent potential long-term consequences on mental health (Haraldsdottir & Watson, 2021).

Kabaddi players exhibit significant levels of muscle and body fitness, affecting their performance and susceptibility to injury. Research has shown that Kabaddi demands certain physical and physiological fitness characteristics such as agility, strength, speed and flexibility (Dahiya & Kumar, 2023). Additionally, research highlights the high prevalence of injuries in Kabaddi due to its aggressive nature, with knee injuries being particularly common among players (Chidambara Raja, 2023; D. R. M. Johnson et al., 2023). Furthermore, a study comparing Kabaddi and Kho-Kho players found differences in resting speed and pulse rate, suggesting varying fitness levels between the two sports (Harry & George, 2021). The prevalence of traumatic orofacial injuries among Kabaddi players underscores the risks associated with contact sports, emphasizing the importance of injury prevention strategies and adequate training to maintain performance and ensure player safety (Kalpana & Saraboji, 2022).

Sports injuries can indeed be avoided by athletes through various preventive measures. Research shows that insufficient warm-up is a common cause of injury during physical

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exercise, emphasizing the importance of proper preparation (Karo-Karo et al., 2023; G. Zhou, 2022). Additionally, a study in adolescent athletes highlighted the importance of neuromuscular training programs and education to prevent overtraining and risky maneuvers, reducing the incidence of musculoskeletal injuries (de Sire, 2022; Ram et al., 2022; Ram & Singh, 2021). Understanding the causes and factors that lead to injuries is essential to implement effective prevention strategies, as highlighted in a survey analyzing sports injuries across different specialties and athlete profiles (Golovashenko et al., 2022). Moreover, a focus on sports injury prevention in training is essential to ensure the health and well-being of athletes, emphasizing the need to strengthen preventive measures to minimize the negative impact of injuries on athletes' physical health and training continuity (Kusuma & Novita, 2023; W. Zhou & Chu, 2022).

Sports injuries in athletes can stem from various factors as highlighted in research. Excessive workload, early sports involvement, incorrect training methods, and rule violations contribute significantly to injuries (Selumyan & Petrosyan, 2023). Excessive physical strain, repetitive microtraumatization, and impact forces that exceed tissue resistance are the main causes of occupational diseases in athletes (Serhata et al., 2023). Injuries can be acute or chronic, with different types such as open wounds or closed fractures (Golovashenko et al., 2022). Psychological factors such as insecurity, reduced self-confidence, and fear of team impact play a role in the post-injury rehabilitation process (Sun, 2023). In addition, there are gender-based differences in sports-related injuries, with women experiencing higher rates of non-contact musculoskeletal injuries due to hormonal influences and training factors, emphasizing the importance of preventative measures and awareness among coaches and athletes (Raj et al., 2023).

Research on kabaddi has been extensive, covering various aspects such as injuries, physical fitness, psychomotor skills, and nutritional profiles of athletes. In addition, research has explored the impact of angina training with elastic bands on speed during direction changes, showing significant improvements in athlete performance (Utama et al., 2022). Evaluations of psychomotor skills have revealed differences between kabaddi and kho-kho players in areas such as speed, agility, balance, freezing, and eye-hand coordination (Chidambara Raja, 2023; Utama et al., 2022). Furthermore, comparisons between kabaddi and kho-kho players have been made regarding resting speed and pulse rate, suggesting differences in physical attributes between the two sports (Finco & Maciel, 2020). Training programs that meet the demands of sports can be developed with the use of this research. This study is crucial as a result. The purpose of the study is to give readers with recommendations based on the research findings.

Materials and Methods

The research method used was a systematic literature review (SLR) to study and interpret the analysis of sports injuries in kabaddi players. Systematic literature reviews play an important role in guiding future research by providing a comprehensive summary of existing knowledge, identifying gaps in the literature, and suggesting areas for further investigation. These reviews help researchers understand the

current state of a particular topic, develop new hypotheses, test theories, and generate new insights. By systematically analyzing and synthesizing a body of literature, systematic reviews offer a solid foundation for future research efforts, allowing scholars to build on existing work and push the boundaries of knowledge. They also contribute to improving the rigor and quality of research in various fields, including business, management, healthcare, and social sciences, by offering a structured approach to data collection and analysis. Ultimately, systematic literature reviews serve as a valuable resource for researchers, practitioners, and policy makers seeking evidence-based decision making and policy development.

Study Participants

This study is comparable to an analysis of sports injuries among kabaddi players since its population consists of articles published in international journals that are indexed by a very reliable database, namely Scopus. H-Index articles and publications from 2020–2024 published in international journals with Elsevier homepages are the samples that were chosen. The research data sources used in this study are of two different types: primary and secondary. In this study, a data coding sheet was the instrument. The information is helpful in explaining the exclusion of specific studies from the synthesis in addition to acting as an internal audit.

Data Collection Techniques and Instruments

Planning

Planning is the initial step in the systematic review process, which involves assembling a review panel of professionals and experts to create review questions. Data synthesis and analysis will follow from the review questions. The chapter on problem formulation has addressed the review questions.

Data Collection

The study's secondary data came from studies done by earlier researchers and published in international journals that were indexed by Scopus, a very reliable database. The keywords "kabaddi" AND "injuries" were used in the article search. To improve the quantity of article searches, the author additionally examines the references of the articles that are searched.

Inclusion and Exclusion Criteria

The study's inclusion criterion is that only keyword-related data were utilized. Only English articles that meet predefined criteria are included in the data, which is original content utilized between 2020 and 2024. In the meantime, these are the exclusion standards: Information that is not about injuries sustained in kabaddi, is not an original piece (including reviews), is not in the English language, and is indexed based on pre-established standards. The information was utilized between 2020 and 2024.

The database yielded 104 articles in total when articles were searched using keywords. Following filtration based on the language, article type, and publication period 2020–2024, 63 articles were found. Additionally, a total of 5 articles were

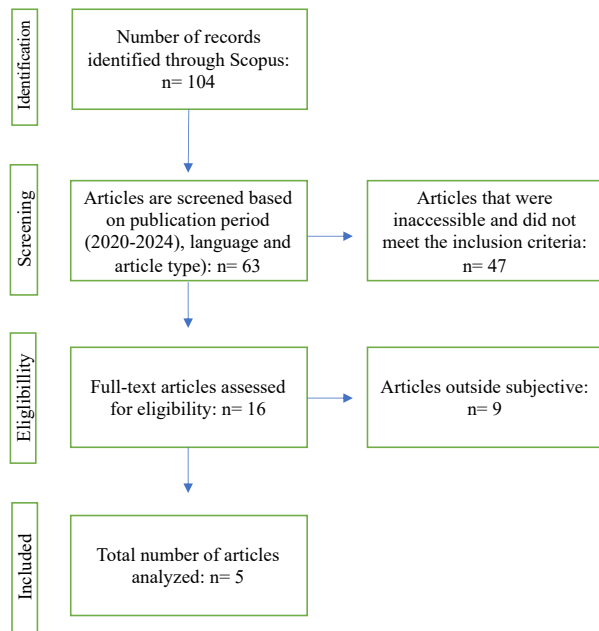


Fig. 1. PRISMA scheme in the literature selection process

acquired after the articles were chosen based on inclusion and exclusion criteria based on relevancy (Figure 1).

Study Instruments

The researcher employed analysis of annotated bibliographies. Annotated bibliographies are analyzed based on a number of factors, including the author’s credentials and goals, the identity of the referenced source, a brief synopsis of the material, and the significance of the sources cited in relation to the formulation of the problem.

Results

The table below shows the total number of publications during the selected time period, year of publication.

Table 1. Evolution of the number of publication at year

No	Year	Number of Article
1	2020	2
2	2021	1
3	2022	0
4	2023	2
5	2024	0

Table 2. Review of research results

No	Author and Years	Method	Findings
1	(Dahiya & Kumar, 2023)	Observation of regression in kabaddi injuries	ACL tear injury Knees injury
2	(R. M. Johnson et al., 2023)	Observational cross-sectional study with cluster random sampling	Prevalence of traumatic orofacial injuries and traumatic episodes
3	(Pal et al., 2021)	Comprehensive literature review	Knee and ankle injuries
4	(Yallappa, 2020)	Application of biomechanics in Kabaddi technique	Knee injury Ankle injury
5	(Park & Kim, 2020)	Injuries recorded on the IOC daily injury report form	Knee injury Shoulder injury

According to the literature, sports injuries of kabaddi players shown in the table above based on a review consisting of five studies there are four articles summarized Knee injuries, one article on ACL tear injuries, one article summarized Prevalence of traumatic orofacial injuries and traumatic episodes, two articles summarized Ankle injuries and one article summarized Shoulder injuries.

