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Зміст

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Original Scientific Article

Social Adaptation of Athletes in Ukraine: Challenges and Priority Areas of Support

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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. Sport represents a crucial component of human life, yet the intensity of training, coupled with significant physical and psycho-emotional strain, often restricts athletes' opportunities for holistic personal development and limits their integration into the social environment. These challenges become especially acute during the transition from active competitive activity to the post-career stage.

Objectives. This study aimed to conduct a comprehensive analysis of the level of awareness among specialists in the field of physical culture and sport regarding the concept of athletes' social adaptation and to identify the key problems athletes encounter throughout this process.

Materials and Methods. The study was based on an anonymous online survey involving 150 specialists representing diverse sectors of the field of physical culture and sport in Ukraine. A set of complementary methods was employed, including system analysis, analysis and synthesis of scientific literature, sociological survey, and statistical analysis, using the chi-square (χ^2) test to assess the relationship between professional experience and awareness levels.

Results. The findings indicate that 87.3% of respondents considered the social adaptation of athletes to be "undoubtedly very important". The most critical challenges during athletes' professional careers were identified as the imbalance between sport and education (54.5%) and psychological overload and stress (40.0%). In the post-career stage, the leading difficulties were related to employment (33.8%) and financial instability (26.9%). The most effective forms of post-career support were recognized as employment assistance (mean score = 4.3) and financial support (mean score = 4.0). At the same time, the primary barriers to implementing adaptation programs included insufficient funding (37.3%) and athletes' limited awareness of available opportunities (19.3%).

Conclusions. The study underscores the urgency of developing and institutionalizing comprehensive national programs for the social adaptation of athletes in Ukraine, ensuring their continuity across all career stages.
Keywords: social adaptation, athletes, sports career, support mechanisms, challenges, dual career.

Introduction

Sport constitutes an integral part of human life, fostering not only physical abilities but also exerting a significant influence on social identity and personal development. Nevertheless, demanding training schedules, high psychological and physical workloads, and constant competitive pressures often limit athletes' opportunities for holistic development and hinder their full integration into the social environment (Korzh et al., 2024; Ponomaryov et al., 2024). The interplay of these factors creates substantial challenges for social adaptation, which become particularly critical during the transition from an active athletic career to the post-sport stage of life (Pryimak, 2025a; Leeder et al., 2025). Previous studies emphasize the necessity of psychological support to help athletes overcome critical stages in their careers and highlight the importance of effectively managing these transitions (Aptsiauri, 2024; Samuel et al., 2011). At the same time, scholars stress the need for the development of effective adaptation programs that take into account the specific characteristics of athletes' transition to life after sport (Voorheis et al., 2023; Voronova et al., 2024).

The relevance of examining the problem of athletes' social adaptation in Ukraine is shaped by several factors, among which the absence of comprehensive and systematic support programs and the insufficient awareness of specialists regarding athletes' actual needs are particularly significant (Voronova et al., 2020; Polishchuk et al., 2025). Effective social adaptation is a crucial condition for psychological well-being, professional self-realization, and the full integration of individuals into society after the completion of a sports career (Pryimak, 2025b; Choi et al., 2021). Within this context, athletes' education acquires special importance, being viewed not only as a tool for individual development but also as a strategic factor in sustaining sport at the national level. Domestic research highlights the importance of Olympic education, which is regarded as an integral component of the national educational and sports system (Bulatova et al., 2019; Radchenko et al., 2024).

An analysis of contemporary scientific literature demonstrates a growing scholarly interest in the issue of athletes' social adaptation within the international academic community. The works of researchers such as Hong et al. (2023) and Glandorf et al. (2023) emphasize the importance of psychological and social preparation for career termination, while also noting the economic challenges that arise during the post-career stage (Nuetzel, 2023; Pilkington et al., 2024). Considerable attention has also been devoted to mental health, stress, and professional burnout, which emerge as critical dimensions of the adaptation process (Thornton et al., 2023; Tossici et al., 2024; Trigueros et al., 2019). Ukrainian studies likewise address the problem of social adaptation, particularly in the context of the role of educational programs and psychological support. The works of Pryimak (2024, 2025c) focus on the distinctive features of athletes' adaptation at different stages of their sports careers and their interactions with the social environment-factors essential for a comprehensive understanding of the adaptation process. Furthermore, research on models of professional growth and career development offers valuable conceptual guidelines for the design of effective support programs for athletes in the post-career period (Pryimak, 2025d; Samuel et al., 2023).

Despite these contributions, several aspects of the broader issue remain highly relevant for further academic inquiry. Specifically, these include the level of awareness among Ukrainian specialists in physical culture and sport regarding athletes' social adaptation, their perceptions of the effectiveness and content of existing programs, the identification of athletes' primary needs within the Ukrainian context, and a systematic analysis of the barriers that hinder the implementation of effective support initiatives. These considerations highlight the urgency of addressing existing gaps through a focused examination of the aforementioned aspects under contemporary Ukrainian conditions.

The purpose of the study is to examine the level of awareness among specialists in the field of physical culture and sport regarding athletes' social adaptation and, based on the results of the conducted survey, to substantiate the necessity of developing and implementing social adaptation programs within the activities of physical culture and sports organizations.

Materials and Methods

Study Participants

The study employed an anonymous questionnaire survey aimed at assessing the level of awareness among specialists in the field of physical culture and sport regarding athletes' social adaptation, as well as substantiating the necessity of developing and implementing relevant programs within the activities of physical culture and sports organizations. A total of 150 respondents (n = 150), representing leading specialists in the field of physical culture and sport in Ukraine, participated in the research. The sample was formed on the principles of voluntary participation and accessibility, which allowed for the inclusion of a broad range of physical culture and sports organizations, as well as higher education institutions with a physical culture profile. Such a composition of participants ensured a sufficiently broad and representative reflection of professional perspectives on the issue under investigation.

The largest proportion of respondents represented children and youth sports schools (36.0%, n = 54), underscoring the importance of addressing athletes' adaptation from an early age. A substantial share of participants were affiliated with higher education institutions specializing in physical culture and sport (13.3%, n = 20) and with the Ministry of Youth and Sports of Ukraine (12.7%, n = 19). Specialists from sports clubs (7.3%, n = 11), physical culture and sports societies (6.7%, n = 10), and local administrations (6.0%, n = 9) were also represented. Smaller groups included respondents from schools of higher sports mastery (5.3%, n = 8), the National Olympic Committee of Ukraine and its regional branches (4.7%, n = 7), non-governmental and charitable organizations (3.3%, n = 5), municipal institutions (2.7%, n = 4), and the Olympic Academy of Ukraine with its regional branches (2.0%, n = 3).

An analysis of respondents' professional experience revealed that the majority were highly experienced specialists. Nearly half (47.3%, n = 71) reported more than 20 years of professional experience, 24.0% (n = 36) had 11–20 years, 17.3% (n = 26) had 6–10 years, while only 11.3% (n = 17) reported less than 5 years of work experience. The professional positions of participants covered a wide spectrum, ranging from coaches, academic staff, and sports managers to administrative personnel and senior executives of physical culture and sports organizations. This diversity provided a multifaceted perspective on the research problem and contributed to a deeper understanding of the complex processes of athletes' social adaptation. The largest group consisted of coaches (44.7%, n = 67), making their perspectives particularly valuable. Managers and executives of physical culture and sports organizations accounted for 22.7% (n = 34), senior specialists (including managers and administrators) represented 19.3% (n = 29), while academic staff comprised 13.3% (n = 20).

Study Organization

The study was conducted between May and August 2025. The research process included theoretical preparation, the development of research instruments, data collection, and subsequent analysis. The primary stage of data collection was implemented through an anonymous online questionnaire, which ensured confidentiality of responses and allowed for the inclusion of specialists from diverse regions of Ukraine, thereby minimizing geographical limitations.

To achieve the stated research aim, a set of complementary methods was employed.

System Analysis

This method was applied to examine the process of athletes' social adaptation as a complex, multi-component system. It enabled the identification of the structural elements of this system (e.g., individual characteristics of the athlete, the social environment, and institutional factors), their interrelations, and their functions. The use of system analysis contributed to a deeper understanding of adaptation mechanisms and facilitated the identification of key leverage points for the development of effective support programs.

Analysis and Synthesis of Scientific Literature

This method was used to comprehensively review contemporary national and international research, concepts, and theories related to athletes' social adaptation, the factors influencing this process, and existing support programs. The aim was to establish the theoretical foundations of the study, identify key problems and unresolved issues, and substantiate the relevance of the chosen topic.

Sociological Survey (anonymous online questionnaire)

The primary method of collecting empirical data was an anonymous online survey. A specially designed questionnaire was developed to capture the core aspects of specialists' awareness in the field of physical culture and sport regarding athletes' social adaptation, their perceptions of existing programs, and their assessment of athletes' priority needs within the Ukrainian context. The questionnaire included closed-ended questions (with multiple-choice options and rating scales for quantitative analysis) as well as open-ended questions to obtain deeper qualitative insights and clarify respondents' positions.

Statistical Analysis

Statistical methods were applied for the quantitative processing, analysis, and interpretation of the collected data. Descriptive statistics, including frequency analysis, calculation of means, and percentages, were used to summarize and present the results. In addition, the chi-square (χ^2) test was employed to assess statistically significant relationships between categorical variables (in particular, professional experience and level of awareness). Data analysis was carried out using Microsoft Excel and Statistica software.

Results

The analysis of the obtained results made it possible to form a comprehensive understanding of respondents' awareness of the concept of "social adaptation of athletes" and to identify key challenges and priority areas of support. The vast majority of specialists (87.3%) defined social adaptation as an "undoubtedly very important" component of the athlete support system; 12.0% of respondents considered it "important but not a priority," while only 0.7% regarded it as "not particularly important". These findings indicate a high level of recognition of the problem's significance among experts and highlight the urgent need for the development and implementation of effective support mechanisms.

The effective design and implementation of social adaptation programs require a unified understanding of the concept among specialists. The study revealed a certain degree of variability in respondents' interpretations of the term "social adaptation of athletes". The distribution of responses reflecting these differences in perception is presented in Figure 1.

As shown in Figure 1, the most common definitions among respondents were "successful integration of the athlete into the social environment during and after a sports career" (39.3%) and "the ability of the athlete to balance sport with other spheres of life, such as education, professional activity, and family" (29.7%). This distribution of responses demonstrates respondents' awareness of the multidimensional nature of social adaptation, which extends beyond preparation for the completion of a sports career and encompasses the continuous integration of the individual into various social contexts throughout an athlete's life course.

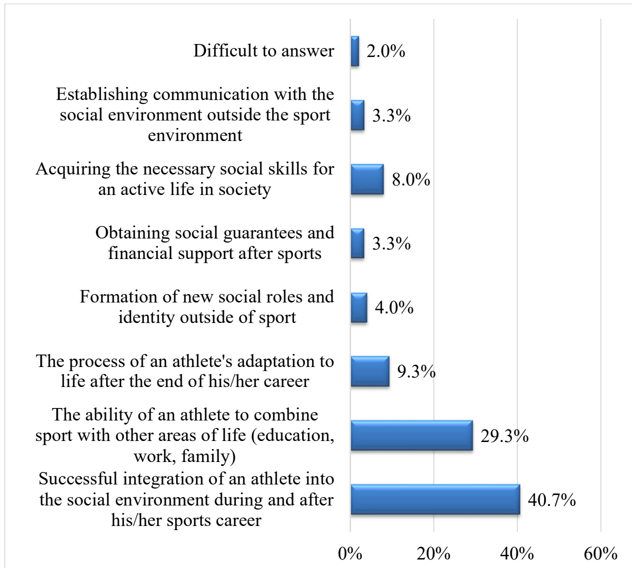

Fig. 1. Understanding of the concept of "social adaptation of athletes", respondents' views (n = 150)

To test the hypothesis regarding the relationship between specialists' professional experience and their level of awareness of existing social adaptation programs, statistical analysis was conducted using the chi-square (χ^2) test. This approach allowed us to determine whether the observed differences in awareness were dependent on work experience or occurred by chance. The following hypotheses were formulated:

Null hypothesis (H_0): The distribution of specialists' awareness levels is independent of their professional experience. In other words, there is no statistically significant association between these variables.

Alternative hypothesis (H_1): There is a statistically significant association between professional experience and awareness level, meaning that specialists' awareness is substantially influenced by their work experience.

The overall distribution of responses, reflecting the number of specialists with different lengths of professional experience across each awareness category, is presented in Table 1.

To examine the relationship between professional experience and specialists' level of awareness, a chi-square (χ^2) test was conducted. The obtained χ^2 value was 128.53 with 12 degrees of freedom (df). Since the p-value (< 0.001) was considerably lower than the standard significance level ($\alpha = 0.05$), the null hypothesis was rejected. This indicates the presence of a statistically significant association between work experience and specialists' level of awareness.

Table 1. Contingency table of observed frequencies

Work experience	Unaware	Heard only	Aware, not involved	Aware, involved	Aware (national level)	Total
≤5 years	12	4	0	0	1	17
6–10 years	12	11	1	0	2	26
11–20 years	4	14	4	6	8	36
≥20 years	2	15	8	5	41	71
Total	30	44	13	11	52	150

Specialists' awareness of existing social adaptation programs is a critical factor for their effective functioning and for encouraging athletes' participation. Within the framework of the study, respondents' level of knowledge about programs implemented both during active sports careers and after retirement was analyzed. The results, reflecting the current state of specialists' awareness, are presented in Figure 2.

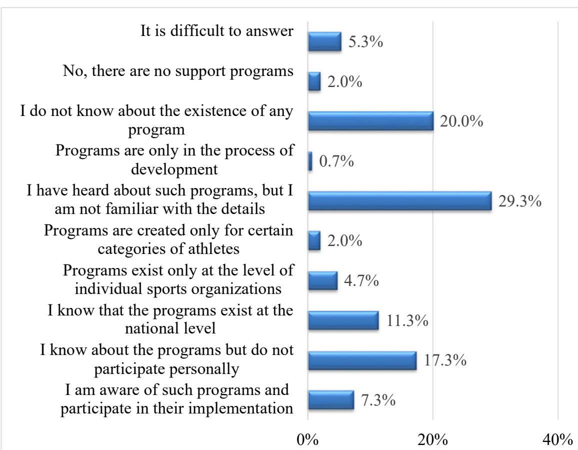

Fig. 2. Respondents' awareness of the existence of social adaptation programs for athletes during and after their sports careers (n = 150)

The findings (Figure 2) indicate that, despite the generally high recognition of the importance of social adaptation, the level of specialists' awareness of existing support programs remains a problematic issue requiring further scholarly investigation. A considerable share of respondents (20.0%) reported being completely unaware of the existence of such programs, while 29.3% stated that they had only heard about them but were unfamiliar with their content or implementation specifics. Only 7.3% of participants not only demonstrated awareness of these programs but also reported direct involvement in their implementation. This situation reflects the absence of a unified, well-structured, and accessible system of support for athletes' social adaptation. The insufficient level of specialists' awareness may significantly limit the effective use of available resources and reduce the degree of engagement of the target audience in relevant programs.

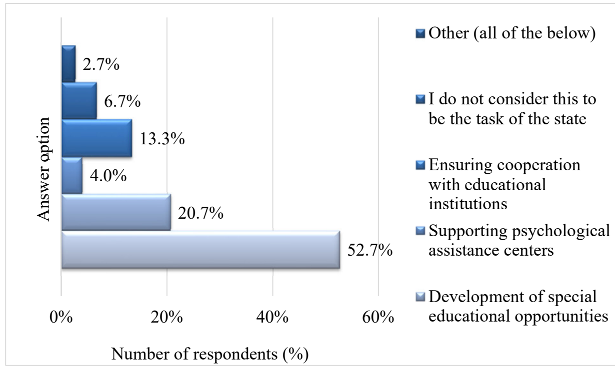

Fig. 3. The Role of the State in Supporting Athletes' Social Adaptation (n = 150)

Regarding the role of the state in the process of athletes' social adaptation, respondents expressed clear and consistent expectations. The majority of specialists assigned primary responsibility to the state for financing and developing targeted programs, reflecting an urgent need to establish a systematic national-level approach to this issue. Figure 3 presents the distribution of respondents' opinions on the functions that, in their view, the state should perform to ensure effective social adaptation of athletes.

As the survey results demonstrate (Figure 3), respondents attributed a leading role to the state primarily in "financing relevant programs" (52.7%) and "creating special educational opportunities" (20.7%). In addition, a substantial proportion of participants (13.3%) emphasized the importance of "establishing cooperation with educational institutions". Several respondents also highlighted the need to develop mechanisms for legal protection and to provide informational support for athletes in the context of their social adaptation.

This distribution of responses reflects specialists' recognition of the necessity for comprehensive, systematic, and institutionally secured state support capable of creating a stable foundation for the successful social adaptation of athletes.

Identifying the main difficulties athletes face during their sports careers from a social perspective is essential for designing effective support programs. A clear understanding of these challenges enables the development of targeted interventions aimed at improving athletes' quality of life and promoting their harmonious integration into society. The distribution of responses to this question, reflecting the key social challenges encountered during the active sports career stage, is presented in Table 2.

The survey results (Table 2) indicate that the most common difficulties faced by athletes in the context of social adaptation are "lack of balance between sport and education" (55.3%), "insufficient future planning" (41.3%), and "overload and stress" (39.3%).

These findings emphasize the multidimensional nature of the challenges athletes encounter, as they extend beyond purely athletic activity and directly affect their social development, psychological well-being, and overall quality of life.

Table 2. Key social challenges faced by athletes during their sports careers (n = 150)

Challenges During the Sports Career	n (respondents)	n (%)
Lack of balance between sport and education	83	55.3
Social isolation / limited social circle	45	30.0
Insufficient communication skills	25	16.7
Overload and stress	59	39.3
Inadequate future planning	62	41.3
Low level of civic engagement	30	20.0
Insufficient communication with family	13	8.7
Other (all specified items)	2	1.3

For the development of effective strategies to address these difficulties, it is crucial to understand the underlying factors that cause them. To this end, respondents were asked to identify the key factors that, in their opinion, underlie these problems during the course of a sports career. The aggregated results, which reveal the root causes of these challenges, are presented in Table 3.