Discussion

Kabaddi players are at a significant risk of sustaining an ACL tear injury, as highlighted in various research papers. Studies have shown that the incidence of ACL tears is very high in kabaddi players, with a large number of injuries attributed to incorrect movements such as scissor grips (Pal et al., 2021). In addition, the prevalence of meniscus tears is also increased in kabaddi athletes, with most injuries occurring during competitive matches and leading to considerable durations of time lost in the sport (Yallappa, 2020). The aggressive nature of kabaddi, which involves rapid movements such as holding, pushing, catching and jumping, directly contributes to increased susceptibility to injury, especially in the knee region (Mondal, 2017). These findings underscore the importance of implementing injury prevention strategies and stricter regulations in Kabaddi to reduce the burden of ACL tear injuries and increase player safety and career longevity.

Kabaddi, an aggressive sport originating from India, poses a significant risk of knee injury to its players, with studies highlighting the prevalence of such injuries (Dahiya & Kumar, 2023; Mondal, 2017). Research into the profile of knee injuries among elite Iranian karateka also revealed a high incidence of knee injuries, particularly involving the anterior cruciate ligament (ACL), articular cartilage and meniscus (Naserpour et al., 2021). A comparative study between soccer and kabaddi players further emphasized the higher incidence of meniscus tears in kabaddi athletes, especially in the lateral meniscus, indicating the vulnerability of the knee in this sport (Gupta et al., 2020). Additionally, a study focusing on the effects of rehabilitation in male kabaddi knee injuries showed that interventions such as strapping, sports massage, stretching, and strengthening exercises can effectively reduce pain and improve range of motion in injured players (Dhillon et al., 2016). These findings underscore the importance of injury prevention strategies and rehabilitation programs to keep kabaddi players’ knees healthy.

Ankle injuries are a common concern in Kabaddi, with research highlighting their frequency and impact on

players. Research shows that knee injuries are common in Kabaddi players, followed by ankle injuries, emphasizing the vulnerability of the lower extremities in this sport (Dahiya & Kumar, 2023; Mondal, 2017; Pal et al., 2021). Ankle ligament OEO is particularly important, with varying percentages reported across different age groups and genders of Kabaddi players, demonstrating the importance of these injuries across different demographics. Furthermore, ankle injuries are often associated with the aggressive and combative nature of Kabaddi, where fast movements such as holding, pushing, catching and jumping increase the risk of injury, especially to the lower extremities (Kim et al., 2015). Understanding the pattern and frequency of ankle injuries in Kabaddi is crucial to implementing effective preventive measures and ensuring long-term player health and safety.

Shoulder injuries are a significant concern in Kabaddi, with a focus on knee injuries in the sport. Research has highlighted the prevalence of knee injuries, such as ACL tears and meniscus tears, leading to retirement from the sport and significant time loss in competition (Dahiya & Kumar, 2023). While knee injuries are predominant, the upper extremities, including the shoulders, are also prone to injury in kabaddi, with contact with opponents being the main cause (Dhillon et al., 2016). Epidemiological data from various studies emphasize the need for injury prevention programs and immediate treatment after injury to reduce the incidence of shoulder and other injuries in kabaddi players (Jayati, 2004).

Conclusions

Based on the results of the analysis of sports injuries in kabaddi players with systematic review, it can be concluded that injuries that often occur in Kabaadi Players are ACL tear injuries, knees injuries, prevalence of traumatic orofacial injuries, prevalence of traumatic episodes, ankle injuries and shoulder injuries.

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Conflict of interest

The author guarantees that there is no conflict of interest.

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Аналіз спортивних травм гравців у кабадді: Систематичний огляд

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

Реферат. Стаття: 6 с., 2 табл., 1 рис., 32 джерела.

Мета дослідження. Метою цього дослідження було проаналізувати спортивні травми гравців у кабадді за допомогою систематичного огляду.

Матеріали та методи. Дане оглядове дослідження проведено відповідно до керівних принципів PRISMA для систематичних оглядів і мета-аналізів. Матеріали дослідження мали бути опубліковані протягом попередніх п'яти років, з 2020 по 2024 рік. Процедура пошуку проводилася за ключовими словами (1) кабадді та (2) травми. В рамках цього дослідження використовувалась пошукова система наукометричної бази даних Scopus.

Результати. За результатами пошуку в базі даних було отримано 104 статті, які були відібрані згідно з встановленими критеріями і розділені на 5 статей. У чотирьох статтях представлено огляд травм колінного суглоба, одна стаття присвячена дослідженню розриву передньої хрестоподібної зв'язки, одна стаття містить аналіз поширеності травматичних ушкоджень орофасіальної ділянки та травматичних випадків, дві статті описують травми гомілковостопного суглоба, а у одній статті розглянуто та узагальнено аспекти травм плечового суглоба.

Висновки. Аналіз спортивних травм гравців у кабадді з використанням результатів систематичного огляду дозволяє зробити висновок, що найпоширенішими травмами серед гравців кабадді є розриви передньої хрестоподібної зв'язки, травми колінного суглоба, поширеність травматичних ушкоджень орофасіальної ділянки, переважання травматичних випадків, травми гомілковостопного суглоба та травми плечового суглоба.

Ключові слова: кабадді, травми.

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REVIEW ARTICLE

Water Aerobic Exercise Improves Mother's Quality of Life During Pregnancy: A Systematic Review

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. This study aimed to analyze the effectiveness, benefits and safety of water aerobic exercise in improving the quality of life of pregnant women from a psychological and physical perspective.

Materials and methods. The present study is defined as a type of systematic review research using searches from journal databases such as MEDLINE-PubMed, Web of Science, Scopus and Science Direct. The inclusion criteria for this study were articles published in the last 5 years and articles discussing pregnancy, aquatic aerobic exercise and quality of life in pregnancy. A total of 53 articles from the Science Direct, PubMed, and Web of Science databases were identified. A total of 8 articles that met the inclusion criteria were selected and analyzed for this systematic review. For standard operations, this study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) assessment.

Results. The findings of this systematic review indicate that participating in aquatic aerobic exercises has been found to reduce pain during labour, reduce the use of epidural analgesics during labour, reduce depression during pregnancy, reduce the risk of fetal distress, stabilize blood pressure, reduce back pain, and improve the psychological condition of pregnant women.

Conclusions. The regular practice of water aerobic exercise carried out from the 2nd trimester of pregnancy contributes to having a positive impact on improving the quality of life of pregnant women.

Keywords: water aerobic exercise, aquatic exercise, quality of life, pregnancy.

Introduction

The quality of life of pregnant women is the main axis for a mother during pregnancy and childbirth, this is a measuring tool used to comprehensively assess the health status of pregnant women starting from physical, psychological to social health (Boutib et al., 2022). Hormonal, anatomical, biological and physiological changes in the mother's body

during pregnancy make them more susceptible to disease, thus affecting the quality of life of pregnant women and the well-being of the fetus (Kazma et al., 2020).

Discomfort during pregnancy experienced by the mother causes a decrease in the quality of life because it is closely related to the mental and psychological readiness of the mother, this can have a negative impact on the health of the mother and fetus, resulting in death (Wu et al., 2021; Roddy Mitchell et al., 2023). Around 287,000 women died during pregnancy and childbirth in 2020, one of the main causes being depression. Worse yet, nearly 95% of all maternal deaths occurred in low- and middle-income countries in

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2020, and most of them are preventable (Roddy Mitchell et al., 2023; Corcoran et al., 2022). In Indonesia, up to 25% of pregnant women experience depression during pregnancy and this increases the maternal mortality rate. Studies show that changes in body image, anatomical changes, and complaints experienced by mothers during pregnancy are the main causes of depression, which can actually be prevented by easy, practical and effective methods, namely regular exercise (Bhattacharjee et al., 2021).

Exercise is one solution that can improve the mother's psychological and physical well-being during pregnancy (Xu et al., 2023). Aerobic water exercise has been proven to be more effective in increasing levels of dopamine, serotonin and noradrenaline which can reduce several complications during pregnancy both psychologically and physically, thereby improving the mother's quality of life during pregnancy (Alizadeh Pahlavani, 2024).

The American College of Obstetricians and Gynecologists recommends that pregnant women need a social environment that encourages them to do things that have a positive impact on their pregnancy (ACOG, 2020). Regularly undertaking a physical exercise program has been proven to be very beneficial and safe during pregnancy (Cancela-Carral et al., 2022). Aerobic water exercise has also been proven to have a therapeutic effect that can prevent various health problems for pregnant women such as back pain, strengthen the mother's muscles and joints, improve blood circulation so that the fetus's nutritional and oxygen needs are met, and provide a relaxing effect so that it can reduce stress levels. mother during pregnancy (Boutib et al., 2023).

The lack of research related to this topic is one of the reasons this sport is not widely known among the general public. This study aims to analyze the effectiveness, benefits and safety of aerobic water exercise in improving the quality of life of pregnant women from a psychological and physical perspective.

Materials and Methods

Study Design

This type of systematic review research uses searches from journal databases such as MEDLINE-Pubmed, Web of Science, Scopus and Science Direct. It is considered a premier platform worldwide as it brings together publications that have scientific impact and relevance.

Eligibility Criteria

The inclusion criteria in this study were articles published in the last 5 years and articles discussing pregnancy, aquatic water exercise and quality of life in pregnancy. Furthermore, the exclusion criteria in this research are journals that are not reputable or are not indexed by Scopus and Web of Science.

Procedure

Titles, abstracts and full texts of articles were screened then verified and stored in Mendeley software. In the first stage, 53 articles from the Science direct, Pubmed and web of science databases were identified. Next, in the second stage, 27 articles were screened based on the suitability of the title

and abstract. In the third stage, 19 articles were ordered for further processing. At this stage we filter based on the overall suitability of the article. Then in the final stage 8 articles were selected that met the inclusion criteria and analyzed for this systematic observation. For operational standards, this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) assessment.

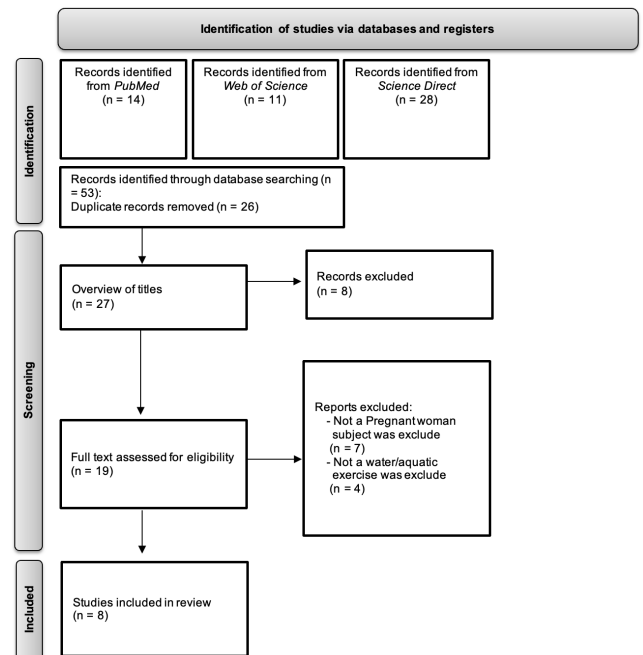


Fig. 1. PRISMA flowchart of the article selection process

Results

Description of Aerobic Water Exercises Include in Review

Based on the articles selected and analyzed as a whole, it was found that the intervention was carried out in accordance with the recommendations of the American College of Sports Medicine, where ideally physical exercise should be carried out regularly 3-5 sessions/week, 55-65% of the maximum heart rate which is the intensity of the mother's exercise. Pregnancy will be lighter than those who are not pregnant, the ideal duration is 20-60 min, and pay attention to a heart rate of no more than 140 bpm and a temperature below 38°C (Physical Activity Guidelines Resources, 2024).

From 8 selected articles (Navas et al., 2020; Navas et al., 2021a; Rodríguez-Blancue et al., 2020; Rodríguez-Blancue, Sanchez-García, et al., 2019; Rodríguez-Blancue, Sánchez-García, et al., 2019a; Vázquez-Lara et al., 2019; Granath, et al., 2022; Vallim et al., 2021), all implemented Aerobic water exercise in the intervention group which consisted of 3-4 phases, namely:

1. Warm up outside the water (5-7 min);
2. Warming up in water (5-10 min);
3. Aerobic Water Exercise moderate intensity (20 min);
4. Stretching and Relaxation (5 min).

The movements in aerobic water exercise are guided by a trained midwife or nurse who has attended the Study of

Table 1. Summary of the design and intervention of the studies

Author	Design	Participants	Gestational Age	Intervention	Outcome
(Navas et al., 2020)	Randomised Control Trial	IG = 160 CG = 160	Pregnant women aged 18-40 years with a gestational age of 14-20 weeks	IG = Pregnant women will take aerobic water exercise classes 3x/week for 5 months. Aerobic water exercise in this study consisted of: 1. Warm up outside the water (5-7 min) 2. Warming up in water (5-10 min) 3. Medium intensity water exercise (20 min) 4. Relax and regulate your breathing (5 min) 5. Playful exercise (5 min) CG = Pregnant women will receive standard antenatal care by a midwife or other health practitioner.	1. Aerobic Water Exercise can reduce pain during labor. Measuring Tool: Visual Analogue Scale (VAS). 2. Aerobic water exercise can reduce the use of epidural analgesia during labor. Measuring tools: reviewed by members of the research team themselves. 3. Aerobic water exercise can reduce levels of depression during the antenatal to postnatal period Measuring tools: Edinburgh Postnatal 4. Depression Scale (EPDS), EuroQol five dimension (EQ-5D)
(Navas et al., 2021)	Randomised Control Trial	IG = 145 CG = 141	Pregnant women aged 18-40 years with a gestational age of 14-20 weeks	IG = Pregnant women will take aerobic water exercise classes 3x/week for 5 months. Aquatic exercise in this research consists of: 1. Warm up outside the water, including neck stretching; pectoral muscles; shoulder; back; thighs and ankle and knee mobility training (5-7 min) 2. Warm up in the water, including a leisurely walk; small jump; walk back and forth in the water (5-10 min) 3. Moderate intensity water exercise (20 min) 4. Relax and regulate your breathing (5 min) 5. Playful exercise (5 min) CG = Pregnant women will receive standard antenatal care and are still advised to do physical activity.	1. Aquatic Exercise can significantly reduce pain during labor compared to standard care. Measuring Tool: Visual Analogue Scale (VAS). IG= mean \pm SD 7.55 \pm 2.20 CG= mean \pm SD 8.15 \pm 1.95 2. Intrapartum fetal distress in IG is less than in CG IG = 25/120 (n=20.8%) CG = 28/119 (n=23.5%)
(Rodríguez-Blanque et al., 2020)	Randomised clinical trial	IG = 65 CG = 64	Pregnant woman with 12 weeks of gestation	IG = Given moderate intensity physical activity in water for 60 min, 3x/week, supervised by a midwife or nurse with a sports science degree who has undertaken SWEP training. Physical exercise in water in this study was divided into 3 phases per session, including: 1. Warm-up 2. Main phase (Aerobic Water Exercise) 3. Stretch and relaxi CG = The control group was given standard care recommended during pregnancy by a midwife or ob-gyn doctor who was provided during the research.	The results of the health assessment from the HRQoL summary showed that the IG experienced a decrease of 3.93 at the end of the study, while the CG experienced a greater decrease of 8.07 points. Even in the mental health component, the CG score drops to \leq 42, which is a point indicating a threshold risk of depression.

Table 1 (continued)