The analysis shows that among the main causes of the identified difficulties, respondents most frequently cited "high levels of physical and psychological stress and lack of time" (60.7%) and "absence of state or municipal programs for social adaptation" (38.6%) (Table 3).

Continuing the analysis of the challenges athletes face in the context of social adaptation, it is essential to consider the specific difficulties that arise during the post-career period. The conclusion of a sports career is accompanied by profound transformations in an athlete's life, which are often even more dramatic than those encountered during active professional activity. These challenges are largely associated with the loss of a familiar social environment, stable income, and the professional role that has long shaped the athlete's identity.

Table 3. Factors underlying athletes' difficulties during their sports careers (n = 150)

Reasons for difficulties during a sports career	n (respondents)	n (%)
High levels of physical and psychological stress; lack of time	93	62.0
Insufficient support from coaches	8	5.3
Insufficient support from sports managers / sports organizations	33	22.0
Insufficient support from family	5	3.3
Absence of state or municipal adaptation programs	56	37.3
Limited initiative or motivation of the athletes themselves	34	22.7
Low level of awareness about available opportunities	47	31.3
Limited access to quality psychological assistance	12	8.0
Other (please specify)	3	2.0

During this stage, issues such as employment, financial stability, social integration, and the preservation of psychological well-being become particularly pressing. Table 4 presents the main difficulties athletes encounter after the end of their careers, outlining the primary challenges of post-sport life and highlighting the directions in which support is most urgently needed.

Table 4. Post-career challenges experienced by athletes (n = 150)

Difficulties after the end of a sports career	n (respondents)	n (%)
Sharp decrease or loss of income	85	56.7
Difficulties in finding new professional employment	107	71.3
Lack of adequate psychological support	26	17.3
Insufficient level of education/qualification	43	28.7
Challenging social adaptation / feelings of isolation	56	37.3
Health problems	49	32.7

For the development of effective support systems, it is important not only to identify the key problems athletes face but also to determine the forms of assistance perceived by specialists as the most effective. Within this study, respondents' evaluations of the importance and potential effectiveness of various types of support for athletes during the post-career period were analyzed. A five-point scale was used (where 1 – not effective at all; 2 – slightly effective; 3 – moderately effective; 4 – fairly effective; 5 – highly effective).

The results indicate that the highest mean scores were recorded for "career guidance and career path development" (M = 3.88), "financial counseling, including budgeting and investment advice" (M = 3.88), and "building a support network" (M = 3.76). These findings suggest that respondents attach particular importance to practical forms of assistance that can ensure a smooth transition to post-sport life, promote professional self-realization, and enhance financial literacy. The detailed results of respondents' evaluations of different forms of support are presented in Table 5.

The analysis of the data presented in Table 5 confirms the priority of career guidance, career path development, and financial counseling as key components of an effective athlete support system. The findings demonstrate specialists' recognition of the necessity for a comprehensive approach to ensuring athletes' successful reintegration into society after the completion of their sports careers. The high evaluation of mentoring programs involving former athletes further emphasizes their significance as an effective mechanism for transferring unique experience, fostering motivation, and facilitating adaptation through personal example and social support.

Alongside the identification of effective forms of support, an equally important task is to uncover and analyze the barriers that hinder the implementation or initiation of social adaptation programs for athletes. Understanding these obstacles provides the basis for developing strategies to overcome them and for ensuring the effective realization of adaptation initiatives. Among the most significant barriers identified by respondents were "limited funding or lack of resources" (37.3%) and "low levels of awareness or interest among athletes themselves" (19.3%). These factors have a systemic nature and require comprehensive solutions at

Table 5. Assessment of the importance of support measures for athletes in the post-career stage (n = 150)

Form of support	n					M
	Not effective at all (1 point)	Slightly effective (2 points)	Moderately effective (3 points)	Fairly effective (4 points)	Very effective (5 points)	
Individual consultations with a psychologist	7	29	40	43	31	3.4
Educational programs with flexible schedules	6	19	33	55	37	3.7
Courses in communication skills development	7	21	56	40	26	3.4
Participation in volunteer or social projects	10	25	44	50	21	3.3
Mentorship programs from former athletes	10	14	38	48	40	3.6
Career counseling	7	18	36	57	32	3.6
Psychological support (individual and group)	5	22	34	40	49	3.7
Career guidance and career path planning	7	12	21	60	50	3.9
Financial counseling (budgeting, investments)	6	16	22	48	58	3.9
Establishing a support network	6	14	28	60	42	3.8
Opportunities for formal education/training	8	16	25	57	44	3.8

Notes: n – number of respondents; M (Max = 5) – arithmetic mean value.

the state level. A detailed list of the identified barriers is presented in Table 6.

Table 6. Barriers to the implementation of athletes' social adaptation programs (n = 150)

Barriers	n (respondents)	n (%)
Limited funding or lack of resources	56	37.3
Insufficient number of qualified specialists	20	13.3
Lack of political or institutional support	26	17.3
Low level of awareness or interest among athletes themselves	29	19.3
Lack of interagency coordination	7	4.7
Difficult to answer	12	8.0
Total	150	100.0

Building on the analysis of support forms presented in Table 5, the following table provides more detailed information on the perceived effectiveness of specific measures aimed at supporting athletes' social adaptation after career termination. These data are based on mean scores provided by respondents using a five-point scale and are critical for identifying the most promising directions for the allocation of resources and efforts (Table 7).

According to the data presented in Table 7, respondents identified the most effective support measures as "employment assistance" (M = 4.3) and "financial support/ compensation" (M = 4.0). These results highlight the strong demand among athletes for practical career and material assistance after the completion of their sports careers, serving as an important reference point for the development of targeted social adaptation programs.

Discussion

This study provides a comprehensive overview of the current state and challenges of athletes' social adaptation in Ukraine, focusing on specialists' awareness, difficulties encountered during and after sports careers, and the perceived effectiveness and importance of various forms of support.

The findings demonstrate a high level of recognition of the significance of this issue among professionals: 87.3% of respondents identified athletes' social adaptation as "undoubtedly very important." This aligns with global trends, where increasing attention is being paid to the holistic

Table 7. Effectiveness ratings of specific support measures for athletes in the post-career stage (n = 150)

Form of support	n					M
	Not effective at all (1 point)	Slightly effective (2 points)	Moderately effective (3 points)	Fairly effective (4 points)	Very effective (5 points)	
Programs of professional retraining / advanced training	4	17	28	59	42	3.8
Psychological support and rehabilitation	7	14	40	53	36	3.6
Financial support / compensations	6	13	20	45	66	4.0
Individual career counseling	7	12	31	72	28	3.7
Employment assistance	3	6	15	39	87	4.3
Mentorship programs	5	12	39	56	38	3.7

Notes: n – number of respondents; M (Max = 5) – arithmetic mean value development of athletes and their well-being after retirement from professional sport (Brown et al., 2018; Pierce et al., 2024).

A key result with significant practical implications is the statistically significant relationship between specialists' length of professional experience and their awareness of social support programs for athletes. This finding not only confirms that awareness depends on experience but also points to a systemic gap in knowledge transfer within the field. The highest levels of awareness were reported by specialists with more than 20 years of experience, who were more likely to be informed about national-level programs. By contrast, younger professionals often reported no knowledge or only superficial awareness of such initiatives. This highlights the ineffectiveness of existing information mechanisms in reaching new generations of specialists, creating a substantial barrier to the expansion and implementation of social adaptation programs.

The study also revealed heterogeneity in specialists' interpretations of the concept of "athletes' social adaptation" (Figure 1). The majority of respondents emphasized integration into the social environment during and after the career (40.7%) and the ability to combine sport with other spheres of life, such as education, professional activity, and family (29.3%), Harmonizing sport with educational, professional, and personal domains was viewed as a key condition for successful social adaptation and as a critical factor for a smooth transition to post-sport life, This approach is consistent with the dual career concept, which has been widely studied and implemented internationally (Ryba et al,, 2015; Stambulova et al., 2020). Conversely, overly narrow understandings of social adaptation (e.g., limited only to financial aid or psychological rehabilitation) may impede the creation of comprehensive support programs, as the absence of a shared conceptual framework disperses efforts and reduces alignment between program content and athletes' actual needs.

Another important finding is the generally low level of specialists' awareness of existing social adaptation programs (Figure 2): nearly half of the respondents (49.3%) reported either no knowledge or only superficial awareness. This points to systemic communication deficiencies and the absence of a centralized national platform for information dissemination. Given that program effectiveness depends on awareness and engagement of the target audience, such shortcomings represent a serious barrier to implementation.

The study also highlights expectations regarding the role of the state in the process of athletes' social adaptation (Figure 3). Respondents clearly expect active state involvement, primarily in financing adaptation programs (52.7%) and creating educational opportunities (20.7%). This finding corresponds with the analysis of underlying causes of adaptation difficulties, where the absence of state or municipal programs was identified as a leading factor (37.3%, Table 2). Thus, there is a clear societal demand for a systemic and institutionalized state-level approach that goes beyond isolated initiatives.

The analysis of challenges athletes face during their professional careers (Table 2) revealed dominant problems such as lack of balance between sport and education (55.3%), insufficient future planning (41.3%), and overload/stress (39.3%). These findings are consistent with prior research (Nuetzel, 2023; Pilkington et al., 2024; Trigueros et al., 2019; Tossici et al., 2024), which emphasize the prevalence of mental health issues and burnout among athletes. This demonstrates that social challenges are not confined to the post-career stage but accompany athletes throughout their professional trajectory, thereby underscoring the importance of early and preventive interventions.

The main factors underlying these difficulties (Table 3) were identified as high levels of physical and psychological stress combined with lack of time (62.0%) and the absence of adequate state programs of support. These findings stress the need for integrated approaches that combine athletic, academic, social, and psychological dimensions. Our earlier studies (Pryimak, 2024; Pryimak, 2025c) also confirmed that the nature of an athlete's interaction with the social environment at different stages of their career is central to the adaptation process.

In the post-career stage, challenges assume a different nature (Table 4). The most frequently reported difficulties were finding new employment (71.3%) and loss of income (56.7%). These findings correspond with the scholarly literature describing the phenomenon of role exit (Samuel et al., 2011), whereby retirement from professional sport is often accompanied by a loss of social status and economic instability. Feelings of isolation and the need for psychological support also remain significant concerns for retired athletes.

The evaluation of the effectiveness of various forms of support (Tables 5 and 7) indicated the prioritization of career guidance, career development, and financial counseling, which directly address the key challenges of the post-career period. The high value attributed to mentoring programs involving former athletes highlights the importance of personal experience as a resource for adaptation, a point also emphasized in contemporary research (Voorheis et al., 2023).

At the same time, serious barriers to the implementation of adaptation programs remain, including limited funding (37.3%) and low awareness or interest among athletes themselves (19.3%) (Table 6). These factors create a dual challenge: on the one hand, the need for adequate resourcing, and on the other, the need for effective mechanisms to motivate and inform athletes about available opportunities.

Finally, the expectations of specialists regarding the state's leading role in financing adaptation programs (52.7%) and expanding educational opportunities (20.7%) further underline the necessity of systemic policy-level solutions. The significance of cooperation with educational institutions (13.3% of respondents) also aligns with the recommendations of Bulatova et al. (2019) and Radchenko et al. (2024) on the importance of Olympic education. The implementation of professional growth management models, as substantiated in the works of Pryimak (2025d) and Pierce et al. (2017), could provide the foundation for building an effective national support system for athletes.

Conclusions

This study provided a comprehensive overview of the state of athletes' social adaptation in Ukraine from the perspective of specialists in the field of physical culture and sport. The findings allow for the following conclusions:

The majority of specialists recognize the high importance of athletes' social adaptation, although some heterogeneity in interpreting the concept persists. The dominant view defines adaptation as the integration of athletes throughout their careers and their ability to combine sport with other spheres of life. This perspective aligns with the dual career concept and emphasizes the necessity of a holistic approach.

A significant deficit in specialists' awareness of existing social adaptation programs was identified, indicating a fragmented information environment and the absence of a centralized system of communication and coordination. Statistical analysis, including the χ^2 test, confirmed one of the study's key hypotheses: there is a statistically significant relationship between specialists' professional experience and their level of awareness of social adaptation programs. This finding points to a systemic problem in knowledge dissemination and substantiates the need for targeted educational initiatives aimed at younger professionals. The state is perceived as the primary actor in the process of athletes' social adaptation, bearing responsibility for financing and developing systemic programs, particularly in the domains of education and career support.

The main challenges identified during athletes' active careers were lack of balance between sport and education, insufficient future planning, and overload/stress. After retirement, the most pressing problems were related to employment and financial losses. The primary factors underlying these difficulties include excessive physical and psychological demands, as well as the absence of state-level support programs.

The most effective forms of support were identified as financial assistance for the development and implementation of social adaptation programs and measures facilitating athletes' employment. This underscores the urgent need for practice-oriented solutions. At the same time, limited funding and low levels of athletes' awareness remain the main barriers to program implementation.

The results of this study provide an empirical basis for improving policies and support programs for athletes in Ukraine. They emphasize the necessity of shifting from fragmented initiatives to a comprehensive, multi-level, and continuous support system that accompanies athletes throughout their entire careers. Theoretically, the study confirms the relevance of the dual career concept and highlights the importance of systemic support in minimizing the negative consequences of athletic transitions.

Future Research Directions

Future research should focus on analyzing the direct experiences of athletes themselves, particularly their subjective needs, challenges, and evaluations of the effectiveness of existing forms of support. A promising avenue also lies in conducting comparative studies of social adaptation programs across different countries in order to identify best practices. Furthermore, an important task is the development and pilot implementation of innovative support models tailored to the socio-economic realities of Ukraine.

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Conflict of Interest

The authors declare no conflict of interest.

References

Korzh, N. L., Zakharina, Ye. A., & Cherednychenko, I. A. (2024). Factors of desocialization of athletes in the context of their post-sports life. *Olympicus,* (1), 98-105. https://doi.org/10.24195/olympicus/2024-1.14

Ponomaryov, V., Korchagin, M., & Baich, M. (2024). Crisis stages of sports career development of single combat athletes and the formation of ways to overcome them. *Martial Arts,* (1(31)), 80-91. https://doi.org/10.15391/ed.2024-1.08

Pryimak, M. M. (2025a). Socio-psychological adaptation of athletes after the completion of their sports career. *Zenodo.* https://doi.org/10.5281/zenodo.14769845

Leeder, T. M., & Beaumont, L. C. (2023). Navigating the athlete-to-coach transition: understanding the experiences, philosophies, and practices of British orienteering coaches. *Journal of Adventure Education and Outdoor Learning, 25*(2), 476-492. https://doi.org/10.1080/14729679.2023.2274095

Aptsiauri L. (2024) Problems of social adaptation of the athlete after the end of the sports career. *Health of nation and improvement of physical culture and sports education.* 200-204. https://repository.kpi.kharkov.ua/handle/KhPI-Press/77389

Samuel, R. D., & Tenenbaum, G. (2011). The Role of Change in Athletes' Careers: A Scheme of Change for Sport Psychology Practice. *The Sport Psychologist, 25*(2), 233-252. https://doi.org/10.1123/tsp.25.2.233

Voorheis, P., Silver, M., & Consonni, J. (2023). Adaptation to life after sport for retired athletes: A scoping review of existing reviews and programs. *PLOS ONE, 18*(9), e0291683. https://doi.org/10.1371/journal.pone.0291683

Voronova, V., Shynkaruk, O., Kovalchuk, V., & Marchenko, G. (2024). Ascertaining the Peculiarities of Athletes' Adaptation Course to Post–Sports Life. *Physical Education Theory and Methodology, 24*(4), 579-585. https://doi.org/10.17309/tmfv.2024.4.09

Voronova, V., Petrovska, T., Kovalchuk, V., & Smoliar, I. (2020). Psychological research of a personality as a subject of sports activity. *Theory and Methods of Physical Education and Sport,* (2), 116-123. https://doi.org/10.32652/tmfvs.2020.2.116-123

Polishchuk, V., Perepelytsia, M., & Polishchuk, V. (2025). Psychological and pedagogical support in the "Coach-athlete-parents" system. *Physical Culture, Sports, and Health of the Nation: A Collection of Scientific Papers, 19*(38), 382-391. https://doi.org/10.31652/2071-5285-2025-19(38)-382-391

Pryimak, M. M. (2025b). Features of social adaptation of athletes at different stages of a sports career. *Sport Science Spectrum,* (1), 77-82. https://doi.org/10.32782/spectrum/2025-1-11

Choi J., & Kim H. D. (2021). Sustainable careers of athletes: themes and concepts regarding transition theories involving athletes. *Sustainability, 13*(9), 4824. https://doi.org/10.3390/su13094824

Bulatova, M. M., Bubka, S. N., & Platonov, V. M. (2019). Olympic sport in the system of humanitarian education: A study guide. *Persha Drukarnia.* https://reposit.uni-sport.edu.ua/items/48f7a19f-c5ac-43b6-9cfc-e23d85b8a26f

Radchenko, L., Yermolova, V., & Krol, I. (2024). Olympic education is a component of the national education system. Scientific *Journal of Mykhailo Drahomanov Ukrainian State University. Series 15,* (12(185)), 162-165. https://doi.org/10.31392/UDU-nc.series15.2024.12(185).34

Hong, H. J., & Minikin, B. (2023). An international analysis of career assistance programmes for high-performance athletes. *International Journal of Sport Policy and Politics, 15*(4), 705-724. https://doi.org/10.1080/19406940.2023.2242873

Glandorf, H. L., Madigan, D. J., Kavanagh, O., & Mallinson-Howard, S. H. (2023). Mental and physical health outcomes of burnout in athletes: a systematic review and meta-analysis. *International Review of Sport and Exercise Psychology, 18*(1), 372-416. https://doi.org/10.1080/1750984X.2023.2225187

Nuetzel, B. (2023). Coping strategies for handling stress and providing mental health in elite athletes: a systematic review. *Frontiers in Sports and Active Living,* 5. https://doi.org/10.3389/fspor.2023.1265783