Author	Design	Participants	Gestational Age	Intervention	Outcome
(Rodríguez-Blanche, Sanchez-Garcia, et al., 2019)	Randomised Clinical Trial	IG = 65 CG = 64	Third trimester pregnant women without any contraindications to doing water exercise	IG = Given moderate intensity physical activity in water for 60 min, 3x/week, supervised by a midwife or nurse with a sports science degree who has undertaken SWEP training. Physical exercise in water in this study was divided into 3 phases per session, including: 1. Warm-up 2. Main phase (Aerobic Water Exercise) 3. Stretching and relaxation CG = Control group given standard care.	Water exercise during pregnancy which is carried out routinely 3x/week for 60 min at 20-37 weeks of pregnancy has been proven to be able to minimize the rate of perineal tearing during delivery.
(Rodríguez-Blanche, Sánchez-García, et al., 2019a)	Randomised Control Trial	IG = 60 CG = 60	Pregnant woman with 12 weeks of gestation	IG = Intervention is carried out when pregnant women are 20-37 weeks gestation by being given moderate intensity physical activity in water according to the SWEP (Study of Water Exercise during Prgnancy) method guided by trained midwife professionals. CG = Control group was given standard care recommended during pregnancy by a midwife or ob-gyn doctor who was provided during the study.	Water exercise performed during pregnancy has shown a positive impact on shorter duration of labor compared to those receiving standard care. This can improve the mother's quality of life and reduce the risk of postnatal depression.
(Vázquez-Lara et al., 2019)	Randomised Clinical Trial	IG = 18 CG = 28	Second trimester pregnant women who are physically and psychologically healthy	IG = Aquatic exercise program for pregnant women (AEPWP) is given for 6 weeks starting from 24-28 weeks of pregnancy to 32-36 weeks, carried out 2x/week for 45 min/session. To provide hyperbaric stimulation, the intervention is carried out in a pool at neck level. CG = Provided standard antenatal care, monitored directly by the research team and midwife	The aquatic exercise program given to IG has a positive impact, namely stabilizing the blood pressure of pregnant women after regular exercise compared to pregnant women in CG whose blood pressure is higher.
(Granath, et al., 2022)	Randomised Control Trial	IG = 132 CG = 134	Healthy pregnant women in second trimester and third trimester	IG = Water aerobics is given for the first 45 min and followed by 15 min of relaxation, guided by a trained midwife instructor. CG = Given Land-Based Physical Exercise (LBPE), specifically designed for pregnant women and guided by trained Midwives.	Water exercise carried out regularly during pregnancy can significantly reduce back pain in mothers compared to LBPE. Pregnant women with LBP after intervention: IG = 19 CG = 34
(Vallim et al., 2021)	Randomised Clinical Trial	IG = 31 CG = 35	Pregnant women with a gestational age of 28-36 weeks	IG = Pregnant women will take part in aerobic water exercise classes specifically for pregnant women 3-5x/week for 50 min/session in accordance with the recommendations of the American College of Sports Medicine. CG = Receive antenatal care according to standards	Most participants showed better psychological conditions in the intervention group. Measuring tool: WHOQOL-BREF questionnaire

*IG: Intervention Group; CG: Control Group; SD: Standard Deviation

Water Exercise during Pregnancy (SWEP) training course (Rodríguez-Blanke, Sánchez-García, et al., 2019).

Participants who took part in the study were healthy pregnant women without any complications from their current or previous pregnancies. If during the study one of the following events occurs: Dizziness, chest pain, shortness of breath, swollen legs, reduced fetal movement, contractions, bleeding, and premature rupture of membranes, then the physical exercise will be stopped and the participant will be taken to hospital for treatment. according to complaint (Navas et al., 2020; Navas et al., 2021a; Rodríguez-Blanke et al., 2020; Rodríguez-Blanke, Sanchez-Garcia, et al., 2019; Rodríguez-Blanke, Sánchez-García, et al., 2019a; Vázquez-Lara et al., 2019; Granath, et al., 2022; Vallim et al., 2021).

Ideal gestational age when doing water exercise

The division of groups in the articles we analyzed all divided the research participants into two groups, namely the intervention group and the control group, both of whom were given antenatal care during pregnancy by a midwife or obstetrician-gynecologist in accordance with standards and provided aerobic water exercise in the intervention group (Navas et al., 2020; Navas et al., 2021a; Rodríguez-Blanke et al., 2020; Rodríguez-Blanke, Sanchez-Garcia, et al., 2019; Rodríguez-Blanke, Sánchez-García, et al., 2019a; Vázquez-Lara et al., 2019; Vallim et al., 2021). There is one article that provides a physical exercise intervention on land to a control group that compares it with an intervention group that was given physical exercise in the water (Granath, et al., 2022).

The research participants involved in this study were pregnant women in the second trimester of pregnancy, which physiologically at this gestational age has changed the structure of the spine so that pregnant women often complain of back pain, the burden of the fetus carried by the mother will increase, and Other complaints felt by pregnant women will increase at this gestational age, so that it will affect the decline in the mother's quality of life during pregnancy (Lagadec et al., 2018). Therefore, providing physical exercise in water here is 2x more effective in improving bone posture because movements carried out in water can strengthen bones and muscles, so that back pain in pregnant women can be reduced (Wu et al., 2021; Peng et al., 2022). If done regularly, water exercise will also relax the pelvic muscles, which can reduce tearing of the birth canal during labor (Cancela-Carral et al., 2022; Wu et al., 2021). In theory, water exercise can increase a person's hormones dopamine, serotonin and noradrenaline so that if applied to pregnant women it will have a positive impact on the mother's quality of life during pregnancy (Kepley et al., 2023). Apart from that, water exercise also has a therapeutic effect compared to exercise done on land, which can also reduce maternal depression in dealing with complaints during pregnancy (Cancela-Carral et al., 2022; Wu et al., 2021).

Quality of Life Post-intervention

The mother's quality of life during pregnancy is often influenced by several factors, such as a lack of support system from those closest to her, complaints felt during pregnancy, changes in body image, fear of facing childbirth, and others (Kepley et al., 2023). In this systematic review,

various outcomes were found after participants were given the intervention. Aerobic water exercise, which was carried out regularly by research participants, had a positive impact on them compared to the control group who were only given standard antenatal care (Navas et al., 2020; Navas et al., 2021a; Rodríguez-Blanke et al., 2020; Rodríguez-Blanke, Sanchez-Garcia, et al., 2019; Rodríguez-Blanke, Sánchez-García, et al., 2019a; Vázquez-Lara et al., 2019; Vallim et al., 2021). There was less pain during childbirth in the group of participants who did aerobic water exercise regularly. This was monitored by the research team itself starting from the participant recruitment process, namely pregnant women aged 12 weeks, then carried out health screening and given intervention when the mother entered the second trimester and assessed pain during labor using VAS (Navas et al., 2020; Navas et al., 2021a).

The quality of life of pregnant women is closely related to the incidence of depression during pregnancy until postpartum. In the above study, measuring the possibility of depressive symptoms using the Edinburgh Postnatal Depression Scale (EPDS) questionnaire, which has adequate sensitivity and specificity for identifying depressive symptoms during pregnancy. The results obtained were that after the water exercise intervention was given, depressive symptoms decreased in the intervention group compared to the control group (Navas et al., 2020).

Research that compares the differences in effect between water exercise and land base physical exercise (LBPE) also shows that after being given regular intervention, the water exercise group can reduce back pain more than the LBPE group (Granath, et al., 2022).

Discussion

This systematic review aims to analyze the benefits of aerobic water exercise in improving the mother's quality of life during pregnancy. From a search in the journal database, 8 relevant articles were found. The limited amount of recent research that addresses this issue shows that Aerobic water exercise has a positive impact in improving the quality of life of mothers and has not received much attention, even though improving the quality of life of mothers during pregnancy is the main axis in the realization of global problems, namely maternal and fetal mortality rates (Pascual & Langaker, 2023).

Aerobic water exercise is carried out according to the recommendations of the American College of Sports Medicine, namely carried out regularly 3-5 sessions/week, 55-65% of maximum heart rate, where the intensity of exercise in pregnant women will be lighter than in non-pregnant conditions, duration ideally 20-60 min, and pay attention to a heart rate of no more than 140 bpm and a temperature below 38°C (Stine et al., 2023). For pregnant women, doing physical exercise in water can provide many benefits, such as improving body image, reducing back pain, and managing the mother's emotions during pregnancy (Kepley et al., 2023; Gangakhedkar, 2022).

Measuring the quality of life of pregnant women can be assessed using a standard instrument, namely the EQ-5D, which has a very good level of validity and reliability for assessing the health condition of each individual (Feng et al., 2021). The EQ-5D questionnaire has a preference basis

with specific questions for each dimension, consisting of mobility, discomfort, pain, and maternal anxiety/depression during pregnancy (Navas et al., 2020; Navas et al., 2021a; Feng et al., 2021). Pain measurement is also included in the questionnaire which is measured using the Visual Analog Scale (VAS), which is used to measure maternal labor pain (Navas et al., 2020; Navas et al., 2021; Zhang et al., 2023). Assessment of maternal quality of life using this questionnaire was also applied to the articles analyzed, which showed the results that aerobic water exercise was able to reduce maternal depression symptoms during the antenatal to postnatal period and was able to reduce pain during childbirth so that the mother's quality of life increased (Navas et al., 2020; Navas et al., 2021a). Other studies use different measuring instruments to assess the level of maternal depression such as the Edinburgh Postnatal Depression Scale (EPDS) questionnaire, Health-Related Quality of Life (HRQoL) questionnaire (Navas et al., 2020; Navas et al., 2021a; Rodríguez-Blanque et al., 2020). This is in accordance with previous research which states that physical exercise can significantly reduce depression in mothers compared to mothers who do not do physical exercise during pregnancy (Sánchez-Polán et al., 2021; Silva-Jose et al., 2023).