Pilkington, V., Rice, S., Olive, L., Walton, C., & Purcell, R. (2024). Athlete Mental Health and Wellbeing During the Transition into Elite Sport: Strategies to Prepare the System. *Sports Medicine - Open, 10*(1). https://doi.org/10.1186/s40798-024-00690-z

Thornton, J., Rosen, C., Davenport, M., Mountjoy, M. L., Dorian, P., Gouttebarge, V., Breau, B., Pila, E., Reilly, K., Yuan, J., Mok, K., Di Ciacca, S., Speechley, M., & Crossley, K. (2023). Beyond the medals: a cross-sectional study exploring retired elite female athletes' health. *BMJ Open Sport & Exercise Medicine, 9*(1), e001479. https://doi.org/10.1136/bmjsem-2022-001479

Tossici, G., Zurloni, V., & Nitri, A. (2024). Stress and sport performance: a PNEI multidisciplinary approach. *Frontiers in Psychology,* 15. https://doi.org/10.3389/fpsyg.2024.1358771

Trigueros, R., Aguilar-Parra, J. M., Álvarez, J. F., González-Bernal, J. J., & López-Liria, R. (2019). Emotion, Psychological Well-Being and Their Influence on Resilience. A Study with Semi-Professional Athletes. *International Journal of Environmental Research and Public Health, 16*(21), 4192. https://doi.org/10.3390/ijerph16214192

Pryimak, M., Bihun, V., & Lazorenko, T. (2024). Models of management of professional growth and career development of employees. *Scientific Innovations and Advanced Technologies,* (2(30)). https://doi.org/10.52058/2786-5274-2024-2(30)-498-509

Pryimak, M. (2025c). Main aspects of the interaction of an athlete with the social environment in the context of their social adaptation. *Scientific Journal of Mykhailo Drahomanov Ukrainian State University. Series 15,* (1(186)), 136-141. https://doi.org/10.31392/UDU–nc.series15.2025.01(186).28

Pryimak, M. M. (2025d). Sports career at different stages of age development: management strategies and challenges. *Zenodo.* https://doi.org/10.5281/zenodo.14955062

Samuel, R. D., Stambulova, N., Galily, Y., & Tenenbaum, G. (2023). Adaptation to change: a meta-model of adaptation in sport. *International Journal of Sport and Exercise Psychology, 22*(4), 953-977. https://doi.org/10.1080/1612197X.2023.2168726

Brown, C. J., Webb, T. L., Robinson, M. A., & Cotgreave, R. (2018). Athletes' experiences of social support during their transition out of elite sport: An interpretive phenomenological analysis. *Psychology of Sport and Exercise,* 36, 71-80. https://doi.org/10.1016/j.psychsport.2018.01.003

Pierce, S., Sangalang, M., Kisvari, L., Kellar, L., & Martin, E. (2024). Supporting Collegiate Students in the United States Through Athletic and Career Transitions. *Journal of Sport Psychology in Action, 16*(1), 31-43. https://doi.org/10.1080/21520704.2024.2377148

Ryba, T. V., Ronkainen, N. J., & Selänne, H. (2015). Elite athletic career as a context for life design. *Journal of Vocational Behavior,* 88, 47-55. https://doi.org/10.1016/j.jvb.2015.02.002

Stambulova, N. B., Ryba, T. V., & Henriksen, K. (2020). Career development and transitions of athletes: the International Society of Sport Psychology Position Stand Revisited. *International Journal of Sport and Exercise Psychology, 19*(4), 524-550. https://doi.org/10.1080/1612197X.2020.1737836

Pierce, S., Gould, D., & Camiré, M. (2017). Definition and Model of Life Skills Transfer. *International Review of Sport and Exercise Psychology,* 10, 186-211. https://doi.org/10.1080/1750984X.2016.1199727

Соціальна адаптація спортсменів в Україні: виклики та пріоритетні напрями підтримки

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 7 табл., 3 рис., 30 джерел.

Історія питання. Спорт – важлива частина життя значної частини населення. Проте інтенсивний тренувальний процес, високий рівень фізичних та психоемоційних навантажень істотно звужують спектр можливостей для всебічного особистісного розвитку спортсменів та обмежують їхню інтеграцію в соціальне середовище. Сукупність цих чинників формує комплексні виклики для процесів соціальної адаптації, що набувають особливої актуальності в період переходу від активної спортивної діяльності до посткар’єрного етапу життя.

Мета дослідження полягала у здійсненні ґрунтовного та комплексного аналізу рівня обізнаності фахівців сфери фізичної культури та спорту щодо сутності соціальної адаптації спортсменів, а також ідентифікація ключових проблем, з якими стикаються атлети в процесі їх соціальної адаптації.

Матеріал та методи. Методологія дослідження ґрунтувалася на проведенні анонімного онлайн-опитування, в якому взяли участь 150 фахівців сфери фізичної культури і спорту. Було застосовано комплекс методів, зокрема системний аналіз, аналіз і синтез наукової літератури, соціологічне опитування та статистичний аналіз, включно з критерієм хі-квадрат (χ^2) для перевірки взаємозв’язку між професійним досвідом та рівнем обізнаності.

Результати дослідження засвідчили, що 87.3% респондентів розглядають соціальну адаптацію спортсменів як «безумовно, дуже важливу». Серед провідних труднощів, з якими спортсмени стикаються у процесі професійної кар’єри, респонденти виокремили дисбаланс між спортивною діяльністю та освітнім процесом (54.5%), а також психологічні проблеми/стрес (40.0%). У посткар’єрний період ключовими викликами визначено працевлаштування (33.8%) та фінансові труднощі (26.9%), що виникають в житті спортсменів. Найбільш результативними формами підтримки постспортивної адаптації спортсменів визнано сприяння у працевлаштуванні (середній бал – 4.3) та надання фінансової допомоги у розробці відповідних адаптаційних програм (середній бал – 4.0). Водночас серед головних бар’єрів реалізації програм соціальної адаптації названо обмежене фінансування їх розробки та реалізації (37.3%) та недостатній рівень обізнаності спортсменів щодо існуючих адаптаційних можливостей (19.3%).

Висновки. Дослідження підкреслює актуальність і необхідність розроблення та впровадження комплексних системних програм соціальної адаптації спортсменів на загальнодержавному рівні в Україні.

Ключові слова: соціальна адаптація, спортсмени, спортивна кар’єра, підтримка, виклики, подвійна кар’єра.

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Original Scientific Article

Thai Cultural Dance with Ruesi Dadton (traditional Thai exercise): The Effects on Physical Health, Cognitive Performance, and Quality of Life in Older Adults

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Abstract

Background. Regular physical activity offers substantial benefits for older adults. However, it must be varied and engaging to sustain their participation. Lampleon Ruesi Dadton (LRD), a form of Thai cultural dance, has been developed as an integrated exercise program specifically tailored for older adults.

Objectives. This pilot study aimed to investigate the effects of LRD on physical health, cognitive performance, and quality of life (QoL) among eleven older adult women.

Materials and Methods. Participants attended 20-minute LRD dance sessions three times per week for four weeks. The assessment of physical health, cognition, and QoL was conducted. Physical performance was evaluated using the Timed Up and Go (TUG) test for balance, two dynamometers to measure handgrip strength and back-and-leg strength, and the Sit-and-Reach test to assess flexibility.

Results. Significant improvements in physical health were demonstrated by the TUG test ($p = 0.014$) and Sit-and-Reach test ($p = 0.035$). In terms of QoL, notable gains were observed in the social relationship domain ($p = 0.008$) and overall QoL ($p = 0.010$).

Conclusions. The present findings indicate that LRD has the potential to improve physical health and QoL among older adults. Overall, Thai cultural dance incorporating Ruesi Dadton represents a feasible and promising strategy for health promotion in this population. Further research, including long-term follow-up and randomized controlled trials, is warranted to confirm these preliminary results.

Keywords: cognition, dancing, exercise, integrative medicine, physical functional performance, quality of life.

Introduction

Thailand, the second-fastest aging country in ASEAN (Glinskaya et al., 2021), is prioritizing older persons' welfare through policies, community-based care, and volunteer-supported long-term care to address age-related physical decline, frailty (To et al., 2022), and sarcopenia (Wang, 2024). To counter these declines, international guidelines recommend regular physical activity as a key strategy for promoting healthy longevity (Izquierdo et al., 2025).

Adequate and appropriate physical activity is linked to substantial health benefits in this population (Izquierdo et al., 2021). Even among acutely hospitalized older individuals, daily physical activity is recommended, including approximately 40 minutes of light-intensity activity and 25 minutes of moderate-intensity activity (Gallardo-Gómez et al., 2023). Randomized controlled trials indicate that dance-based exercise benefits both cognitive and physical health (Esmail et al., 2020), while systematic reviews and meta-analyses demonstrate its efficacy in improving muscle strength, balance, and flexibility in older adults (Hwang & Braun, 2015; Sooktho et al., 2022).

Cultural dance represents an alternative form of physical activity that has been widely adopted worldwide to promote exercise participation and improve health outcomes among older adults (Mishra & Shukla, 2022). In Thailand, cultural dance programs incorporating cognitive stimulation have been shown to significantly enhance cognitive performance in this population (Sanprakhon et al., 2025). Likewise, other Thai cultural dance interventions have demonstrated beneficial effects on postural control and balance, highlighting their potential role in fall-prevention strategies for older adults (Noopud et al., 2019).

Lam Plearn Ruesi Dadton (LRD) is a dance-based exercise program, culturally inspired by Ruesi Dadton postures and incorporating the Lam Plearn musical style from northeastern Thailand. Although Ruesi Dadton exercises have demonstrated benefits for older adults (Khanthong et al., 2022), the effectiveness of this recently developed cultural dance program has not yet been established. Furthermore, few studies have explored how combining traditional postures with culturally meaningful music may influence physical performance, cognitive function, and quality of life (QoL) in community-dwelling older adults. Addressing this gap, the present study investigates the short-term effects of LRD over a four-week intervention, highlighting an approach that integrates cultural health practices with evidence-based strategies to support healthy aging in culturally diverse populations.

Materials and Methods

Study participants

A single-group, pre–post quasi-experimental study was conducted in March 2025 among 11 female older adults at the Older Adults Club of the Ubon Ratchathani Provincial Administrative Organization. Eligible participants were community-dwelling individuals aged 60 to 79 years who voluntarily provided informed consent. Inclusion criteria required participants to be able to communicate in Thai, perform independent self-care, and have no history of regular exercise prior to enrollment. Exclusion criteria included medical conditions that contraindicated physical activity, such as acute arthritis or acute coronary artery disease. Individuals with severe neurological impairments—such as residual deficits following a stroke—or diagnosed psychiatric disorders were also excluded. Participants with uncontrolled chronic conditions, including hypertension exceeding 160/90 mmHg, were considered ineligible. Additionally, participants who attended fewer than 50% of the scheduled exercise sessions (i.e., fewer than six sessions) were excluded from the final analysis.

This study employed a sample size based on recommendations from a previous pilot study (Sarafadeen et al., 2020), which suggested recruiting between 10 and 12 participants. Ethical approval was granted by the Human Research Ethics Committee of the Ubon Ratchathani Provincial Public Health Office (Approval No. SSJ.UB 01.004). Written informed consent was obtained from all participants prior to recruitment. The study was prospectively registered with the Thai Clinical Trials Registry (TCTR) under the identification number TCTR20250416008.

Experimental Design

The LRD postures were developed based on 15 traditional Ruesi Dadton postures (Khanthong et al., 2024) provided by the Thai Ministry of Public Health. Figure 1 presents the structure of the LRD dance exercise, which consisted of three phases: warm-up, main dance exercise, and cool-down. The warm-up phase comprised seven movements adapted from the northeastern Thai dance style, including pumping fists, side-front arm swings, arm wiggles, trunk twists, body percussion, forward pinch, and pinch circle. The main dance exercise phase was divided into five segments, each incorporating three Ruesi Dadton postures synchronized with the song lyrics and repeated twice, including a reprise of the warm-up postures. The cool-down phase consisted of five Ruesi Dadton postures performed with verbal guidance to promote deep breathing.

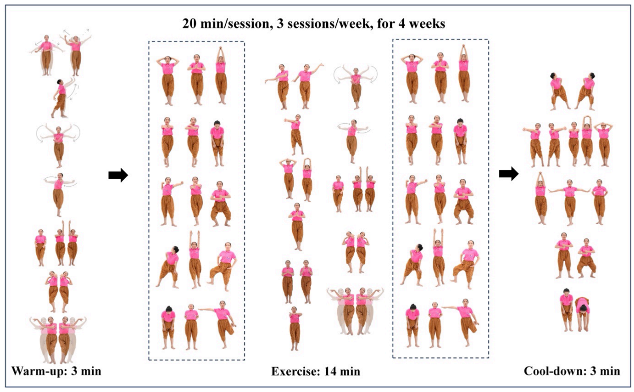

Fig. 1. Lam Plearn Ruesi Dadton dance protocol

Study procedure

Outcome measurements were collected before and after participation in the LRD dance exercise program. The intervention began with a three-day training course that provided participants with essential knowledge on physical exercise for older adults, the Lam Plearn rhythm and dance style, and Ruesi Dadton exercises. Eleven participants took part in the LRD intervention, which consisted of 20-minute sessions held three times per week (Monday, Wednesday, and Friday) over four consecutive weeks at 8:30 a.m. Each session was guided by an instructor with visual support from a recorded Lam Plearn Ruesi Dadton instructional video projected on a screen.

The LRD were performed at an intensity corresponding to 40–60% of each participant's maximum heart rate (HRmax). Exercise intensity was monitored and controlled using a Heart Zones device (Rhythm+2.0; Scosche Industries, P.R.C.). The training program was conducted without implementing exercise progression. Posture and rhythm were supervised and corrected by the researchers (PK and PT) to ensure proper technique. All sessions were conducted in a safe environment with drinking water available at all times. The exercise sessions were conducted at the Center for the Promotion and Development of Older Adults' Well-being, Ubon Ratchathani Rajabhat University, which is located in close proximity to the university's Thai Traditional Medicine Clinic to ensure participant safety.

Measurements

1. Physical assessments

Four physical assessment stations—balance, grip strength, leg press, and flexibility—were administered sequentially. Each assessment was performed three times, with a two-minute rest between trials. All evaluators held degrees in health sciences and were trained by the researcher (PK), a physical therapist.

The Timed Up and Go (TUG) test was employed to evaluate dynamic balance. A 3-meter path was clearly marked on the floor with directional arrows, and a pillar was positioned at the turnaround point to guide movement. A Thai traditional medicine student provided standardized instructions and demonstrated the procedure to ensure participants fully understood the protocol. The stopwatch was activated as the participant rose from the chair, walked 3 meters, turned at the designated point, and returned to sit down. Timing was stopped once the participant was fully seated, and the duration was recorded in seconds. The fastest time from the three trials was used for analysis.

Grip strength was measured using a hydraulic hand dynamometer (model J00105, Lafayette Instrument Company, Lafayette, IN, USA). The test was performed on the dominant hand. Participants were seated with their forearm positioned close to the body, the elbow flexed at 90 degrees, and the wrist maintained in a neutral (mid-prone) position. The highest grip strength value from the trials was recorded for analysis.

The Back and Leg Strength Dynamometer (Back-A Takei Physical Fitness Test; model T.K.K. 5002, Japan) was used to assess the back-and-leg strength ratio. Participants stood on the platform with their knees flexed at approximately 110°, grasped the handle, and exerted maximal force through their legs. The highest force output (in kilograms) was recorded and then normalized by dividing it by the participant's body weight (in kilograms), resulting in a dimensionless ratio.

Sit-and-Reach box (Model 383040, Grand Sport, Thailand) was used to measure the flexibility of the lower back and hamstrings. Prior to testing, participants completed a standardized warm-up consisting of a 10-minute easy-paced walk and four static stretching exercises targeting major muscle groups. Each stretch was held for 10 seconds and repeated twice. The stretches included a standing quadriceps stretch, hamstring stretch, chest stretch, and side bend stretch. After the warm-up, participants sat on the floor with their legs fully extended and the soles of their feet flat against the Sit-and-Reach box, positioned firmly against a wall. With hands overlapping, they were instructed to slowly reach forward as far as possible without bending their knees, pushing the measurement slider forward. The final position was held for two seconds, and the maximum reach distance was recorded in centimeters.

2. Cognitive assessments

Cognitive function was assessed by an experienced psychiatrist using three standardized tools: Verbal Fluency (VF), Trail Making Test Part A (TMT-A), and Part B (TMT-B). The VF test evaluated memory function by instructing participants to name as many animals as possible within one minute. The TMT-A and TMT-B, using the TMT–Thai Modification version (Chompukum & Wongphaet, 2007), assessed executive function; participants were required to connect a sequence of numbers (TMT-A) and to alternate between numbers and letters (TMT-B). The psychiatrist provided standardized instructions for each task and recorded completion times in seconds using a stopwatch.

3. QoL

The Thai abbreviated version of the World Health Organization Quality of Life questionnaire (WHOQOL-BREF-THAI) comprises 26 items, assessed using a 5-point Likert scale ranging from 'none' to 'very much.' The items are distributed across four domains: physical health, psychological well-being, social relationships, and environmental conditions (Mahatnirunkul et al., 1998). Each domain is categorized into three levels—low, average, and good—based on specific score ranges. For the physical health domain, scores of 7–16 indicate a low level, 17–26 an average level, and 27–35 a good level. The psychological domain is classified as low (6–14), average (15–22), and good (23–30). The social relationships domain is categorized as low (3–7), average (8–11), and good (12–15). For the environmental domain, scores of 8–18 indicate a low level, 19–29 an average level, and 30–40 a good level. The total score, ranging from 26 to 130, is similarly divided into low (26–60), average (61–95), and good (96–130) levels of overall quality of life.

Statistical analysis

Data were analyzed using Jamovi (version 2.2.3.0). Normality was assessed with the Shapiro–Wilk test, which indicated non-normal distributions for most variables; therefore, non-parametric tests were applied. The Wilcoxon signed-rank test evaluated pre–post differences, and effect sizes were reported as rank-biserial correlations (r), interpreted as small (0.1), medium (0.3), and large (0.5).

Results

Firstly, all participants were informed about the intervention and provided written informed consent prior to enrolment. Twelve participants met the eligibility criteria, but one left for another province after two weeks and was excluded. The socio-demographic characteristics of the remaining 11 participants are presented in Table 1.

Table 1. Socio-demographic characteristics of the participants (n = 11)

Variable		Frequency (%), Mean ± SD
Age (year)	60-64	2 (18.2)
	65-69	2 (18.2)
	70-74	3 (27.3)
	75-79	4 (36.4)
Marital status	Single	2 (18.2)
	Widowed	5 (45.4)
	Married	4 (36.4)
Educational level	Bachelor's degree	7 (63.6)
	Graduate education	4 (36.4)
Occupational status	None	3 (27.3)
	Retired government officials	8 (72.7)
Social activities	Occasionally	3 (27.3)
	Regularly	8 (72.7)
Exercise frequency	Occasionally	6 (54.5)
	Regularly	5 (45.5)
Religious activities	Occasionally	8 (72.7)
	Regularly	3 (27.3)
Number of regularly taken medications		1.91 ± 1.81

Table 2. Pre-and post-assessment of physical and cognitive performance (n = 11)

Variable	(Mean ± SD)				95% CI	p	r
	Pre	Post	Change score	Δ (% Change)			
TUG (s)	8.76 ± 0.99	8.10 ± 0.79	0.66 ± 0.73	8.39 ± 0.09	0.10, 1.12	0.014*	0.818
Grip strength (kg)	25.70 ± 4.45	25.40 ± 5.33	-0.36 ± 2.80	-1.53 ± 0.11	-3.00, 3.50	0.734	0.179
Back-and-leg strength ratio	79.50 ± 18.6	83.00 ± 23.90	0.06 ± 0.32	5.36 ± 0.23	-15.00, 6.75	0.286	-0.379
Sit-and-Reach (cm)	10.60 ± 6.45	11.90 ± 6.17	1.27 ± 1.62	23.41 ± 0.32	-3.50, 1.00	0.035*	-1.000
VF (words)	18.50 ± 3.27	20.50 ± 4.18	2.00 ± 3.92	12.63 ± 0.24	-5.50, 1.00	0.138	-0.545
TMT-A (s)	47.10 ± 26.00	44.00 ± 15.80	3.09 ± 24.02	8.44 ± 0.47	-9.00, 23.00	0.700	-0.152
TMT-B (s)	109.00 ± 47.60	123.00 ± 44.60	14.55 ± 39.10	-8.46 ± 0.33	-46.00, 13.00	0.221	-0.455

* showed statistically significant results ($p < 0.05$). Note: a positive change score indicates improvement. SD = standard deviation; CI = confidence interval; r = Rank biserial correlation from Wilcoxon signed-rank test; TUG = Timed Up and Go; kg = Kilograms; BW = Body weight; VF = Verbal Fluency; TMT-A = Trail Making Test Part A; TMT-B = Trail Making Test Part B

Table 3. Pre- and post-assessment of QoL domains and overall score (n = 11)

QoL domain		(Mean ± SD)		95% CI	p	r
		Pre	Post			
Physical health	score	27.50 ± 3.17	29.50 ± 2.84	-5.00, 1.00	0.196	-0.455
	level	Good	Good			
Psycho-logical	score	25.20 ± 2.56	27.00 ± 2.49	-4.00, 0.50	0.084	-0.667
	level	Good	Good			
Social relation-ship	score	11.70 ± 1.56	13.60 ± 1.12	-3.00, 2.00	0.008*	-1.000
	level	Average	Good			
Environ-mental	score	32.80 ± 2.75	34.20 ± 2.89	-4.00, 1.00	0.148	-0.527
	level	Good	Good			
Total	score	105.00 ± 7.76	114.00 ± 7.13	-14.00, 4.00	0.011*	-0.879
	level	Good	Good			

* showed statistically significant results ($p < 0.05$). Note: QoL = quality of life; SD = standard deviation; CI = confidence interval; r = Rank biserial correlation from Wilcoxon signed-rank test; QoL = Quality of life

The physical and cognitive performance outcomes are summarized in Table 2. Significant improvements were observed in the TUG test (p = 0.014, r = 0.818, 95% CI [0.10, 1.12]) and the Sit-and-Reach test (p = 0.035, r = -1.000, 95% CI [-3.50, 1.00]). The TUG demonstrated at 8.39 ± 0.09% improvement in delta change scores, while the Sit-and-Reach test showed the highest delta change at 23.41 ± 0.32%. Cognitive performance outcomes did not reach statistical significance; however, a large effect size was observed for the VF test (r = –0.545), which demonstrated a 12.63 ± 0.24% improvement in delta change scores.

All QoL domains demonstrated medium to large effect sizes, with significant differences observed in the total QoL score and the social relationships domain (Table 3). Additionally, the social relationships domain improved from an average to a good level, with the highest effect size among all domains.

Discussion

The present study found that participation in LRD dance-based exercise for 20 minutes, three times per week over a four-week period resulted in significant improvements in dynamic balance, flexibility, and QoL among older adult women. Although the improvement in VF did not reach statistical significance, the large effect size indicates a potentially meaningful cognitive benefit. These outcomes align with a mechanistic framework suggesting that regular participation in dance enhances physical function, stimulates cognitive processes, and supports social connection (Rice et al., 2025).

For physical health outcomes, balance, strength, and flexibility were evaluated. Dynamic balance, as measured by the TUG test, showed a statistically significant improvement with a large effect size. This enhancement is likely attributable to the continuous and rhythmic movements characteristic of LRD, which may directly improve functional mobility. Previous systematic reviews and meta-analyses have demonstrated that dance-based exercise significantly improves TUG performance (Mattle et al., 2020) and may contribute to reducing fall risk (Li et al., 2024) and fall incidence (Liu et al., 2021) among older adults.

No significant changes were observed in grip strength or back-and-leg strength ratio following the intervention. Consistent with a previous study on Ruesi Dadton, participants maintained, rather than improved, grip strength after a three-month intervention, whereas the control group showed a significant decline (Khanthong et al., 2021). A medium effect size was observed for back-and-leg strength ratio, while grip strength showed a small effect size. These findings are supported by systematic reviews and meta-analyses indicating that dance-based interventions in older adults generally improve lower-body strength but have limited effects on upper-body strength (Mattle et al., 2020).

The Sit-and-Reach test showed a statistically significant improvement, accompanied by a large effect size. This gain may be attributed to the inclusion of specific Ruesi Dadton postures, particularly those performed during the cool-down phase. Similar improvements in flexibility among older adults have been observed in previous studies involving Ruesi Dadton (Khanthong et al., 2021, 2022) and cultural dance interventions (Douka et al., 2019).

Three questionnaires were used to assess executive function: VF, TMT-A, and TMT-B. Although none of the changes reached statistical significance, VF demonstrated a large effect size and the highest percent change compared with TMT-A and TMT-B. These findings suggest a potential improvement in cognitive outcomes, which is supported by systematic reviews and meta-analyses indicating that dance interventions may enhance global cognitive function and executive function in older adults adults (Predovan et al., 2019; Hewston et al., 2021), including those with mild cognitive impairment (Huang et al., 2023).

Statistically significant improvements in QoL were observed only in the social relationships domain and the total QoL score. Nevertheless, large effect sizes were observed across all domains, except for physical health, which showed a medium effect size. The greatest improvement occurred in the social relationships domain, likely reflecting the frequent interpersonal interactions participants experienced during the program. These findings correspond with systematic reviews indicating that dance-based exercise can enhance QoL and promote physical activity among older adults (Lu et al., 2024). Furthermore, such interventions have been reported to improve emotional and social well-being, particularly by strengthening interpersonal connections that may help mitigate loneliness (Fonseca et al., 2025).

This study has several limitations. First, the small sample size and short intervention period may have limited the ability to detect statistically significant effects. Second, the absence of a control group and the lack of blinding may have introduced potential biases, including expectancy and placebo effects. Third, the relatively low exercise volume—20 minutes per session, three times per week, totaling 60 minutes—may have been insufficient to elicit measurable changes. Future studies should employ larger sample sizes, adopt randomized controlled trial designs, and investigate the impact of varying exercise volumes.

Conclusions

In conclusion, the findings suggest that LRD is a feasible intervention for improving physical performance and QoL in older adults. While cognitive improvements did not reach statistical significance, the observed large effect size for VF indicates a potential benefit that deserves further investigation.

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Conflict of interest

The authors declare that they have no financial, personal, or professional conflicts of interest that could have influenced this study.

AI Disclosure

No artificial intelligence tools were used in the preparation of this manuscript.

References

Glinskaya, E., Walker, T., & Wanniarachchi, T. (2021). *Caring for Thailand's aging population.* https://doi.org/10.1596/35693

To, T. L., Doan, T. N., Ho, W. C., & Liao, W. C. (2022). Prevalence of frailty among community-dwelling older adults in Asian countries: a systematic review and meta-analysis. *Healthcare, 10*(5), 895. https://doi.org/10.3390/healthcare10050895

Wang, B., Nong, C., Zhang, J., Deng, L., Li, W., Zhang, X., & Liu, P. (2024). Prevalence and associated body composition factors of sarcopenia in community-dwelling older adults. *European Journal of Medical Research, 29*(1), 598. https://doi.org/10.1186/s40001-024-02185-9

Izquierdo, M., de Souto Barreto, P., Arai, H., Bischoff-Ferrari, H. A., Cadore, E. L., Cesari, M., ... & Singh, M. A. F. (2025). Global consensus on optimal exercise recommendations for enhancing healthy longevity in older adults (ICFSR). *The Journal of nutrition, health and aging, 29*(1), 100401. https://doi.org/10.1016/j.jnha.2024.100401

Izquierdo, M., Duque, G., & Morley, J. E. (2021). Physical activity guidelines for older people: knowledge gaps and future directions. *The Lancet Healthy Longevity, 2*(6), e380-e383. https://doi.org/10.1016/S2666-7568(21)00079-9

Gallardo-Gómez, D., del Pozo-Cruz, J., Pedder, H., Alfonso-Rosa, R. M., Álvarez-Barbosa, F., Noetel, M., ... & del Pozo Cruz, B. (2023). Optimal dose and type of physical activity to improve functional capacity and minimise adverse events in acutely hospitalised older adults: a systematic review with dose-response network meta-analysis of randomised controlled trials. *British Journal of Sports Medicine, 57*(19), 1272-1278. https://doi.org/10.1136/bjsports-2022-106409

Esmail, A., Vrinceanu, T., Lussier, M., Predovan, D., Berryman, N., Houle, J., ... & Bherer, L. (2020). Effects of Dance/Movement Training vs. Aerobic Exercise Training on cognition, physical fitness and quality of life in older adults: A randomized controlled trial. *Journal of bodywork and movement therapies, 24*(1), 212-220. https://doi.org/10.1016/j.jbmt.2019.05.004

Hwang, P. W. N., & Braun, K. L. (2015). The effectiveness of dance interventions to improve older adults' health: a systematic literature review. *Alternative therapies in health and medicine, 21*(5), 64-70.

Sooktho, S., Songserm, N., Woradet, S., & Suksatan, W. (2022). A Meta-analysis of the effects of Dance Programs on Physical Performance: Appropriate Health Promotion for healthy older adults. *Annals of geriatric medicine and research, 26*(3), 196-207. https://doi.org/10.4235/agmr.22.0066

Mishra, S. S., & Shukla, S. (2022). Effect of Indian folk-dance therapy on physical performances and quality of life in elderly. *Biomedical Human Kinetics, 14*(1), 244-251. https://doi.org/10.2478/bhk-2022-0030

Sanprakhon, P., Suriyawong, W., Longphasuk, N., Khatichop, N., Arpaichiraratana, C., Wongwiseskul, S., ... & Thaipisuttikul, P. (2025). Effects of traditional Thai folk dance combined with cognitive stimulation program on behavior and cognition among older adults with cognitive decline: A randomized controlled trial. *The Journal of Prevention of Alzheimer's Disease, 12*(4), 100066. https://doi.org/10.1016/j.tjpad.2025.100066

Noopud, P., Suputtitada, A., Khongprasert, S., & Kanungsukkasem, V. (2019). Effects of Thai traditional dance on balance performance in daily life among older women. *Aging clinical and experimental research, 31*(7), 961-967. https://doi.org/10.1007/s40520-018-1040-8

Khanthong, P., Dechakhamphu, A., & Natason, A. (2022). Effect of Ruesi Dadton on vital capacity, flexibility and range of motion in healthy elderly individuals. *Science, Engineering and Health Studies,* 22050003-22050003. https://doi.org/10.14456/sehs.2022.8

Sarafadeen, R., Ganiyu, S. O., & Ibrahim, A. A. (2020). Effects of spinal stabilization exercise with real-time ultrasound imaging biofeedback in individuals with chronic nonspecific low back pain: a pilot study. *Journal of exercise rehabilitation, 16*(3), 293-299. https://doi.org/10.12965/jer.2040380.190

Khanthong, P., Sriyakul, K., Dechakhamphu, A., Krajarng, A., Kamalashiran, C., Jayathavaj, V., & Tungsukruthai, P. (2024). A randomized controlled trial on the effects of traditional Thai mind-body exercise (Ruesi Dadton) on biomarkers in mild cognitive impairment. *European Journal of Physical and Rehabilitation Medicine, 60*(4), 604-610. https://doi.org/10.23736/S1973-9087.24.08015-8

Chompukum, P., & Wongphaet, P. (2007). Normative data for Trail Making Test–Thai modification. *Journal of Thai Rehabilitation Medicine,* 17, 26–30.

Mahatnirunkul, S., Tuntipivatanaskul, W., & Pumpisanchai, W. (1998). Comparison of the WHOQOL-100 and the WHOQOL-BREF (26 items). *Journal of Mental Health of Thailand, 5*(3), 4–15.

Rice, P. E., Thumuluri, D., Barnstaple, R., Fanning, J., Laurita-Spanglet, J., Soriano, C. T., & Hugenschmidt, C. E. (2025). Moving towards a medicine of dance: a scoping review of characteristics of dance interventions targeting older adults and a theoretical framework. *Journal of Alzheimer's Disease, 105*(4), 1183-1221. https://doi.org/10.3233/JAD-230741

Mattle, M., Chocano-Bedoya, P. O., Fischbacher, M., Meyer, U., Abderhalden, L. A., Lang, W., ... & Bischoff-Ferrari, H. A. (2020). Association of dance-based mind-motor activities with falls and physical function among healthy older adults: A systematic review and meta-analysis. *JAMA Network Open, 3*(9), e2017688. https://doi.org/10.1001/jamanetworkopen.2020.17688

Li, Y., Wang, Z., Li, J., Yang, H., & Fang, Z. (2024). The effects of dance interventions on reducing the risk of falls in older adults: a network meta-analysis. *Frontiers in public health,* 12,1496692. https://doi.org/10.3389/fpubh.2024.1496692

Liu, X., Shen, P. L., & Tsai, Y. S. (2021). Dance intervention effects on physical function in healthy older adults: a systematic review and meta-analysis. *Aging clinical and experimental research, 33*(2), 253-263. https://doi.org/10.1007/s40520-019-01440-y

Khanthong, P., Sriyakul, K., Dechakhamphu, A., Krajarng, A., Kamalashiran, C., & Tungsukruthai, P. (2021). Traditional Thai exercise (Ruesi Dadton) for improving motor and cognitive functions in mild cognitive impairment: a randomized controlled trial. *Journal of exercise rehabilitation, 17*(5), 331-338. https://doi.org/10.12965/jer.2142542.271

Douka, S., Zilidou, V. I., Lilou, O., & Manou, V. (2019). Traditional dance improves the physical fitness and well-being of the elderly. *Frontiers in aging neuroscience,* 11, 75. https://doi.org/10.3389/fnagi.2019.00075

Predovan, D., Julien, A., Esmail, A., & Bherer, L. (2019). Effects of dancing on cognition in healthy older adults: a systematic review. *Journal of Cognitive Enhancement, 3*(2), 161-167. https://doi.org/10.1007/s41465-018-0103-2

Hewston, P., Kennedy, C. C., Borhan, S., Merom, D., Santaguida, P., Ioannidis, G., ... & Papaioannou, A. (2021). Effects of dance on cognitive function in older adults: a systematic review and meta-analysis. *Age and ageing, 50*(4), 1084-1092. https://doi.org/10.1093/ageing/afaa270

Huang, C. S., Yan, Y. J., Luo, Y. T., Lin, R., & Li, H. (2023). Effects of dance therapy on cognitive and mental health in adults aged 55 years and older with mild cognitive impairment: a systematic review and meta-analysis. *BMC geriatrics, 23*(1), 695. https://doi.org/10.1186/s12877-023-04406-y

Lu, J., Abd Rahman, N. A., Wyon, M., & Shaharudin, S. (2024). The effects of dance interventions on physical function and quality of life among middle-aged and older adults: A systematic review. *PloS one, 19*(4), e0301236. https://doi.org/10.1371/journal.pone.0301236

Fonseca, I., Rueda, M., & Cabanzo, C. (2025). The effect of dance interventions on well-being dimensions in older adults: a systematic review. *Frontiers in Sports and Active Living,* 7, 1594754. https://doi.org/10.3389/fspor.2025.1594754

Тайський культурний танець в комбінації з Ruesi Dadton (традиційними тайськими вправами): Вплив на фізичне здоров'я, когнітивну працездатність та якість життя в осіб похилого віку

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Реферат. Стаття: 7 с., 3 табл., 1 рис., 28 джерел.

Історія питання. Регулярна фізична активність пропонує суттєві переваги для осіб похилого віку. Однак, щоб забезпечити залученість даної категорії осіб до зазначеного процесу, така діяльність має бути різноманітною та цікавою. Lampleon Ruesi Dadton (LRD) — форма тайського культурного танцю, яка розроблена як інтегрована програма вправ, спеціально адаптована для осіб похилого віку.

Мета дослідження. Метою цього пілотного дослідження було вивчення впливу методики LRD на фізичне здоров'я, когнітивну працездатність та якість життя (ЯЖ) серед одинадцяти жінок похилого віку.