Preeclampsia is one of the most common causes of maternal death throughout the world. This can be prevented through early screening during the first trimester of pregnancy by monitoring the increase in blood pressure in pregnant women (Shandilya, Sinha & Rani, 2023). Stabilizing blood pressure can also be done by doing regular aerobic water exercise, which has been proven in the analyzed article that the Aquatic exercise program for pregnant women (AEPWP) is given for 6 weeks starting from 24-28 weeks of pregnancy to 32-36 weeks, done 2x/week for 45 min/session. To provide hyperbaric stimulation, the intervention was carried out in a pool with a depth of neck level, which significantly stabilized maternal blood pressure during pregnancy compared to the group that was not given the intervention (Vázquez-Lara et al., 2019).

From this systematic review, relevant articles have proven that aerobic water exercise can reduce pain during labor, reduce the use of epidural analgesics during labor, reduce maternal depression during pregnancy, reduce the risk of fetal distress, stabilize maternal blood pressure, reduce maternal back pain, and improve the condition of the mother. maternal psychology.

Strenght and Limitations

This systematic review has the advantage that it lies in the research design that analyzed only randomized control trials, considered the most reliable scientific evidence because it eliminates false causality. Providing aerobic water exercise which has a stable intensity and duration so that the results obtained are very relevant and recommended. The limitation that we encountered is that there is still limited recent research that addresses this issue, showing that Aerobic water exercise has a positive impact in improving the quality of life of mothers, it has not received much attention, even though improving the quality of life of mothers during pregnancy is the main axis in realizing global problems, namely reducing mortality rates mother and fetus.

Conclusions

Based on the relevant articles that we found, we can conclude that Aerobic Water Exercise which is carried out regularly starting from the 2nd trimester of pregnancy will have a positive impact in improving the quality of life of pregnant women.

Conflicts of Interest

The authors declare no conflict of interest.

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Виконання вправ з аквааеробіки покращує якість життя матері під час вагітності: Систематичний огляд

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

Реферат. Стаття: 8 с., 1 табл., 1 рис., 31 джерело.

Мета дослідження. Метою цього дослідження було проаналізувати ефективність, переваги та безпеку виконання вправ з аквааеробіки для покращення якості життя вагітних жінок з психологічної та фізичної точок зору.

Матеріали та методи. Представлене дослідження визначається як вид систематичного огляду з використанням пошукових запитів у наукометричних базах даних журналів, як-от MEDLINE-PubMed, Web of Science, Scopus і Science Direct. Критеріями включення до цього дослідження були статті, опубліковані за останні 5 років, в яких обговорювалися питання вагітності, виконання вправ з аквааеробіки та якості життя під час вагітності. Загалом було виявлено 53 статті з наукометричних баз даних Science Direct, PubMed та Web of Science. Для систематичного огляду було відібрано та проаналізовано 8 статей, які відповідали критеріям включення. Що стосується стандартних операцій, дане дослідження проводилося відповідно до рекомендацій “Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)” (Переважні елементи звітності для систематичних оглядів і мета-аналізів).

Результати. Отримані результати систематичного огляду вказують на те, що залучення до занять аквааеробікою сприяє зниженню більшого синдрому під час пологів, зменшенню застосування епідуральних анальгетиків під час пологів, зниженню рівня депресії під час вагітності, зниженню ризику дистресу плода, стабілізації артеріального тиску, зменшенню болю в спині та покращенню психологічного стану вагітних жінок.

Висновки. Регулярна практика виконання вправ з аквааеробіки, починаючи з 2-го триместру вагітності, сприяє позитивному впливу на покращення якості життя вагітних жінок.

Ключові слова: вправи з аквааеробіки, вправи у воді, якість життя, вагітність.

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REVIEW ARTICLE

Championing Olympic Excellence: A Bibliometric Analysis of Biomechanics Impacting Tennis Performance on the World Stage

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Abstract

Objectives. The study aims to comprehensively analyze the existing literature on the relationship between biomechanics and tennis performance, with a particular focus on enhancing Olympic accomplishment.

Materials and methods. Scopus was used to search three fields in each record: (1) Author's name, (2) Journal Name where the paper was published, (3) Total citations. Bibliometric analysis was employed as a component of the analysis. To obtain a comprehensive and accurate understanding, the data was analyzed and interpreted using several methods of data triangulation. VOSviewer software was applied to generate distance-based co-occurrence maps for bibliometric analysis and synthesis. The terms extracted from keywords, titles, and abstracts were categorized and organized based on their level of interconnectedness. The keywords "Biomechanics" and "tennis performance" are commonly employed in the study, and their meanings are often interpreted in different settings. The search yielded 240 papers and 6137 citations, which were used in the study conducted between 2000 and 2024.

Results. The study's findings identified "key authors, countries, and subject areas" contributing to the field of biomechanics research in tennis, emphasizing interdisciplinary collaboration and future research directions.

Conclusions. In conclusion, the study provides a foundation for continued research and innovation in championing Olympic excellence through biomechanics research in tennis.

Keywords: biomechanics, tennis performance, Olympics, bibliometric analysis, VosViewer.

Introduction

To attain Olympic excellence in tennis, it is necessary to thoroughly comprehend the biomechanical elements that impact performance at worldwide levels (Martin et.al., 2021). Although tennis players aim to achieve their highest level of physical fitness and technical proficiency, there still needs to be more knowledge regarding the specific biomechanical processes that contribute to optimal performance (Lambrich & Muehlbauer, 2023). These factors impede coaches, players, and sports researchers from fully exploiting the capabilities of biomechanics to optimize tennis performance at the highest levels (Papageorgiou, 2021). Hence, it is imperative to thoroughly examine and promote the importance of biomechanics in enhancing tennis performance at

worldwide levels, thereby contributing to the progress of Olympic excellence in tennis (Zhu, 2017).

The impact of biomechanics on tennis performance at the world level, especially in promoting Olympic excellence, is significant (Ferrandez et.al., 2021). Biomechanics, the scientific discipline that investigates the mechanical properties and behaviors of living beings, is essential for comprehending and enhancing the actions executed by tennis players (Brocherie & Dinu, 2022). Biomechanics offers useful insights for enhancing technique, power, and effectiveness on the court by analyzing the forces, angles, and kinematics associated with each stroke (Touzard et.al., 2019).

At the pinnacle of competition, even small modifications in a player's biomechanics can have a substantial impact on their performance (Wood et.al., 2023). Biomechanical analysis assists tennis players in optimizing their strokes for increased speed, precision, and consistency across several aspects of their game, such as the serve, forehand, backhand, and volley (Pardiwala et.al., 2020). Understanding the ideal

racket angle and contact point for a serve can result in faster serves with enhanced accuracy, providing players with a competitive advantage over their opponents (Li et.al., 2023).

In addition, biomechanics plays a crucial role in identifying possible injury hazards and assisting in the development of methods to prevent injuries (Hayes et. al., 2023). Through the examination of the biomechanics of motions, coaches, and sports scientists can create training programs that reduce bodily strain and enhance performance (Yu et. al., 2018). In the sport of tennis, which is physically demanding and intensive, injuries caused by repetitive movements and overexertion are common (Suprunenko, 2021). This makes it even more crucial to devote attention to this concern.

In the worldwide arena of Olympic competition, the incorporation of biomechanics into training programs and coaching methods is becoming more prevalent (Brito et al., 2023). Olympic winners utilize biomechanical data to precisely refine their technique, optimize their physical fitness, and strategically plan their gameplay in order to surpass their opponents (Pluim et al., 2023). Consequently, sportsmen demonstrate extraordinary accomplishments on the tennis court, shattering records, and mesmerizing spectators with their agility and talent (Fletcher et al., 2021).

Biomechanics plays a crucial role in tennis performance at the global level, particularly in the quest for Olympic success. Its significance cannot be exaggerated (Yeadon & Pain, 2023). By employing biomechanical analysis and implementation, athletes can enhance their abilities, minimize the risk of injuries, and attain unprecedented levels of success, thereby establishing themselves as champions in the realm of tennis (Deng et al., 2022).

Bibliometric analysis, a method that employs quantitative techniques to examine a large amount of published research in a specific field (Donthu et al., 2021; Mukherjee et.al., 2022), can be utilized as a rigorous approach to increase the objectivity of the study. The study aims to provide a concise overview of research trends, serving as a guide for future research endeavors. Therefore, the study aims to review and provide an overview of Biomechanics Impacting Tennis Performance on the World Stage research published in top-tier journals using bibliometric analysis, contributing seminal insights to the following research questions (RQs):

- Which author and journals have published the most number of studies on the subjects of biomechanics and tennis performance?
- Which papers on the subject of biomechanics and tennis performance have received the most number of citations?
- What are the leading keywords in papers about the fields of biomechanics and tennis performance?
- Which countries display strong collaboration networks in the field of biomechanics and tennis performance?