Матеріали та методи. Учасники відвідували 20-хвилинні заняття з танцю LRD тричі на тиждень протягом чотирьох тижнів. Проведено оцінку фізичного здоров'я, когнітивних функцій та якості життя. Фізичну працездатність оцінювали за допомогою використання тесту «Встань та йди» (Timed Up and Go, TUG) для перевірки рівноваги, двох динамометрів для вимірювання сили хвату кистей рук та сили спини і ніг, а також тесту Sit-and-Reach (згинання тулуба вперед, сидячи на підлозі з витягнутими вперед руками) з метою оцінки гнучкості.

Результати. Значні поліпшення показників фізичного здоров'я продемонстровано за допомогою тесту TUG ($p = 0.014$) і тесту Sit-and-Reach ($p = 0.035$). Що стосується якості життя, помітні покращення спостерігалися в галузі соціальних відносин ($p = 0.008$) і загальної якості життя ($p = 0.010$).

Висновки. Отримані результати свідчать про потенціал застосування методики LRD у поліпшенні фізичного здоров'я та якості життя серед людей похилого віку. Загалом, тайський культурний танець, що включає Ruesi Dadton, є доцільною та перспективною стратегією щодо зміцнення здоров'я цієї групи населення. Для підтвердження зазначених попередніх результатів необхідні подальші дослідження, включаючи довгострокове спостереження та рандомізовані контрольовані випробування.

Ключові слова: когніція, танці, фізичні вправи, інтегративна медицина, фізична функціональна працездатність, якість життя.

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The Effects of a Structured Yoga Intervention on Cognitive, Psychological, and Functional Performance in Competitive Women's Basketball Players: A Two-Group Controlled Experimental Study

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Abstract

Background. Yoga has received a lot of focus as a holistic training method combining physical, psychological, and cognitive development, although there is still a lack of controlled evidence in women's competitive team sports.

Objectives. This study aimed to evaluate the impact of an eight-week structured yoga intervention on cognitive focus, psychological resilience, perceived stress, and functional performance of collegiate women's basketball players.

Materials and Methods. A total of thirty athletes (aged 19-24 years) were randomly divided into an Experimental Group (yoga + routine training) and a Control Group (routine training only). Cognitive (d_2 Test of Attention), psychological (CD-RISC-10, PSS-10), and physical (vertical jump, sprint, agility) outcomes were assessed before and after the intervention. Data analysis was performed using mixed ANOVA and confirmatory ANCOVA with baseline covariates. Effect sizes (Cohen's d, partial η^2), along with 95% confidence intervals, were calculated, and the p-values were adjusted according to the Benjamini-Hochberg false discovery rate (FDR) method.

Results. For cognitive focus ($p < .001$), resilience ($p = .004$), stress reduction ($p = .002$), and agility ($p = .011$), significant Group × Time interactions were noted. ANCOVA verified the strength of these effects, even after controlling for differences in baseline. PCA revealed two latent dimensions, namely psychological-cognitive and motor performance, which together accounted for more than 75 % of the variance.

Conclusions. The yoga program markedly improved psychophysiological readiness and functional efficiency in comparison to routine training. These findings suggest that yoga can be an integrative approach for enhancing athletes' performance at the preparation stage.

Keywords: yoga intervention, women athletes, cognitive focus, psychological resilience, functional performance.

Introduction

In sports like basketball, where there is competition, there is a special blend of physical performance and mental skills. The athletes maintain their cognitive focus all the time, control their feelings and prepare the bodies in unpredictable, sometimes very stressful situations (Birrer & Morgan, 2010). It is even more so in women's team sports, where the players sometimes have to face stereotypes based on gender, psychosocial stressors, or even competing academic or social obligations (Kavoura et al., 2015; Wachsmuth et al., 2018). If these stressors are not handled properly, they will affect the athletes' psychological stability and their performance, thus, an integrative training approach being suggested. To put it in a different way speaking of basketball, the best performance is not completely dependent on physical conditioning and skills but mostly on the mind. Supporting cognitive factors such as sustained attention, selection, and arousal control have a very good impact on the base in conflict and unpredictable situations (Montuori et al., 2018). Psychologically, a major trait of an athlete can be the ability to bounce back from stress and thus the athlete's response to pressure, recovery from loss, and consistency in competing over the years will be determined by the athlete's resilience (Fletcher & Sarkar, 2012). Interestingly, because of the overlapping of the psychological and physical areas, the majority of training programs seem to be focused on the acquisition of technical and physical skills with no or very little mental training (Simonsmeier et al., 2021).

logical needs (Woodyard, 2011). On the other hand, physical exercise, yoga not only presents but also passes on its benefits through the regulation of the autonomic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis (Pascoe et al., 2017). To mention some, yoga has been seen to increase vagal tone, activate the prefrontal cortex, and lower cortisol release, thus treating anxiety and improving cognitive performance (Gothe et al., 2013; Streeter et al., 2012). Yoga for athletes is supported by empirical evidence. Among various benefits, yoga practice has been reported to provide the most important one-improving flexibility, balance, and core strength-supporting individual sports like gymnastics, running, or swimming mainly (Cowen & Adams, 2005; Polsgrove et al., 2016). The number of studies involving competitive team-sport athletes is limited, especially females, who being different from males in neuroendocrine and psychosocial stress and recovery, may need a different approach (Mücke et al., 2018). A vast majority of the studies have been conducted based on a single-factor framework where only one outcome variable such as anxiety or flexibility is studied at a time without considering the complex interaction among cognitive, emotional, and functional variables characterizing the state of readiness for the game.

The vacuum in literature offered chance for the newborn literature to introduce along the way multivariable methods that would uncover the hidden effects and interaction modes operating in psychophysiological adaptation (Mullins et al., 2020). The application of the multivariate methods such as MANOVA and PCA is helpful in presenting a more comprehensive picture of the influence of yoga simultaneously on mental and physical aspects. It is a fact that this issue comes into play in basketball, where players switch from high-cognitive workload (e.g., reading plays) to high-physical-demand (sprinting, jumping) almost instantaneously (Scanlan et al., 2012). Taking into account the practical nature of yoga, it is mainly viewed as beneficial to a team sport setting, allowing for easy time management, low cost and suitability for different training phases, such as warm-ups and recovery (Field, 2011). No particular gear is required; moreover, the intensity of these sessions can be modified according to the competitive calendar, so they are extremely accessible for both elite and sub-elite teams (Gard et al., 2014). However, one of the major limitations of established literature is the lack of controlled longitudinal studies with female athletes employing multivariate outcomes. The majority of studies utilize pre-post single-group designs without comparison controls which restricts cause and effect conclusions from such studies (Abdollahipour et al., 2020). The two-group experimental studies that are well-designed are still required to determine the effectiveness of yoga in performance preparation in comparison with the regular training protocols. Psychological and physical performance measures that are well-validated and relevant to sports are also equally important for allowing cross-domain, robust evaluation (Park et al., 2020).

Therefore, the current research was intended to see whether an eight-week yoga program would make any impact on the four major areas of performance in women basketball players: cognitive focus, psychological resilience, perceived stress, and composite physical performance (agility, sprint, and jump). The experiment was conducted in a two-group controlled trial manner. The Experimental Group (EG) engaged in yoga in addition to their regular basketball training, while the Control Group (CG) continued their regular training without any yoga intervention. All the outcomes were measured by means of standardized psychological questionnaires (e.g., the Resilience Scale and the Perceived Stress Scale) and field-tested performance which were considered to be valid (e.g., vertical jump and shuttle run tests). A multivariate approach employing 2×2 mixed ANOVA was used for interaction effect analysis, and then paired t-tests and effect sizes were further conducted. Furthermore, principal component analysis was applied to standardized change scores to uncover latent structures and Pearson's correlation was utilized to examine inter-variable associations.

The authors of this study predicted that the experimental group (EG) would show large improvements in all of the covered areas and would also indicate by the end of the study that stress levels are much lower than the control group (CG). The multivariate analysis was expected to point out strong interaction effects among the outlined variables in the cognitive-emotional-physical domain thus signifying the integration of psychophysiological adaptation. Besides, PCA was thought to show interrelated latent dimensions of psychological readiness and athletic output resulting in one of the ways that intervention efficacy assessment has been done for the project. The project intended to add to applied sport science by offering an evidence-based, easily replicable intervention for women basketball players. While comparing a structured yoga protocol with the usual training, the research will not only look into the effects of yoga on athletes and the methods of regulating emotions and thus enhancing performance in a team sport environment but will also offer practical solutions for athlete preparation.

Materials and Methods

Study Design

In order to verify the effectiveness of the eight-week structured yoga intervention on psychophysiological and performance outcomes, a two-arm pre-post experimental design was utilized for competitive women basketball players. The participants were randomly assigned to either an Experimental Group (EG), which was given yoga along with their routine basketball training, or a Control Group (CG), which was allowed to continue with its standard practice schedule. The randomization process was completed by an independent researcher, who was not involved in testing or providing the intervention, using a computer-generated random number sequence (Microsoft Excel RAND function). Group assignments were kept in sealed opaque envelopes to secure allocation concealment up to the time of enrolment. Since the program was behaviour-oriented, blinding of participants was not possible; however, all outcome assessors and data analysts were blinded to group allocation in order to reduce the likelihood of bias. The assessments took place at baseline and right after the intervention employing cognitive, psychological, and physical performance measures that are standard and under the same environmental conditions.

Participants and Eligibility

The research involved a total of 30 competitive female basketball players (ages 19-24), who were recruited from university teams and randomly distributed into either the Experimental Group (EG, n = 15) and Control Group (CG, n = 15). They were paired by age, playing experience, and baseline scores. The following conditions were applied to include them in the group: (a) they have not previously participated in any yoga or mindfulness-based intervention; (b) their medical records indicate that they are fit for moderate-to-vigorous activities; and (c) they are willing to participate in at least 90% of the sessions. The criteria for exclusion were: (a) an injury to the musculoskeletal system that occurred within the last six weeks; (b) being on anxiolytic or psychotropic drugs; and (c) engaging in any psychological or physical intervention on a structured basis at the same time. The participants signed informed consent forms in triplicate. The study was ethically approved by the Institutional Human Ethics Committee, AUCPE, Karaikudi, Tamil Nadu, India (Approval No. RC. R1/Ph.D/R20162276/DC&CV/2021). Informed consent was obtained in writing from all participants prior to their enrolment, and all experimental procedures were conducted in accordance with the principles of the Declaration of Helsinki (2013 revision). Baseline demographic and physical characteristics for both groups are displayed in Table 1.

Table 1. Baseline Characteristics of Participants in Experimental and Control Groups

Variable	EG(n = 15)	CG(n = 15)	$t_{(28)}$	p
Age (years)	21.4 ± 1.2	21.6 ± 1.3	0.45	.654
Height (cm)	167.3 ± 4.9	166.8 ± 5.2	0.29	.771
Weight (kg)	61.2 ± 5.8	60.5 ± 6.3	0.34	.736
Years of basketball training	6.1 ± 1.5	6.3 ± 1.4	0.42	.678
Weekly practice hours	8.3 ± 2.1	8.0 ± 2.0	0.39	.700

Intervention Protocol

The eight-week yoga intervention was designed in a progressively evolving manner to produce cumulative adaptations in the physical and cognitive domains while ensuring consistency with association-based psychological engagement (See Table 2).

Outcome Measures

Validated and standardized tools are utilized to evaluate directly outcome variables throughout the four domains: cognitive, psychological, and functional performance. Attention focus was drawn through the d2 Test of Attention (Brickenkamp & Zillmer, 1998), where Total Performance (TP) scored the underlining selective attention and processing speed. Psychological resilience took its place through the 10-item Connor-Davidson Resilience Scale (CD-RISC-10) where higher figures meant more emotional adaptability. Perceived stress was claimed via the 10-item Perceived Stress

Table 2. Structured Yoga Intervention Timeline (8 Weeks, 24 Sessions)

Week	Session Focus	Pranayama	Asanas (Postures)	Mindfulness / Relaxation	Progression Notes
Week 1	Foundation: Breathing and Basic Mobility	Diaphragmatic breathing	Tadasana, Vrikshasana, Bhujangasana	Body scan meditation	Introduction to yoga principles; slow-paced movements
Week 2	Stability and Balance	Alternate nostril	Virabhadrasana I & II, Trikonasana	Guided breath awareness	Increased hold duration (10-15 sec); posture corrections
Week 3	Dynamic Flexibility and Core Activation	Ujjayi breathing	Setu Bandhasana, Naukasana, Marjariasana	Mindfulness of movement	Introduction to flow sequences; transitions between postures
Week 4	Lower-Body Strength and Recovery	Kapalabhati (mild)	Utkatasana, Anjaneyasana, Supta Padangusthasana	Progressive muscle relaxation (PMR)	Increased repetition; emphasis on alignment
Week 5	Mental Focus and Full-Body Flow	Anulom-Vilom	Surya Namaskar (slow), Virabhadrasana III	Focused attention training	Integration of learned asanas into continuous sequences
Week 6	Integrated Core and Balance Control	Bhramari	Bakasana prep, Ardha Chandrasana, Salabhasana	Visualization practice	Hold times increased to 20 sec; minor postural challenges
Week 7	Stress Regulation and Autonomic Reset	Sheetali breathing	Supine twist, Balasana, Paschimottanasana	Deep diaphragmatic relaxation	Slower tempo; restorative session emphasis
Week 8	Consolidation and Recovery	Practitioner's choice	Mixed postures based on participant feedback	Self-guided mindfulness & journaling	Recap of full protocol; emphasis on self-awareness

Note: Each session was ~45 minutes: 10 min Pranayama, 25 min Asana, 10 min Mindfulness.

Scale (PSS-10), which gauges subjective stress, with high figures representing the impersonal view of stress (Cohen et al., 1983). Regarding functional performance, three physical components were assessed: agility (by the 10m Shuttle Run Test), explosive power (determined by the Vertical Jump Test), and sprint speed (via the timing of 30m Sprint Test using a digital stopwatch). Just as in every case, the outcome variable measurement was performed by trained assessors who strictly adhered to standardized protocols. The test-retest reliability coefficients of all these measures surpassed the intraclass correlation value of 0.85, thus, temporal stability was assured. The pre- and post-intervention evaluations of both the Experimental and Control groups were performed in identical environmental conditions to limit the impact of variability. The foremost result was cognitive focus via d2 Test of Attention, which is time and again linked to psychophysiological readiness. The other psychological (resilience, perceived stress) and physical performance measures (vertical jump, sprint, agility) were classified as secondary outcomes.

Statistical Analysis

Data were analysed using IBM SPSS Statistics (Version 25.0; IBM Corp., Armonk, NY, USA). Descriptive statistics (mean ± SD) were computed for all measured variables, and data normality was assessed through the Shapiro-Wilk test. Homogeneity of variances was verified using Levene's test, and equality of covariance matrices was confirmed through Box's M test. A two-way mixed-design ANOVA (Group × Time) was performed to examine within- and between-group differences across all dependent variables. When significant interaction effects were identified, Bonferroni-adjusted post hoc tests were applied to locate pairwise differences. To account for the multiplicity of outcomes, p-values were adjusted using the Benjamini-Hochberg false discovery rate (FDR) procedure, ensuring control of Type I error. Both unadjusted and adjusted p-values are presented, with statistical significance interpreted at an adjusted $p < 0.05$. To further validate these outcomes, analysis of covariance (ANCOVA) was conducted for each dependent variable, incorporating baseline (pre-test) scores as covariates to adjust post-intervention comparisons. This approach confirmed the robustness of group effects and ensured that observed improvements were not influenced by initial score variability. Effect sizes were expressed as partial eta squared (η^2) for ANOVA models and Cohen's d with 95 % confidence intervals for within-group pre-post changes, applying Hedges' g correction for small sample bias. Effect sizes were interpreted as small (≥ 0.20), medium (≥ 0.50), and large (≥ 0.80). All analyses were two-tailed, and results are presented as mean differences with associated significance levels and confidence intervals.

Results

Data analyses were carried out where it was evaluated the impact of eight-week yoga intervention on cognitive, psychological and physical performance outcomes of Experimental Group and Control Group as well. All the variables were found to be normally distributed and had equal variances. A 2 × 2 mixed ANOVA showed significant interaction effects for Group × Time in a moderate number of outcome measures, which indicated that the changes in the groups were different. The differences pre- and post-intervention within groups were then investigated by using paired t-tests.

Table 3. Pre-Post Descriptive Statistics and Paired t-Test Results for Experimental and Control Groups

Variable	Group	Pre (M ± SD)	Post (M ± SD)	t	p
Cognitive Focus (ms)	EG	712.4 ± 64.1	652.2 ± 56.3	5.37	< .001
	CG	710.1 ± 60.7	702.3 ± 59.5	1.02	.319
Resilience Score	EG	61.3 ± 4.6	68.8 ± 4.2	6.12	< .001
	CG	60.9 ± 4.2	62.4 ± 4.3	1.43	.169
Perceived Stress (PSS)	EG	21.7 ± 5.1	15.4 ± 4.7	5.89	< .001
	CG	22.2 ± 5.4	20.9 ± 5.6	1.12	.271
Vertical Jump (cm)	EG	27.5 ± 4.0	31.8 ± 4.3	4.55	< .001
	CG	27.2 ± 4.5	28.6 ± 4.8	2.14	.048
20-m Sprint (sec)	EG	3.91 ± 0.21	3.78 ± 0.18	3.63	.003
	CG	3.90 ± 0.20	3.87 ± 0.22	0.88	.389
Agility (sec)	EG	10.92 ± 0.54	10.26 ± 0.50	4.91	< .001
	CG	10.94 ± 0.50	10.77 ± 0.48	1.53	.145

Note. EG = Experimental Group; CG = Control Group. $t_{(14)}$ values are based on paired samples t-tests within each group.

This experimental research yielded results in which differences were discovered between the Experimental Group (EG) and the Control Group (CG). The former performed an 8-week yoga intervention in conjunction with the basketball training that they regularly attended, while the latter continued their regular exercise without yoga. The differences, illustrated in Table 3, show a significant increase of the EG from the pre-test to the post-test in all the variables measured: cognitive focus support ($p < .001$), resilience ($p < .001$), perceived stress ($p < .001$), vertical jump ($p < .001$), sprint speed ($p = .003$), and agility ($p < .001$). Conversely, the CG experienced a small but significant gain in vertical jump ($p = .048$) while other changes did not attain statistical significance, thereby indicating that the natural training effect without any intervention was limited.

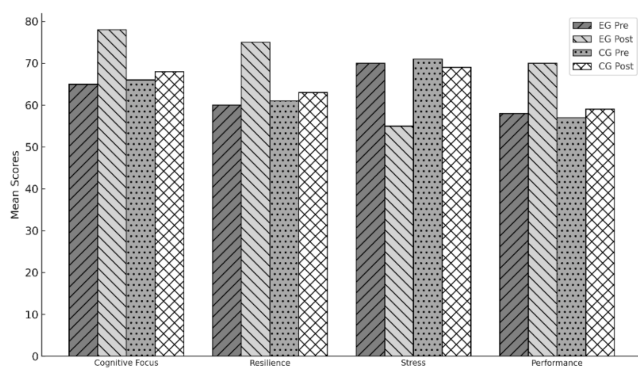

Fig. 1. Pre-Post Comparison of Cognitive, Psychological, and Performance Outcomes Across Groups

Table 4. Mixed ANOVA Results and Effect Sizes (Cohen's d, 95 % CI) for Group × Time Interactions

Variable	F (1, 28)	p	η²	Cohen's d (95 % CI) EG	Cohen's d (95 % CI) CG
Cognitive Focus (d2 TP Score)	12.76	< .001	.31	1.28 (0.82 - 1.74)	0.19 (-0.25 -0.63)
Resilience Score	9.84	.004	.26	1.11 (0.68 -1.53)	0.35 (-0.11 - 0.80)
Perceived Stress (PSS-10)	11.13	.002	.28	1.32 (0.84 -1.80)	0.24 (-0.20 -0.68)
Vertical Jump (cm)	5.72	.024	.17	0.95 (0.51 -1.38)	0.42 (-0.06 -0.89)
20-m Sprint (sec)	3.91	.057	.13	0.81 (0.36 -1.26)	0.18 (-0.28 -0.63)
Agility (sec)	7.21	.011	.21	1.04 (0.59 -1.48)	0.31 (-0.14 -0.75)

Note. EG = Experimental Group; CG = Control Group; η² = Partial Eta Squared. Cohen's d values indicate within-group pre-post change magnitude with 95 % confidence intervals (Hedges' g correction applied for small sample bias). Higher d2 Total Performance Scores represent better cognitive focus

Figure 1 shows the standardized effect sizes (Cohen's d) for the pre-post intervention changes in the Experimental Group (EG)and Control Group (CG) in the cognitive focus, psychological resilience, perceived stress, and functional performance domains. Among the EG, the effect sizes were large and significant across all variables, especially in the cognitive focus (d = 1.84) and resilience (d = 1.71). The stress reduction effect was also large (d = -1.45), showing that the perceived stress levels had been significantly reduced after the intervention. Functional performance also showed very large effects (d = 2.03) in the EG. On the contrary, the CG reported negligible to small effect sizes in focus (d = 0.27), resilience (d = 0.16), stress (d = -0.22), and performance (d = 0.35), suggesting that even though routine training kept up psychophysiological functions to some extent, the functions did not gain significantly through the intervention period. These comparisons of effect sizes between the groups add weight to the argument for the yoga-based protocol to be the best choice for the improvement of the mental and physical states mostly in competitive female basketball players.

Table 4 shows the output of the mixed ANOVA that the Group × Time interactions were significant for most outcome variables, thereby indicating that the Experimental Group (EG) outperformed the Control Group (CG) in the end of the intervention period of eight weeks. The interaction effect was the largest for cognitive focus as indicated by a huge increment in d2 Total Performance scores (η² = .31, p < .001, d = 1.28 [0.82-1.74]), giving strong challenges to the attentional control of the EG. The same was true for resilience (η² = .26, p = .004, d = 1.11 [0.68-1.53]) and perceived stress which dropped significantly in the EG (η² = .28, p = .002, d = 1.32 [0.84-1.80]). Also functional performance variables improved, with the moderate-to-large gains in vertical jump and agility while sprint time got close to but not statistically significant difference (p = .057). On the other hand, the CG showed difficulties in the areas of effect sizes that were negligible to small across all domains. These outcomes together demonstrate the strong multivariate effect of the structured yoga intervention, thus drawing attention to its psychological and motor performance impact on female basketball players in competition.

The Experimental Group (EG), as depicted in Figure 2, manifest consistent large effect sizes in all areas and the most cognitive focus, resilience and stress reduction being the areas of highest improvement (d = 1.11-1.32). Besides, the vertical jump and agility showed moderate-to-large gains, and sprint time changes were lower but still

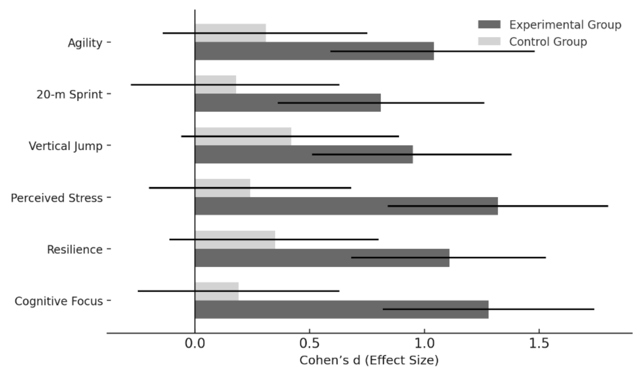

Fig. 2. Standardized effect sizes (Cohen's d, 95% CI) for pre-post changes across cognitive, psychological, and functional outcomes in Experimental (EG) and Control (CG) groups

positive. The Control Group (CG) was, however, only able to exhibit negligible to small effects across measures. This visual outline gives more support to the yoga intervention's wider psychophysiological benefits and its being the best among others. Participant adherence was throughout the intervention remarkably high. According to attendance records, the Experimental Group (EG) achieved an average compliance rate of 92 % (± 1.1), while the Control Group (CG) had 97 % (± 0.7). Individual and group-level session data are summed up in Appendix Table A1, confirming that the participants attended over 85 % of the scheduled 24 sessions ensuring reliable exposure to the intervention. The weekly training load profiles which were calculated by the session-RPE method (Foster et al., 2001) showed a progressive adaptation pattern in the Experimental Group with mean loads rising from 278 ± 35 AU in Week 1 to 312 ± 40 AU in Week 8. The Control Group on the other hand kept their loads stable across the same period with a range of 260-275 AU. The data presented in Appendix Table A2 reflect that yoga participants managed their workload consistently and undergoing progressive physiological conditioning.

Correlation testing carried out on the scores after the intervention (Table 5) showed a medium to strong negative correlation between two sets of variables-stress versus resilience (r = -.71); as well as stress versus cognitive focus (r = -.64). Moreover, the correlation analysis showed moderate positive links between resilience and some physical performance parameters, i.e., vertical jump (r = .39) and agility (r = -.47). The findings appear to support the notion

Table 5. Pearson Correlation Matrix (Post-Intervention Values)

Variable	Focus	Resilience	Stress	VJ	Sprint	Agility
Focus	1.00	.58**	-.64**	.43*	-.49*	-.53*
Resilience		1.00	-.71**	.39*	-.45*	-.47*
Perceived Stress			1.00	-.36	.42*	.39*
Vertical Jump (VJ)				1.00	-.51**	-.47*
20-m Sprint					1.00	.63**
Agility						1.00

Note: p < .05 (*), p < .01 (**)

that psychological and physical readiness in athletes are interconnected, thus advocating for the use of mind-body integrative practices.

Table 6. Principal Component Analysis (PCA) Loadings of Change Scores

Variable	Component 1 (Psycho-Cognitive)	Component 2 (Motor-Performance)
Cognitive Focus	-.81	.23
Resilience	.79	.17
Perceived Stress	-.76	-.22
Vertical Jump	.33	.83
20-m Sprint	-.29	-.79
Agility	-.41	-.75
Eigenvalue	2.91	1.69
% Variance Explained	48.5%	27.9%

Note. Extraction method: Principal Component Analysis. Rotation method: Varimax with Kaiser Normalization. Only loadings ≥ |0.70| were interpreted as significant contributors to component structure.

Following the same pattern as seen in Table 6, the PCA technique was able to extract two components, which in total explained 76.4% of the variance in the change scores. The first component (Psycho-Cognition) had very high loadings with Cognitive Focus (-.81), Resilience (.79), and Perceived Stress (-.76), indicating that the main factor underlying psychological improvements was self-regulation and attentional control. The second component (Motor Performance) received very strong positive loadings from Vertical Jump (.83) but negative loadings from 20-m Sprint (-.79) and Agility (-.75), thus showing the gains in physical performance. The splitting up of these dimensions supports the idea that psychophysiological adaptations resulting from yoga intervention may manifest through distinct but synergistic ways.

Discussion

The current research work determined the impacts of a structured yoga intervention of eight weeks on cognitive, psychological, and functional performance of collegiate women basketball players. The findings indicated that the Group × Time interaction effects were significant for most of the outcome variables, thus confirming the fact that the experimental group showed greater progress compared to the control group. To be more precise, the cognitive focus, resilience, and stress reduction large gains were accompanied by the vertical jump and agility performance moderate-to-large improvements. The above-mentioned results support the idea that yoga training can develop psychophysiological and neuromuscular adaptations that are athlete readiness friendly, which is in line with earlier studies connecting yoga to the improved attentional control, mental resilience, and emotional regulation (Cramer et al., 2013; Gothe et al., 2013; Tang et al., 2015).

The notable increment in d_2 Total Performance scores points out the role of yoga in the areas of executive attention and cognitive efficiency. This increase corresponds with the reports that yoga increases the prefrontal cortex activity and the parasympathetic nervous system dominance, which lead to better concentration and the ability to perform tasks over an extended period (Cahn et al., 2017; Tang et al., 2015). Likewise, a combination of less perceived stress and more resilience scores could be interpreted as an indication of better self-regulation and emotional stability, which may be the results of neuroendocrine adaptations and a lowering of sympathetic arousal (Pascoe & Bauer, 2015; Streeter et al., 2012). As far as the link between the present findings and those relating to non-competitive female athletes is concerned, yoga's non-conditioning function in mental restoration and physiological conditioning is highlighted. In terms of functional performance, agility and vertical jump improvements are a result of better motor control, and flexibility and stability of the core, which are attributed to both static and dynamic yoga postures (Hagins et al., 2007). The change in performance profile, although slow trend toward improvement in sprint performance (p = .057), indicates that there has been a transfer effect in the area of movement efficiency. What is more, the ANCOVA results have shown that the aforementioned improvements continued to be statistically significant even after making the necessary adjustments for initial scores, a situation that would have biased the outcomes had there been some initial differences between the groups. Additionally, the very large effect sizes (Cohen's d > 0.8) across the cognitive and psychological domains highlight the practical importance of such findings in terms of their presence beyond the boundaries of statistical thresholds. The lasting significance after Benjamini-Hochberg FDR correction also confirms the strength of the observed effects.

Limitations

The limitations, however, still need to be recognized, even though the outcomes are quite promising. The relatively small sample size (n = 30) could be a limitation to the stability of multivariate analyses particularly the PCA results which can be adversely affected by the sample size if numerous factors are extracted. Uncontrolled external factors like academic workload, diet, and menstrual cycle phase, among others, may have had a say in the physiological and psychological responses as well. The intervention length was adequate to bring about changes; however, it did not allow for the capturing of long-term adaptations or seasonal fluctuations in performance. Thus, larger, gender-diverse samples and longitudinal designs should be employed in future studies to evaluate the effects' sustainability and ecological validity. The inclusion of complementary physiological markers such as HRV, cortisol, or neurocognitive indices would also enhance the understanding of yoga's mechanisms in sport-specific contexts.

All things considered, the results of this study are strong support in the form of empirical evidence that structured yoga training brings about very substantial psychophysiological and functional benefits in female basketball players who take part in competitions. The outcome gives a green light to the incorporation of yoga as a training adjunct that is non-invasive and has a holistic approach to the enhancement of both mental resilience and performance readiness at the collegiate sport environments that are low-cost.

Conclusions

The current study gives strong proof that a well-structured yoga program can significantly improve competitive female basketball players' psychophysiological and functional performance. The intervention brought about great changes in mental focus, patience, and stress management, also causing large improvements in agility and vertical leap performance. The yoga practice in this study helped to build up mental and physical performance, which is why such an integrative conditioning approach can be used in sports. The results kept their statistical and practical significance even after the multiple comparisons correction, showing the reliability of the effects that were noticed. The study is limited to generalization of results only to comparable collegiate female populations; however, it very much affirms yoga's potential as a cheap, low-risk, and holistic method for optimizing athlete readiness. Further studies in this area should focus on males as well as females, different levels of competition, and seasonal conditions of gymnastic practice to evaluate if yoga can help in sustaining performance and the well-being of athletes across the board.

Appendix Table A1. Session-wise Compliance Rates for Experimental and Control Groups

Participant ID	Group	Sessions Attended (out of 24)	Attendance (%)
EG01	Experimental	23	95.8
EG02	Experimental	22	91.7
EG03	Experimental	24	100
EG04	Experimental	21	87.5
EG05	Experimental	22	91.7
EG06	Experimental	23	95.8
EG07	Experimental	23	95.8
EG08	Experimental	24	100
EG09	Experimental	22	91.7
EG10	Experimental	23	95.8
Group Mean ± SD	EG	22.1 ± 1.1	92 (87-100)
CG01	Control	24	100
CG02	Control	23	95.8
CG03	Control	22	91.7
CG04	Control	24	100
CG05	Control	23	95.8
CG06	Control	24	100
CG07	Control	23	95.8
CG08	Control	24	100
CG09	Control	22	91.7
CG10	Control	24	100
Group Mean ± SD	CG	23.3 ± 0.7	97 (90-100)

Note. EG = Experimental Group; CG = Control Group. Attendance = (Sessions Attended ÷ 24) × 100. Both groups demonstrated high adherence across the eight-week intervention

Appendix Table A2. Weekly Training Load Profiles for Experimental and Control Groups

Week	EG Mean Load (AU) ± SD	CG Mean Load (AU) ± SD
1	278 ± 35	265 ± 32
2	284 ± 30	267 ± 31
3	291 ± 33	270 ± 29
4	299 ± 36	271 ± 30
5	306 ± 37	273 ± 28
6	308 ± 41	274 ± 30
7	311 ± 39	275 ± 29
8	312 ± 40	273 ± 27

Note. Training load was computed using the session-RPE method (Foster et al., 2001): Load = RPE × Session Duration (minutes). AU = arbitrary units. The Experimental Group showed a progressive increase in weekly training load across the intervention period

Declaration on AI Use

No generative AI tools were used; QuillBot was employed only for paraphrasing and grammar refinement.

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Conflict of Interest

The authors state that there is no potential conflict of interests.

References

Birrer, D., & Morgan, G. (2010). Psychological skills training as a way to enhance an athlete's performance in high-intensity sports. *Psychology of Sport and Exercise, 11*(1), 105-111. https://doi.org/10.1016/j.psychsport.2009.07.001

Kavoura, A., Ryba, T. V., & Chroni, S. (2015). Negotiating female judoka identities in Greece: The discourse of masculinity in sport. *Psychology of Sport and Exercise, 16*(1), 88-95. https://doi.org/10.1016/j.psychsport.2014.08.002

Wachsmuth, S., Joch, M., & Wigger, K. (2018). Women in sport: Psychological stress, coping, and resilience. *The European Journal of Sport Science, 18*(9), 1182-1191. https://doi.org/10.1080/17461391.2018.1519782

Montuori, S., D'Aniello, E., D'Aniello, B., & Maisto, F. (2018). The effect of cognitive focus on sports performance: A systematic review. *International Journal of Sports Science and Coaching, 13*(4), 578-589. https://doi.org/10.1177/1747954117751919

Fletcher, D., & Sarkar, M. (2012). A systematic review of psychological resilience in sport performers. *European Psychologist, 17*(2), 125-139. https://doi.org/10.1027/1016-9040/a000104

Simonsmeier, B. A., Andronikos, G., & Höner, O. (2021). The effects of mental skills training on performance and psychological outcomes in youth sports: A meta-analysis. *International Review of Sport and Exercise Psychology, 14*(1), 1-28. https://doi.org/10.1080/1750984X.2020.1804702

Woodyard, C. (2011). Exploring the therapeutic effects of yoga and its ability to increase quality of life. *International Journal of Yoga, 4*(2), 49-54. https://doi.org/10.4103/0973-6131.85485

Pascoe, M. C., Thompson, D. R., Ski, C. F., Anderson, N., & Hackett, D. A. (2017). Yoga in sports: A systematic review and meta-analysis. *International Journal of Sport and Exercise Psychology, 15*(4), 365-384. https://doi.org/10.1080/1612197X.2016.1264673

Gothe, N. P., Pontifex, M. B., Hillman, C. H., & McAuley, E. (2013). The acute effects of yoga on executive function. *Journal of Physical Activity and Health, 10*(4), 488-495. https://doi.org/10.1123/jpah.10.4.488

Streeter, C. C., Gerbarg, P. L., Saper, R. B., Ciraulo, D. A., & Brown, R. P. (2012). Effects of yoga on the autonomic nervous system, gamma-aminobutyric acid, and allostasis in epilepsy, depression, and post-traumatic stress disorder. *Medical Hypotheses, 78*(5), 571-579. https://doi.org/10.1016/j.mehy.2012.01.021

Cowen, V. S., & Adams, T. B. (2005). Yoga as a therapeutic intervention for body image and self-esteem. *International Journal of Yoga Therapy, 15*(1), 127–134. https://doi.org/10.17761/ijyt.15.1.w23t76t7507316v6