The purpose of the study is to thoroughly examine the current body of literature on the relationship between biomechanics and tennis performance, specifically with an emphasis on promoting Olympic success. The study aims to utilize bibliometric analysis with VosViewer to determine the authors and journals that have published the highest number of articles on biomechanics and tennis performance. The study will help to identify the primary contributors to the discipline. Moreover, the study will identify the publications

that have garnered the highest number of citations, so highlighting the most prominent works in the field. The study will uncover the main subjects and areas of concentration in the fields of biomechanics and tennis performance by finding prominent keywords in the literature. Moreover, the study investigates the collaboration networks among countries, providing insights into robust connections and possible opportunities for cooperation. This bibliometric analysis offers significant insights to researchers, coaches, and athletes aiming to improve tennis performance at the Olympic level. It contributes to the progress of sports science and the pursuit of Olympic excellence.

Material and Methods

The study implies that researchers prioritize the most relevant papers pertaining to their investigation on “Championing Olympic Excellence: A Bibliometric Analysis of Biomechanics Impacting Tennis Performance on the World Stage”. The Scopus database was selected as a reputable source for retrieving citation data due to the importance of understanding the function of biomechanics in tennis play. Understanding the principles of biomechanics is one of the primary goals. This is essential because the terms “Biomechanics” and “tennis performance” are commonly used yet can be understood differently depending on the circumstances. The search produced 240 papers and 6137 citations, which were used in the study conducted from 2000 to 2024. This extensive dataset serves as a strong basis for assessing the influence of biomechanics on tennis performance at the global level. Figure 1 illustrated below shows the flow of information during different phases of a systemic screening process.

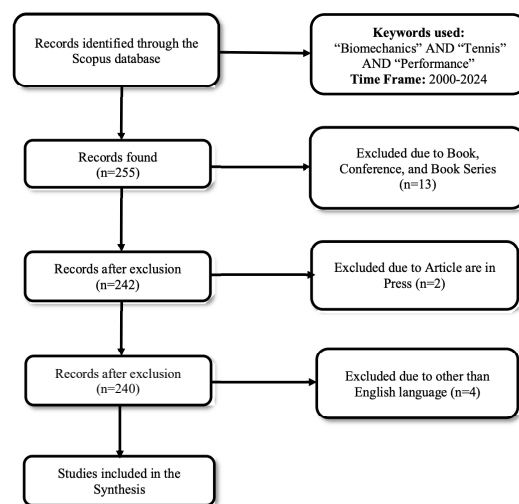


Fig. 1. Visual representation of the flow of information through the different phases of a systemic screening process. Source: Self-prepared by Author

The PRISMA model in Figure 1 provides a structured and transparent overview of the screening process for identifying relevant studies. Initially, 255 records were identified through the Scopus database using specific keywords related to “Biomechanics,” “Tennis,” and “Performance” within the timeframe of 2000-2024. From this initial set, 13 records were excluded as they were from book, conference, or book series

Table 1. Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Keywords	Records conferring the relationship between biomechanics and tennis performance	Records excluded in which variables have no relation
Type of Literature	Journals, Review Articles	Book series, book, chapter in book
Language	English	Other than English
Timeframe	Concerning 2000-2024	<2000
Paper Stage	Final stage	Excluded that are on the running stage

publications, and an additional 2 records were excluded because they were articles in press, not yet published. After applying these exclusion criteria, 242 records remained. Subsequently, four records were further excluded due to being in languages other than English, resulting in a total of 240 records. Finally, 236 studies were included in the synthesis, meeting the criteria for relevance and forming the basis for analysis. Overall, the PRISMA model illustrates how the initial pool of records is progressively refined to select studies for synthesis and analysis, ensuring a systematic and rigorous approach to literature review.

Scopus was used to search three fields in each record: (1) Author's name, (2) Journal Name where the paper was published, (3) Total citations. Bibliometric analysis was utilized as a component of the analysis. In order to obtain a comprehensive and accurate understanding, the data was analyzed and interpreted utilizing several methods of data triangulation. VOSviewer software was utilized to generate distance-based co-occurrence maps for bibliometric analysis and synthesis. The terms extracted from keywords, titles, and abstracts were categorized and organized based on their level of interconnectedness (Van Eck & Waltman, 2010).

The supplementary Table 1 provides a comprehensive overview of the criteria used to select papers for the study on the biomechanics that impact tennis play. The inclusion requirements in the "Criterion" column require that records establish the relationship between biomechanics and tennis performance. This ensures that only papers that are directly pertinent to the study topic are incorporated. Conversely, the exclusion criteria specify that records are eliminated if variables are unrelated to the issue. This process aids in eliminating unnecessary papers that may not provide any valuable insights into the investigation. The literature type

considered includes journals and review articles, which are known for their rigorous and concentrated approach toward specific issues. Excluding book series, individual books, and book chapters are necessary as they may lack the necessary depth or relevance required for the study.

Only publications written in English are included in the study, as the researchers performing the study are proficient in English. Papers written in languages other than English are not included because they may present language barriers. The study encompasses a timeframe from 2000 to 2024, which allows for the inclusion of recent research while also catching a substantial volume of relevant literature. Papers published prior to 2000 are removed due to the potential insufficient relevance to current trends or breakthroughs in the subject. Finally, papers that are in the final stage are included, while those that are in the running stage are excluded. This guarantees that only research that has been finished and evaluated by experts is taken into account for the analysis.

Citation Analysis

The study "Championing Olympic Excellence: A Bibliometric Analysis of Biomechanics Impacting Tennis Performance on the World "Stage" offers general research statistics, including the "number of papers published each year, the most referenced documents, the significant authors, the prominent journals, and the leading countries in the field".

Table 2 above presents a summary of citations, specifically focusing on the top 10 most often cited publications on the subject. The information provided above serves as the foundation for a thorough analysis of the impact of biomechanics on tennis performance and the difficulties encountered by tennis players at the global level.

Table 2. Citation analysis of different authors

Sr. No.	Authors	Source/journal	Total Citations
1.	Liao and Masters (2001)	Journal of Sports Sciences	263
2.	Lees (2003)	Journal of Sports Sciences	228
3.	Schack and Mechsner (2006)	Neuroscience Letters	161
4.	Palut and Zanone (2005)	Journal of Sports Sciences	126
5.	Huys, Cañal-Bruland, Hagemann, Beek, Smeeton, and Williams (2009)	Journal of Motor Behavior	124
6.	Girard, Micallef, and Millet (2005)	Medicine and Science in Sports and Exercise	116
7.	Bahamonde (2000)	Journal of Sports Sciences	115
8.	Kibler, Wilkes, and Sciascia (2013)	Clinics in Sports Medicine	115
9.	Rumball, Lebrun, Di Ciacca, and Orlando (2005)	Sports Medicine	112
10.	Mark Williams, Huys, Cañal-Bruland, and Hagemann (2009)	Human Movement Science	109

An analysis of author citations provides valuable insights into the main subjects and issues discussed in the field of biomechanics that impact tennis performance. Author-based evaluation offers initial insights into the possible impacts on the study field. The study conducted by Liao and Masters (2001) has received 263 citations in the Journal of Sports Sciences. The study conducted two experiments to investigate the idea that learning by analogy activates characteristics of an implicit mode of motor learning. A study conducted by Lees (2003) that examined the recent advancements in the utilization of scientific principles in racket sports has garnered considerable interest. The paper was published in the Journal of Sports Sciences and included 228 citations. The paper “Representation of motor skills in human long-term memory” by Schack & Mechsner (2006) had 161 citations as reported in Neuroscience Letters.

Palut and Zanone (2005) conducted a study in which they utilized self-organization theories and dynamical system models to examine the collective behavior of tennis players. Their research garnered 126 citations in the Journal of Sports Sciences. In their study, Huys et al. (2009) investigated the significance of local dynamical information in predicting the direction of tennis shots. Their research garnered 124 citations in the Journal of Motor Behavior. Girard et al. (2005) published a scholarly study titled “Lower-limb Activity during the Power Serve in Tennis: effects of Performance Level” in the journal Medicine and Science in Sports and Exercise and has been cited 116 times. Bahamonde (2000) highlighted the significance of “Changes in angular momentum during the tennis serve,” which has received 115 citations in the Journal of Sports Sciences.