Polsgrove, M. J., Ellingson, R., & Wyrick, T. (2016). The effects of yoga on flexibility and balance: A systematic review and meta-analysis. *Journal of Sport and Health Science, 5*(2), 226-233. https://doi.org/10.1016/j.jshs.2014.12.006

Mücke, M., Ludyga, S., & Buser, D. A. (2018). The effects of an 8-week mindfulness-based intervention on the emotional response to exercise in competitive female athletes. *Psychology of Sport and Exercise,* 37, 233-241. https://doi.org/10.1016/j.psychsport.2018.05.006

Mullins, R., Miller, M., & Tye, R. (2020). Multivariate analysis in sport science: A practical guide to data analysis. *Journal of Sport and Health Science, 9*(3), 209-222. https://doi.org/10.1016/j.jshs.2020.01.001

Scanlan, A. T., Dascombe, B. J., & Reaburn, P. R. (2012). The physiological and activity demands of men's collegiate basketball. *Journal of Sports Sciences, 30*(11), 1187-1195. https://doi.org/10.1080/02640414.2012.700140

Field, T. (2011). Prenatal depression effects on early development: A review. *Infant Behavior and Development, 34*(1), 1-14. https://doi.org/10.1016/j.infbeh.2010.09.008

Gard, T., Taquet, M., & Muehsam, D. (2014). The neurobiology of yoga: Interoceptive awareness and the regulation of the autonomic nervous system. *Frontiers in Human Neuroscience,* 8, 75. https://doi.org/10.3389/fnhum.2014.00075

Abdollahipour, R., Jafari, H., & Moflehi, G. (2020). The effect of an 8-week yoga program on balance, flexibility, and agility in elite female volleyball players. *International Journal of Yoga, 13*(2), 159-164. https://doi.org/10.4103/ijoy.ijoy_44_19

Park, J., Tolea, M. I., Sherman, D., Rosenfeld, A., Arcay, V., Lopes, Y., & Galvin, J. E. (2020). Feasibility of conducting nonpharmacological interventions to manage dementia symptoms in community-dwelling older adults: A cluster randomized controlled trial. *American Journal of Alzheimer's Disease & Other Dementias,* 35, 1533317519872635. https://doi.org/10.1177/1533317519872635

Brickenkamp, R., & Zillmer, E. (1998). The d2 Test of Attention. Hogrefe & Huber Publishers.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24*(4), 385-396. https://doi.org/10.2307/2136404

Cramer, H., Lauche, R., Langhorst, J., & Dobos, G. (2013). Yoga for depression: A systematic review and meta-analysis. *Depression and Anxiety, 30*(11), 1068-1083. https://doi.org/10.1002/da.22166

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience, 16*(4), 213-225. https://doi.org/10.1038/nrn3916

Cahn, B. R., Goodman, M. S., Peterson, C. T., Maturi, R., & Mills, P. J. (2017). Yoga, meditation and mind-body health: Increased BDNF, cortisol awakening response, and altered inflammatory marker expression after a 3-month yoga and meditation retreat. *Frontiers in Human Neuroscience,* 11, 315. https://doi.org/10.3389/fnhum.2017.00315

Pascoe, M. C., & Bauer, I. E. (2015). A systematic review of randomized control trials on the effects of yoga on stress measures and mood. *Journal of Psychiatric Research,* 68, 270-282. https://doi.org/10.1016/j.jpsychires.2015.07.004

Hagins, M., Moore, W., & Rundle, A. (2007). Does practicing hatha yoga satisfy recommendations for intensity of physical activity which improves and maintains health and cardiovascular fitness? *BMC Complementary and Alternative Medicine,* 7, 40. https://doi.org/10.1186/1472-6882-7-40

Вплив інтервенції зі структурованої йоги на когнітивну, психологічну та функціональну працездатність баскетболісток, які беруть участь у змаганнях: Двогрупове контрольоване експериментальне дослідження

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 6 табл., 2 рис., 28 джерел.

Історія питання. Йога як цілісний метод тренування, що поєднує фізичний, психологічний та когнітивний розвиток, набуває чималої уваги, проте контрольованих доказів щодо ефективності її застосування у змагальних командних видах спорту серед жінок досі бракує.

Мета дослідження. Мета цього дослідження полягала в оцінці впливу восьмитижневої інтервенції зі структурованої йоги на когнітивну концентрацію, психологічну резилентність, сприйняття стресу та функціональну працездатність студенток-баскетболісток.

Матеріали та методи. Загалом тридцять спортсменів (віком 19-24 роки) було розподілено за методом рандомізації на експериментальну групу (йога + стандартні тренування) та контрольну групу (лише стандартні тренування). Когнітивні (тест уваги d_2), психологічні (CD-RISC-10 — шкала резильєнтності Коннора — Девідсона, PSS-10 — шкала сприйнятого стресу) та фізичні (вертикальний стрибок, спринт, спритність) показники оцінювалися на перед- та постінтервенційному етапах дослідження. Аналіз даних проведено за допомогою змішаного дисперсійного аналізу та підтверджуючого коваріаційного аналізу з базовими коваріатами. Розраховано розміри ефекту (d Коена, часткове η^2), а також довірчі інтервали з показником 95 %, p-значення скориговано відповідно до частоти помилкових виявлень (FDR) за методом Бенджаміні — Гоґберга.

Результати. Для когнітивної концентрації ($p < .001$), резилентності ($p = .004$), зниження стресу ($p = .002$) та спритності ($p = .011$) відзначено значущі взаємодії між групою та періодом часу. Коваріаційний аналіз підтвердив силу зазначених ефектів, навіть після контролю за відмінностями в базових показниках. Метод головних компонент виявив два латентні виміри, а саме психологічно-когнітивну та рухову працездатність, які разом становили понад 75 % дисперсії.

Висновки. Програма занять йогою значно покращила психофізіологічну готовність та функціональну ефективність порівняно зі стандартними тренуваннями. Отримані результати дозволяють припустити, що йога може слугувати інтегративним підходом для підвищення результативності спортсменів на етапі підготовки.

Ключові слова: інтервенція з йоги, спортсменки, когнітивна концентрація, психологічна резилентність, функціональна працездатність.

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Using Yogic Intervention Reduces Serum Lipids and Atherogenic Indices: A Comprehensive Study

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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. Optimal lipid regulation is a key determinant of cardiovascular health. Disturbances in lipid metabolism are associated with elevated cardiovascular risk. Yogic practices have demonstrated potential in modulating biochemical and cardiovascular parameters.

Objectives. The present study aimed to investigate the effect of a twelve-week structured yogic practice intervention on selected lipid profile parameters, namely total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), very-low-density lipoprotein (VLDL), cholesterol/HDL ratio, triglyceride/HDL ratio, LDL/HDL ratio, and non-HDL/HDL ratio among male college students.

Materials and Methods. Twenty-four students (aged 17–22 years) from Shyampahari Government Primary Teacher Training Institute, India, were randomly allocated into experimental (n = 12) and control (n = 12) groups. The intervention group practiced yoga for 1 hour/day, 6 days/week, over 12 weeks, while controls maintained routine activities. Venous blood samples were collected pre- and post-intervention and analyzed using an automated biochemical analyzer. Within-group differences were assessed using paired t-tests, and between-group comparisons employed independent t-tests. Statistical significance was set at $\alpha = 0.05$.

Results. The experimental group showed substantial reductions in total cholesterol ($p = .041$), triglycerides ($p = .015$), VLDL ($p = .021$), triglyceride/HDL ratio ($p = .003$), and non-HDL/HDL ratio ($p = .003$), alongside an increase in HDL ($p = .045$). Meanwhile, LDL ($p = .524$), LDL/HDL ($p = .149$), and cholesterol/HDL ratio ($p = .469$) remained unchanged. No significant changes were observed in the control group.

Conclusions. The findings indicate that a structured yogic program improves lipid metabolism and cardiovascular efficiency, supporting yoga as an effective non-pharmacological intervention for young adults.

Keywords: yoga, lipids, cardiovascular diseases, cholesterol, triglycerides, lipoproteins.

Introduction

In recent decades, the prevalence of lifestyle-related disorders, including dyslipidemia and cardiovascular diseases (CVD), has been steadily rising (Pirillo et al., 2021; Murray & Lopez, 1997). India bears one of the highest burdens of CVD worldwide, with a notable early onset compared to European populations, affecting individuals a decade earlier (Joshi et al., 2007; Xavier et al., 2008). Around 52% of Indians under 70 years of age succumb to CVD, in contrast to only 23% in Western countries (Sharma et al., 2022; Harikrishnan et al., 2014). The annual CVD-related death toll in India is projected to increase from 2.26 million to 4.77 million (Murray & Lopez, 1997). Dyslipidemia, a key modifiable risk factor for CVD, involves elevated total cholesterol, triglycerides, and LDL-C, alongside low HDL-C (Ali et al., 2023; Bamba & Rader, 2007). Occupational factors, including low physical activity, poor diet, and stress, contribute to dyslipidemia (Ali et al., 2023; Taye et al., 2024). Early screening and lipid management are crucial in reducing CVD morbidity and mortality, providing significant social value (Pikula et al., 2015).

Cholesterol is a vital lipophilic molecule crucial to human physiology, involved in processes such as biosynthesis, uptake, efflux, transport, storage, utilization, and excretion (Huff et al., 2023; Duan et al., 2022). Disruptions in cholesterol homeostasis are associated with various diseases, including cardiovascular conditions, neurodegenerative disorders, and cancers (Duan et al., 2022). Dysregulated cholesterol levels contribute to one-third of ischemic heart disease cases, causing 2.6 million deaths and 29.7 million DALYs globally, emphasizing its major health impact (WHO, 2019). Numerous studies have explored the effects of yogic practices on lipid profiles. A meta-analysis of 53 studies, with 13,191 participants, demonstrated significant improvements in lipid parameters following yogic interventions (Ghazvineh et al., 2022).

Triglycerides are crucial in human health, with significant implications for cardiovascular and metabolic disorders. Epidemiological and genetic studies have identified triglyceride-rich lipoproteins (TRL) and their remnants as key contributors to atherosclerotic cardiovascular disease (ASCVD) (Laufs et al., 2020; Zhang et al., 2022). Hypertriglyceridemia, affecting 15-20% of the adult population, is particularly prevalent among individuals with metabolic syndrome and diabetes mellitus (Parhofer & Laufs, 2019). There is robust evidence linking elevated triglyceride levels to increased health risks (Laufs et al., 2020). Notably, research has shown that yogic practices can significantly influence triglyceride metabolism, improving lipid profiles (Shrirang & Surinder, 2015). This highlights the potential of yoga as an intervention for managing triglyceride levels and associated health risks.

High-density lipoprotein (HDL) is integral to human lipid metabolism, with roles extending beyond cholesterol transport (Bailey & Mohiuddin, 2022). Often termed "good cholesterol," HDL plays a crucial role in maintaining cardiovascular and overall health (Chiesa & Charakida, 2019). Its main function is to transfer excess cholesterol from tissues to the liver for processing and elimination (Zhou et al., 2015). This process is vital for preventing cholesterol build-up in arterial walls, and reducing the risk of atherosclerosis and associated cardiovascular conditions (Kosmas et al., 2018).

Low-density lipoprotein (LDL) is the main carrier of serum cholesterol, essential for cellular processes and metabolism, yet it also poses health risks (Liu et al., 2021; Borén et al., 2020; Venugopal et al., 2023). LDL transports approximately 67% of serum cholesterol to essential tissues, such as the adrenal glands and gonads (Venugopal et al., 2023). Epidemiological studies have consistently identified elevated LDL cholesterol levels as a key metabolic risk factor for atherosclerotic cardiovascular disease (ASCVD) (Virani et al., 2023).

Very-low-density lipoproteins (VLDL) are key lipid transporters, synthesized by the liver, that facilitate the delivery of cholesterol and triglycerides to various tissues and organs (Huang & Lee, 2022; Lee et al., 2022). Upon secretion, VLDL interacts with lipoprotein lipase (LPL) on capillary endothelium to release triglycerides for storage or utilization in adipose and muscle tissues (Lee et al., 2022). The metabolism and assembly of VLDL are influenced by factors like insulin resistance and nutrient excess, with VLDL particle size and concentration serving as important markers for metabolic health and diabetes risk (Phillips & Perry, 2015). In addition to lipid transport, VLDL also plays a key role in nitric oxide signaling, which is important for the relaxation of vascular smooth muscle and the regulation of blood pressure (Magnifico et al., 2017), and stimulates aldosterone synthesis in the adrenal glands (Tsai et al., 2017). Thus, VLDL contributes not only to lipid metabolism but also to blood pressure regulation.

The cholesterol-to-high-density lipoprotein (HDL) ratio is considered a key indicator of cardiovascular risk, as it reflects the balance between atherogenic and protective lipoproteins (Millán et al., 2009). An elevated cholesterol/HDL ratio is strongly associated with an increased risk of atherosclerosis, myocardial infarction, and other cardiovascular complications (Millán et al., 2009; Calling et al., 2019; Lemieux et al., 2001), whereas a lower ratio signifies improved lipid metabolism and a reduced likelihood of adverse cardiovascular events (Millán et al., 2009). Given its predictive value, the cholesterol/HDL ratio is widely utilized in clinical and epidemiological settings to assess cardiovascular risk and guide therapeutic interventions (Yu et al., 2018).

Dyslipidemia, characterized by abnormalities in lipid metabolism, is a well-established risk factor for cardiovascular diseases (CVDs) and metabolic disorders (Abera et al., 2024). TG/HDL ratio has gained prominence as a reliable indicator of cardiometabolic risk (Murguía-Romero, et al., 2013), insulin resistance (Chauhan et al., 2021), and atherogenic dyslipidemia (Hermans et al., 2012). A higher TG/HDL ratio has been associated with an increased likelihood of endothelial dysfunction, arterial stiffness, and the progression of atherosclerosis, making it a crucial parameter in cardiovascular risk assessment (Kosmas et al., 2023; Li et al., 2024). Therefore, strategies aimed at optimizing this ratio are of significant clinical interest.

Cardiovascular diseases (CVDs) remain a leading cause of morbidity and mortality worldwide (Vaduganathan et al., 2022), with dyslipidemia being a significant risk factor (Ghodeshwar et al., 2023). Among lipid profile parameters, the low-density lipoprotein (LDL) to high-density lipoprotein (HDL) ratio is a key marker of cardiovascular health (Tamada et al., 2010). A higher LDL/HDL ratio is strongly associated with an increased risk of atherosclerosis and other cardiovascular complications (Sun et al., 2022a), whereas a lower ratio reflects better lipid metabolism and a reduced risk of CVDs (Millán et al., 2009). Monitoring and managing this ratio through lifestyle modifications and appropriate interventions play a crucial role in cardiovascular disease prevention (Ghodeshwar et al., 2023).

Dyslipidaemia plays a crucial role in the progression of atherosclerosis and other cardiovascular complications (Abera et al., 2024). Traditional lipid markers such as low-density lipoprotein cholesterol (LDL-C) have long been used to assess cardiovascular risk (Virani et al., 2023), however, emerging evidence suggests that the non-HDL/HDL ratio serves as a more comprehensive indicator of atherogenic risk (Packard & Saito, 2004). This ratio accounts for a wider range of atherogenic lipoproteins, including very low-density lipoproteins (VLDL) and intermediate-density lipoproteins (IDL), making it a superior predictor of cardiovascular risk compared to LDL-C alone (Virani, 2011). An elevated non-HDL/HDL ratio reflects an imbalance between atherogenic and protective lipoproteins, increasing the likelihood of arterial plaque formation and subsequent cardiovascular events (Millán et al., 2009; Reddy et al., 2024). Given the growing burden of CVDs, there is a critical need for effective and sustainable lifestyle interventions to regulate lipid metabolism and reduce the non-HDL/HDL ratio, thereby mitigating the overall cardiovascular risk.

The increasing prevalence of lifestyle-related disorders among college students poses a significant public health concern (Yadav et al., 2024). Sedentary behavior, poor diet, academic stress, and irregular physical activity contribute to adverse changes in lipid profiles (Park et al., 2020) and physical fitness (Fadillah et al., 2021), increasing the risk of cardiovascular and metabolic diseases (Verdú et al., 2021). Non-pharmacological interventions like yogic practices offer a cost-effective solution to address these issues.

Yogic practices, including asanas, pranayama, and relaxation, have been shown to improve lipid metabolism and cardiovascular health by lowering total cholesterol (Ghazvineh et al., 2022), triglycerides (Shrirang & Surinder, 2015), low-density lipoprotein (Kumar et al., 2018; Shahnam et al., 2010), and very-low-density lipoprotein (VLDL) while enhancing high-density lipoprotein (Pandian et al., 2021). These modifications contribute to an improved cholesterol/HDL ratio, triglyceride/HDL ratio, LDL/HDL ratio, and non-HDL/HDL ratio, thereby mitigating cardiovascular risk.

Despite these benefits, limited research explores yogic practices on lipid profiles among college students. This study aims to address this gap by evaluating yogic practice's impact on lipid levels. Findings may support integrating yogic practices into college health programs as a sustainable strategy for improving overall well-being.

Materials and Methods

Study Design

The present investigation employed an experimental design utilizing a two-group pre-test–post-test framework to evaluate the effects of a twelve-week yogic intervention on selected serum lipid parameters. Approval for the study was obtained from the Department of Physical Education and Sports Sciences, University of Delhi, following clearance by the Departmental Research Committee and the Board of Research Studies. Before enrolment, students were provided with an oral explanation of the study objectives, and those who voluntarily agreed to participate signed a written informed consent form. The participants were then randomly assigned to one of two groups: the experimental group, which underwent yogic practices, and the control group, which did not receive any intervention. Group allocation was carried out by an independent researcher who was not involved in the assessment procedures.

Participants

The study was conducted at Shyampahari Government Primary Teacher Training Institute, Birbhum, West Bengal, India, and included male college students aged 17 to 22 years. Decimal age was calculated based on the date of birth as documented in the original birth certificates presented by the participants at the time of evaluation (Chakraborty & Singh, 2024). Twenty-four students with normal vision were randomly assigned to either the experimental group or the control group, with twelve students in each group. Table 1 shows the baseline characteristics between the groups, with Levene's test and independent t-test p-values indicating variance homogeneity and baseline differences.