Kibler et al. (2013) published a scholarly study titled “Mechanics and Pathomechanics in the Overhead Athlete” in the journal Clinics in Sports Medicine. The publication has received 115 citations. A study conducted by Rumball et al. (2005) examined the prevalent injuries documented in the literature, specifically focusing on musculoskeletal issues in the lower back, ribcage, shoulder, wrist, and knee. The study was published along with 112 citations in the field of Sports Medicine. The manuscript, authored by Williams et.al. (2009), investigates the mechanisms involved in anticipating groundstrokes in tennis. This is done by manipulating the dynamic information given at various body regions, including the racket. The study has garnered 109 citations in the journal Human Movement Science. The analysis offers initial insights into the most impactful research and probable avenues for future studies in the subject of biomechanics in tennis performance at the global level.

Yearly Publication

The chart in Figure 2 illustrates the total number of publications on biomechanics and tennis performance that have been indexed in Scopus from the year 2000 to 2024. Between 2000 and 2004, the total number of publications is rather limited, with an annual publication count ranging from 2 to 7 pieces. This indicates a narrow concentration on the subject matter in this timeframe.

Between 2005 and 2014, the number of publications varied but remained consistently low, with an annual range of 5 to 13 papers. This suggests a gradual albeit moderate rise in study interest regarding the relationship between

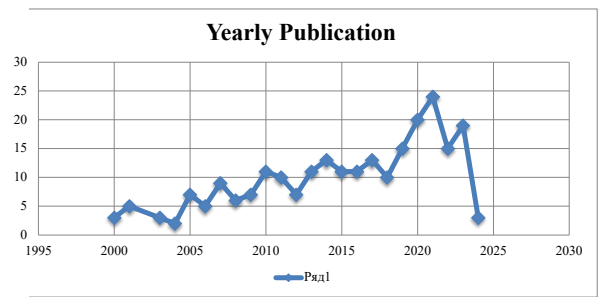


Fig. 2. The number of total publications on biomechanics and tennis performance indexed in Scopus 2000-2024

biomechanics and tennis performance. In 2015, there was a little increase in the number of publications, with 11 papers. This was followed by a consistent pattern in the subsequent years, with an average of 10 to 15 papers being published annually. In 2021, there is a notable increase in research efforts in biomechanics and tennis performance, as evidenced by the peak in publishing with 24 papers.

Nevertheless, in the years 2022 and 2023, the quantity of publications experiences a minor reduction to 15 and 19 papers respectively, suggesting a possible stabilization or tiny fall in research production compared to the preceding year. By 2024, there are merely three articles, suggesting that either the trend observed in prior years persists or it is too early in the year to obtain a comprehensive overview of scientific production. In general, the data indicates an increasing fascination in the field of biomechanics and study on tennis performance for the last twenty years, however, there have been variations in the amount of research conducted from year to year.

Top Authors

The graphical data in Figure 3 represents the top authors and the number of documents they have published in the field.

The above table 3 presents the Top authors and the number of documents they have published in the field. Reid, M. is at the top of the list with 27 articles, demonstrating a noteworthy impact on tennis performance through their considerable contributions to the scientific research of biomechanics. Whiteside, D. has published 13 papers, demonstrating a significant amount of research output. Gu, Y., Martin, C., Bideau, B., Baker, J.S., Elliott, B., Iino, Y., Kulpa, R., and Rogowski, I. have a smaller number of

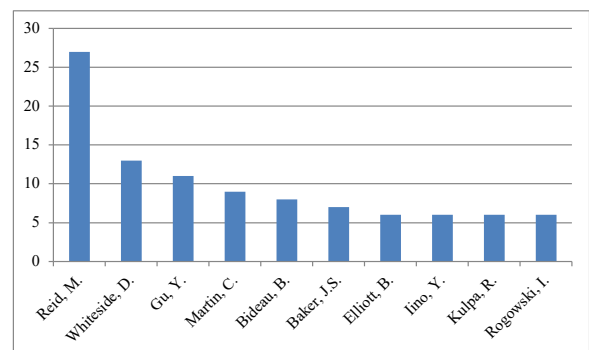


Fig. 3. Top authors and the number of documents they have published in the field

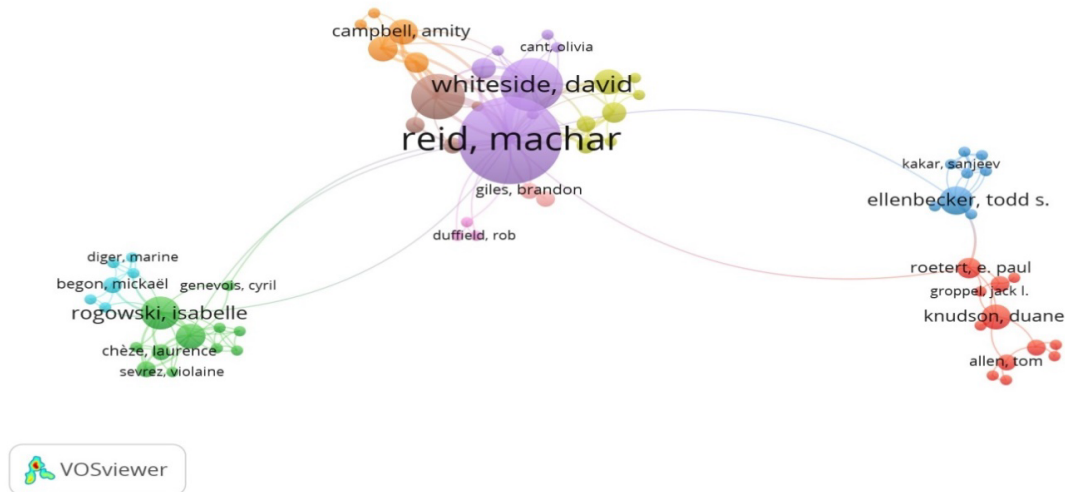


Fig. 4. Co-authorship between Authors

publications but still make a significant impact in the area, with 6 to 11 articles each.

The cluster diagram depicted in Figure 4 indicates that the authors have been actively involved in researching biomechanics and tennis performance, thereby making significant contributions to the existing knowledge in this field. Their work is likely to encompass a wide range of biomechanical elements, such as the analysis of techniques, prevention of injuries, optimization of equipment, and enhancement of performance in the sport of tennis. Their combined endeavors have probably played a significant role in the progress and understanding of how biomechanics impacts tennis performance, leading to valuable insights and developments in the discipline.

Subject Area Analysis

Figure 5 represents the allocation of research papers in different fields of study pertaining to the influence of biomechanics on tennis performance. The subject areas of Medicine and Health Professions have the highest occurrence, with 180 and 143 documents respectively. This suggests a notable emphasis on the medical and health-related elements of biomechanics in tennis, encompassing injury prevention, rehabilitation, and athlete health management.

The fields of Biochemistry, Genetics, and Molecular Biology are represented by 38 documents, indicating a significant focus on the molecular factors that drive biomechanical processes in tennis play. The areas of Psychology, Engineering, and Neuroscience have a lower number of documents, specifically 21, 19, and 18 respectively. These subject areas likely investigate elements such as cognitive readiness, equipment engineering, and neurological systems implicated in tennis performance.

The fields of Multidisciplinary, Computer Science, and Social Sciences all contain a relatively small number of documents, suggesting that scholars from different disciplines are contributing to the study of biomechanics in tennis from different angles. The field of Environmental Science has the lowest number of documents, specifically 10, indicating a relatively lower emphasis on studying the impact of environmental conditions on tennis biomechanics compared to other topic areas.

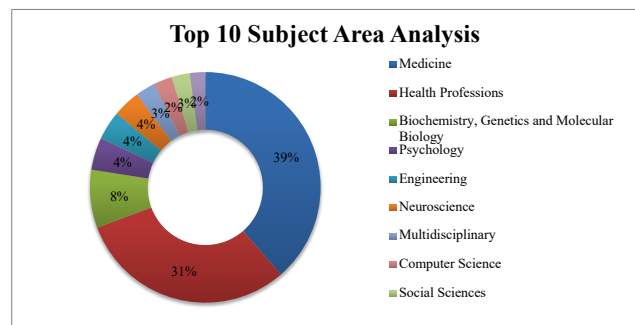


Fig. 5. Distribution of documentation in various subject areas

Overall, the data demonstrates that biomechanics research in tennis is interdisciplinary, including multiple domains to provide a thorough understanding of performance determinants and possible solutions.

Country Analysis

The data in Figure 6 represents the top countries and regions in research collaboration related to biomechanics and tennis performance from 2000 to 2024.

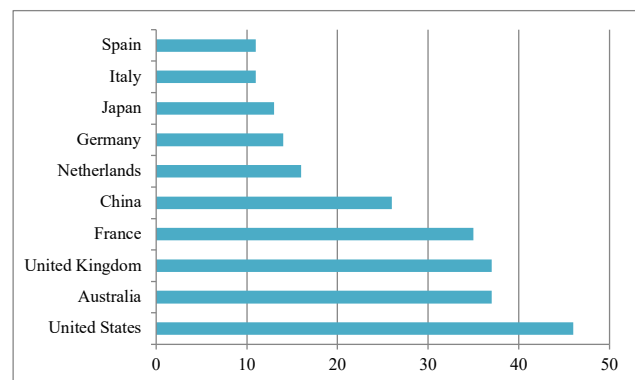


Fig. 6. Top countries and regions in research on documents

performance, with contributions from multiple countries across the globe.

Co-Occurrence of Keywords

Figure 8 illustrates the clustering of keywords based on their co-occurrence. An extensive analysis of keyword co-occurrence has been conducted to understand the development and progression of research on “The Impact of Biomechanics on Tennis Performance on the World Stage.” In order to carry out a study that is significant, a minimum requirement of five instances for a specific term has been employed. As a consequence, there was a grand total of 154 things out of the overall 1893 keywords. Firstly, the presence of keywords depicted with large circles indicates their frequent usage in scholarly articles on this particular topic. It is evident that the circles representing “biomechanics, physiology, task performance, physical performance, females, reviews, muscle training, psychomotor performance, and muscular strength” phrases are greater compared to the circles representing other categories. Less often occurring keywords include “racket sports, elbow injuries, physical activities, torque, lifespan, aerobic activity, and sports” terminology. In the future, scholars may conduct research using these high-frequency keywords to track present trends or explore new possibilities based on less frequently occurring terms.

Discussion

The objective of the study was to comprehend the research collaboration patterns in the fields of biomechanics and tennis performance between the years 2000 and 2024. The study utilized the Scopus database to identify 240 papers and 6137 citations, creating a comprehensive dataset for analysis. The inclusion criteria were designed to select only pertinent papers, specifically targeting journals and review articles published in English from 2000 to 2024. By conducting citation analysis, it was determined that the most influential authors on this subject are Reid, M., who has published 27 papers, and Whiteside, D., who has published 13 papers.

The citation review emphasized prominent articles, including those authored by Liao and Masters (2001) and Lees (2003), which indicated substantial focus on subjects such as motor learning and the utilization of scientific principles in racket sports. Moreover, the allocation of data across different subject areas demonstrated a significant concentration on Medicine and Health Professions, suggesting a prioritization of athlete health and the prevention of injuries. The investigation also identified the foremost countries in scientific collaboration, with the United States taking the lead, followed by the UK and Australia. In addition, an analysis of keyword co-occurrence revealed significant terms such as biomechanics, physiology, and task performance, indicating areas of focus and prospective avenues for future research. Overall, the study offers useful insights into the interdisciplinary aspects of biomechanics research in tennis and its implications for enhancing athletic performance at the global level.

The objective of our study was to analyze the patterns of research collaboration in the fields of biomechanics and tennis

performance during the past 24 years using bibliometric analysis. Daud et al. (2021) aimed to perform a bibliometric analysis in the field of optimization in sports by examining works published from 2011 to 2020. Ultimately, the study presented an overview of the existing body of literature on the subject of optimization in sports within the past decade. In a similar vein, Safari and colleagues (2022) conducted a study to examine the use of network embedding-based visualization in analyzing data science in sports activities using a large-scale dataset. A total of 805 articles published between 1997 and 2020, written by 3141 authors from 1181 institutions across 60 countries, were collected using WOS using R, Cite Space, and VOS viewer.

The number of papers on elbow pain (EP) in overhead sports is growing. Li et al. (2022) performed a bibliometric analysis to discover the research patterns about EP in overhead sports. The VOSviewer software was used to extract and evaluate several metrics from 455 qualified papers, including author name, article title, publishing journal, keywords, organization, publication country/region, and the sum of times cited. This analysis yielded the primary research results for three aspects. Bibliometrics, scientometrics, and informetrics are disciplines that primarily study the statistical evaluation of science by analyzing publications and citations. There is a diverse range of citation metrics that offer insights into the impact or influence of journals, specific articles, and authors. Dindorf et al. (2022) conducted a bibliometric analysis of highly cited articles in the journal *Sports Biomechanics* to investigate the hypothesis of the publication's excellent reputation among scholars. A systematic search was conducted in three prominent databases, namely Google Scholar, Scopus, and Web of Science, to identify the articles with the highest number of citations published in the field of Sports Biomechanics during the initial fifteen-year period (2002-2016) of its publication.

Conclusions

In conclusion, biomechanics has a substantial impact on shaping tennis performance. Through an in-depth understanding of the body's movement and its interaction with equipment, players can enhance their techniques, strength, and precision on the court. By conducting biomechanical analysis, athletes and coaches may pinpoint specific areas that need development, enhance stroke mechanics, and proactively avoid injuries. The comprehension of biomechanics not only improves tennis performance but also adds to the overall progress of the sport. By integrating biomechanical principles into training and coaching tactics, players may strive to achieve enhanced consistency, efficiency, and effectiveness in their game. The study of biomechanics in tennis offers useful insights that can assist players in maximizing their abilities and attaining success at the global level.

The bibliometric analysis of biomechanics' impact on tennis performance at the global level provides significant insights into the scientific field. The analysis identified the key authors, journals, countries, and subject areas that are making significant contributions to this field. Using VOSviewer software, the study investigated co-authorship networks and keyword co-occurrence to identify significant

trends and areas of interest. The notable representation of countries such as the United States, Australia, and the United Kingdom highlights the worldwide interest in this subject.

Suggestions involve promoting global cooperation to further enhance studies in the field of biomechanics and improve tennis play. Furthermore, advocating for multidisciplinary methodologies, namely in fields like psychology and engineering, has the potential to enhance comprehension of the intricate interplay between biomechanics and athletic prowess. Potential future avenues of exploration could include examining nascent technology, such as wearable sensors and virtual reality, in order to augment training methodologies and optimize player performance. In summary, this study establishes a basis for further investigation and advancement in promoting Olympic greatness in tennis through biomechanics research.

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Conflict of interest

The authors declare no conflict of interest regarding the publication of this research paper.

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Досягнення олімпійської досконалості: Бібліометричний аналіз біомеханіки, що впливає на результативність гри у теніс на світовій арені

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

Реферат. Стаття: 10 с., 2 табл., 8 рис., 36 джерел.

Мета дослідження. Дослідження спрямоване на проведення комплексного аналізу наявних літературних джерел щодо взаємозв'язку між біомеханікою та результативністю гри у теніс, з певним акцентом на підвищення рівня олімпійських досягнень.

Матеріали та методи. За допомогою наукометричної бази даних Scopus було проведено пошук за трьома параметрами у кожному записі: (1) ім'я автора, (2) назва журналу, в якому опубліковано статтю, (3) загальна кількість цитувань. В якості складової аналізу було застосовано бібліометричний аналіз. Для отримання комплексного і точного розуміння

інформації, було проведено аналіз та інтерпретацію даних з використанням декількох методів їх триангуляції. З метою створення дистанційних мап спільної зустрічальності для бібліометричного аналізу та синтезу було застосовано програмне забезпечення VOSviewer. Терміни, отримані з ключових слів, назв і анотацій, були класифіковані та систематизовані відповідно до рівня їх взаємопов'язаності. У дослідженні часто використовуються ключові слова «біомеханіка» і «результативність гри у теніс», значення яких часто інтерпретуються в різних контекстах. За результатами пошуку було знайдено 240 статей і 6137 посилань, які було використано в дослідженні, проведеному в період між 2000 і 2024 роками.

Результати. Результати дослідження визначили «ключових авторів, країни та предметні області», що сприяють дослідженню в галузі біомеханіки тенісу, підкреслюючи міждисциплінарну співпрацю та напрямки для подальших наукових досліджень.

Висновки. Таким чином, дане дослідження забезпечує основу для подальшого наукового вивчення та інновацій у досягненні олімпійської досконалості шляхом проведення біомеханічних досліджень у тенісі.

Ключові слова: біомеханіка, результативність гри у теніс, Олімпійські ігри, бібліометричний аналіз, VosViewer.

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