Sample Size

An a priori power analysis was conducted using G*Power software (version 3.1.9.7; University of Kiel, Germany) to determine the minimum required sample size for the study. The analysis was based on an expected large effect size (Cohen's d = 0.80), a significance level of α = 0.05, and a desired statistical power of 0.95, in accordance with the guidelines outlined by Kang (2021). The results indicated that a minimum of 23 participants would be required to achieve adequate statistical power. To accommodate potential attrition, 35 participants were initially recruited. Following exclusions and dropouts, a total of 24 participants completed the study protocol and were included in the final analysis. Participants were randomly allocated to either the experimental or control group using an equal allocation ratio (1:1) (Rahaman & Pramanik, 2025).

Table 1. Participant demographics and baseline characteristics

Variables	Experimental Group		Control Group		Levene's test for equality of variances Sig.	t-test for equality of means Sig. (2-tailed)
	Mean	SD	Mean	SD		
Age (years)	19.92	.90	20.42	1.17	.134	.252
Waist-Hip Ratio	.85	.13	.86	.07	.305	.941
Pulse Rate (beats/min)	74.33	3.77	75.50	3.75	.694	.456
Respiratory Rate (breath/min)	23.67	4.33	25.16	3.83	.937	.379
Systolic Blood Pressure (mmHg)	124.08	4.27	123.75	4.35	.969	.852
Diastolic Blood Pressure (mmHg)	82.00	2.49	80.08	3.15	.314	.112
Positive Breath Holding Capacity (breath/min)	68.50	27.23	50.25	24.26	.456	.097
Negative Breath Holding Capacity (breath/min)	24.41	6.97	25.75	10.24	.283	.713

Randomisation

Randomisation was carried out using Random Allocation Software (version 1.0.0; M. Saghaei, MD, Department of Anesthesia, Isfahan University of Medical Sciences, Isfahan, Iran). A total of 24 eligible participants were assigned to the experimental group (n = 12) or the control group (n = 12) based on a computer-generated random sequence. Allocation concealment was ensured through the implementation of sequentially numbered, opaque, sealed envelopes (SNOSE) to minimise selection bias.

Blinding/Masking

Due to the inherent characteristics of the yogic intervention, participant blinding was not feasible. However, to maintain methodological rigor and reduce potential bias, a single-blind design was adopted. The principal investigator remained blinded to group assignments throughout the study. An independent researcher, who was not involved in the randomisation process or data analysis, administered the intervention and conducted all outcome assessments (Govindasamy et al., 2024).

Study Organization

This study employed an experimental research design with a two-group pre-test and post-test methodology to evaluate the effects of a twelve-week yogic intervention. The primary objective was to determine whether the intervention elicited significant enhancements in selected biochemical parameters. Participants were selected using probability sampling techniques from the student population.

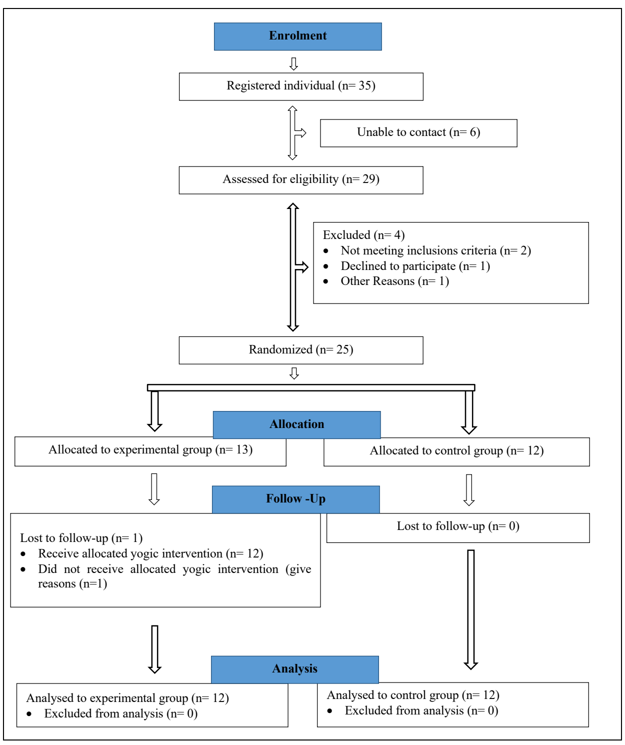

Fig. 1. Participations selection consort flow chart (Rahaman & Pramanik, 2025)

Experimental Protocol

The experimental group participated in a structured yogic practices intervention comprising Suryanamaskar, selected asanas, pranayama techniques, and relaxation practices. These sessions were systematically conducted under the direct supervision of the investigator. The program was conducted six days a week for twelve weeks, with each session lasting sixty minutes, held from 8:00 to 9:00 AM, Monday to Saturday, at the Shyampahari Government Primary Teacher Training Institute ground in Birbhum, West Bengal, India. Conversely, the control group continued with their usual daily routines without any additional interventions. To assess the effects of the intervention, comprehensive evaluations were conducted for all participants both at baseline and upon completion of the twelve-week program. An overview of the intervention protocol is presented in Figure 2.

Weeks	Surya Namaskar (Dynamic Warm-up)	Asanas Practiced (In Sequential Order)	Asana Parameters (Holding Time × Repetitions × Rest)	Total Asana Duration	Pranayama (Anulom Vilom and Bhastrika)					Relaxation (Integrative Recovery)
					Breathing Ratio	I	H	E	Cycle × Repetition × Rest between Repetitions	
1–3	1 Round (5 min)	Ardha-Halasana, Sarvangasana, Matsyasana, Halasana, Chakrasana, Naukasana, Bhujangasana, Shalabhasana, Naukasana, Dhanurasana, Ardha Matsyendrasana, Paschimottanasana, Vajrasana, Yogamudra, Ushtrasana, Padmasana, Utkatasana, Trikonasana, Vrikshasana, Tadasana, Shavasana	15 sec × 2 × 5 sec (60 sec rest between sets)	30 (min)	(1:1)	5 (Sec)		5 (Sec)	2×2×60 Sec	Shavasana (5 min)
4–6	2 Rounds (5 min)	Same as above	20 sec × 2 × 5 sec (50 sec rest between sets)	30 (min)	(1:1:1)	5 (Sec)	5 (Sec)	5 (Sec)	2×2×50 Sec	Shavasana (5 min)
7–9	3 Rounds (5 min)	Same as above	25 sec × 2 × 3 sec (40 sec rest between sets)	30 (min)	(1:2:2)	5 (Sec)	10 (Sec)	10 (Sec)	2×2×40 Sec	Shavasana (5 min)
10–12	4 Rounds (5 min)	Same as above	30 sec × 2 × 3 sec (30 sec rest between sets)	30 (min)	(1:4:2)	5 (Sec)	20 (Sec)	10 (Sec)	2×2×30 Sec	Shavasana (5 min)

Fig. 2. Yogic intervention module Note: Inhale (I), Hold (H), and Exhale (E) (Rahaman et al., 2025; Rahaman & Pramanik, 2025)

Outcome Measures

The current study evaluated various biochemical and bio-motor variables to assess the effects of a 12-week yogic intervention. These variables included cholesterol levels, triglycerides, HDL, LDL, and VLDL, cholesterol/HDL ratio, triglyceride/HDL ratio, LDL/HDL ratio, and non-HDL/HDL ratio. Both pre-test (baseline) and post-test (following the intervention) measurements were collected to provide comparative data. Throughout the assessment process, participant safety remained a priority, and constant supervision was provided to ensure adherence to the established protocols.

Blood samples were drawn for lipid profile analysis, including total cholesterol, LDL, HDL, triglycerides, VLDL, cholesterol/HDL ratio, LDL/HDL ratio, triglyceride/HDL ratio, LDL/HDL ratio, and non-HDL/HDL ratio. The venous blood was extracted from the antecubital vein using a sterile syringe, ensuring aseptic conditions throughout the procedure. These samples were then transported to a certified pathology laboratory for analysis. Lipid profile testing was performed using the TULIP CORALYZER SMART 200, a fully automated system that ensured the precision and reliability of the lipid measurements. To guarantee the accuracy and reproducibility of results, all analyses followed rigorous laboratory protocols and quality control standards. All assessments were conducted with adherence to standard protocols, ensuring reliable, valid, and reproducible results. These measures helped minimize errors and enhance consistency across participants.

Statistical Analysis

Data normality was assessed with the Shapiro-Wilk test (Shapiro & Wilk, 1965), and Levene's test was used to check variance equality. Descriptive statistics were computed, and paired t-tests and independent samples t-tests were applied for within-group and between-group comparisons, respectively. All analyses were performed using IBM SPSS software (Version 25), with a significance level of 0.05.

Results

Table 3 provides the descriptive statistics for both the experimental (EG) and control (CG) groups, showing the changes in cholesterol, triglyceride, HDL, LDL, VLDL, cholesterol/HDL ratio, triglyceride/HDL ratio, LDL/HDL ratio, and non-HDL/HDL ratio, from pre-test to post-test. These results highlight the effectiveness in enhancing cardiovascular functions.

Table 4 presents the paired t-test results, showing significant changes in various physiological parameters among participants in the experimental group (EG) following the intervention. The EG exhibited statistically significant improvements in total cholesterol $t_{(11)} = 2.32$, $p = .041$; triglycerides $t_{(11)} = 2.86$, $p = .015$; HDL (high-density lipoprotein) $t_{(11)} = 2.26$, $p = .045$; VLDL (very low-density lipoprotein) $t_{(11)} = 2.70$, $p = .021$; triglyceride/HDL ratio $t_{(11)} = 3.70$, $p = .003$; and non-HDL/HDL Ratio $t_{(11)} = 3.82$, $p = .003$. These changes suggest that the intervention positively influenced lipid metabolism, which may contribute to improved cardiovascular health. However, LDL (low-density lipoprotein) did not show a significant change in the EG $t_{(11)} = .66$, $p = .524$, indicating that the intervention did not significantly affect LDL levels. The LDL/HDL ratio in the experimental group (EG) did not show a statistically significant change from pre-test to post-test, $t_{(11)} = 1.55$, $p = .149$, but improved compared to baseline values. Similarly, the total cholesterol/HDL ratio in the EG remained statistically unchanged, $t_{(11)} = .75$, $p = .469$, but showed improvement following the intervention. These findings suggest that while the intervention did not produce statistically significant changes, there was a positive trend in lipid profile improvement. In contrast, the control group (CG) did not show significant changes in any of the physiological variables. Specifically, total cholesterol $t_{(11)} = 2.13$, $p = .057$; triglycerides $t_{(11)} = 1.12$, $p = .287$; HDL $t_{(11)} = 1.91$, $p = .082$; LDL $t_{(11)} = 1.42$, $p = .184$; and VLDL $t_{(11)} = 1.30$, $p = .219$; total cholesterol/HDL ratio $t_{(11)} = 1.37$, $p = .198$; triglyceride/HDL Ratio $t_{(11)} = .54$, $p = .603$; LDL/HDL ratio $t_{(11)} = .88$, $p = .397$; and non-HDL/HDL Ratio $t_{(11)} = 1.06$, $p = .311$ did not exhibit significant changes.

Table 3. Descriptive statistics

Variables	Group	Test	N	Mean	SD	% Change
Total Cholesterol (mg/dl)	EG	Pre-test	12	162.50	31.47	-10.87
		Post-test	12	144.83	14.92	
	CG	Pre-test	12	167.33	43.79	11.50
		Post-test	12	186.58	32.55	
Triglyceride (mg/dl)	EG	Pre-test	12	154.08	85.25	-30.83
		Post-test	12	106.58	49.88	
	CG	Pre-test	12	136.42	41.23	11.60
		Post-test	12	152.25	69.59	
HDL (mg/dl)	EG	Pre-test	12	40.92	2.64	6.01
		Post-test	12	43.38	2.92	
	CG	Pre-test	12	40.17	2.62	6.62
		Post-test	12	42.83	5.16	
LDL (mg/dl)	EG	Pre-test	12	90.77	29.37	-3.64
		Post-test	12	87.47	17.56	
	CG	Pre-test	12	99.88	39.96	12.61
		Post-test	12	112.47	31.40	
VLDL(mg/dl)	EG	Pre-test	12	30.82	17.05	-29.36
		Post-test	12	21.77	9.78	
	CG	Pre-test	12	27.28	8.25	13.16
		Post-test	12	30.87	13.51	
Total Cholesterol /HDL Ratio	EG	Pre-test	12	3.63	1.31	-7.71
		Post-test	12	3.35	.38	
	CG	Pre-test	12	3.81	1.54	16.01
		Post-test	12	4.42	1.01	
Triglyceride/ HDL Ratio	EG	Pre-test	12	3.68	1.77	-33.15
		Post-test	12	2.46	1.12	
	CG	Pre-test	12	3.38	.98	5.03
		Post-test	12	3.55	1.54	
LDL/HDL Ratio	EG	Pre-test	12	2.22	.72	-9.01
		Post-test	12	2.02	.39	
	CG	Pre-test	12	2.47	.94	8.50
		Post-test	12	2.68	.95	
Non-HDL/HDL Ratio	EG	Pre-test	12	2.96	.65	-20.61
		Post-test	12	2.35	.38	
	CG	Pre-test	12	3.14	.97	8.92
		Post-test	12	3.42	1.01	

These findings indicate that the intervention had a significant impact on various health markers in the EG, particularly improving lipid profiles (except for LDL). The lack of significant changes in the CG further supports the effectiveness of the intervention. Overall, these results suggest that the intervention played a key role in enhancing important physiological markers, with potential benefits for cardiovascular health.

Table 5 presents independent t-test results comparing pre-and post-test scores between the experimental and control groups for various biochemical variables. In the pre-test, there were no significant differences between the EG and CG for any of the variables. Specifically, total cholesterol $t_{(22)} = .31$, $p = .759$; triglycerides $t_{(22)} = .65$, $p = .525$; HDL $t_{(22)} = .70$, $p = .493$; LDL $t_{(22)} = .64$, $p = .531$; VLDL $t_{(22)} = .65$,

Table 4. A paired t-test compared the pre-test and post-test within the experimental and control groups

Variables	Group	Test	Mean Difference	SD	Std. Error Mean	t	df	Sig. (2-tailed)
Total Cholesterol	EG	Pre-test Post-test	17.67	26.41	7.62	2.32	11	.041*
	CG	Pre-test Post-test	19.25	31.31	9.04	2.13	11	.057
Triglyceride	EG	Pre-test Post-test	47.50	57.49	16.60	2.86	11	.015*
	CG	Pre-test Post-test	15.83	49.05	14.16	1.12	11	.287
HDL	EG	Pre-test Post-test	2.47	3.78	1.09	2.26	11	.045*
	CG	Pre-test Post-test	2.67	4.83	1.39	1.91	11	.082
LDL	EG	Pre-test Post-test	3.30	17.37	5.01	.66	11	.524
	CG	Pre-test Post-test	12.58	30.74	8.88	1.42	11	.184
VLDL	EG	Pre-test Post-test	9.05	11.63	3.36	2.70	11	.021*
	CG	Pre-test Post-test	3.58	9.53	2.75	1.30	11	.219
Total Cholesterol /HDL Ratio	EG	Pre-test Post-test	.28	1.27	.37	.75	11	.469
	CG	Pre-test Post-test	.61	1.53	.44	1.37	11	.198
Triglyceride/HDL Ratio	EG	Pre-test Post-test	1.22	1.14	.33	3.70	11	.003*
	CG	Pre-test Post-test	.17	1.10	.32	.54	11	.603
LDL/HDL Ratio	EG	Pre-test Post-test	.21	.46	.13	1.55	11	.149
	CG	Pre-test Post-test	.22	.86	.25	.88	11	.397
Non-HDL/HDL Ratio	EG	Pre-test Post-test	.60	.55	.16	3.82	11	.003*
	CG	Pre-test Post-test	.28	.90	.26	1.06	11	.311

*Significant at 0.05 level

p = .524; total cholesterol/HDL ratio $t_{(22)} = .31$, p = .757; triglyceride/HDL ratio $t_{(22)} = .51$, p = .616; LDL/HDL ratio $t_{(22)} = .71$, p = .487; and non-HDL/HDL ratio $t_{(22)} = .54$, p = .594, all showed no statistically significant differences between the groups. However, in the post-test, several significant differences were observed in favor of the EG. Total cholesterol $t_{(22)} = 4.04$, p = .001; LDL levels $t_{(22)} = 2.41$, p = .025; total cholesterol/HDL ratio $t_{(22)} = 3.43$, p = .002; LDL/HDL ratio $t_{(22)} = 2.25$, p = .035; non-HDL/HDL ratio $t_{(22)} = 3.43$, p = .002; and showed significant improvements in the EG compared to the CG. Although there were improvements in triglycerides $t_{(22)} = 1.85$, p = .078; VLDL $t_{(22)} = 1.89$, p = .072; triglyceride/HDL ratio $t_{(22)} = 1.98$, p = .060; these changes did not reach statistical significance. Furthermore, no significant differences were found in HDL $t_{(22)} = .32$, p = .751. These findings suggest that the experimental intervention

Table 5. An independent t-test compared pre-test and post-test scores between the experimental and control groups

Variables	Tests	Experimental		Control		t	P-value
		Mean	SD	Mean	SD		
Total Cholesterol	Pre-test	162.50	31.47	167.33	43.79	.31	.759
	Post-test	144.83	14.92	186.58	32.55	4.04	.001*
Triglyceride	Pre-test	154.08	85.25	136.42	41.23	.65	.525
	Post-test	106.58	49.88	152.25	69.59	1.85	.078
HDL	Pre-test	40.92	2.64	40.17	2.62	.70	.493
	Post-test	43.38	2.92	42.83	5.16	.32	.751
LDL	Pre-test	90.77	29.37	99.88	39.96	.64	.531
	Post-test	87.47	17.56	112.47	31.40	2.41	.025*
VLDL	Pre-test	30.82	17.05	27.28	8.25	.65	.524
	Post-test	21.77	9.78	30.87	13.51	1.89	.072
Total Cholesterol /HDL Ratio	Pre-test	3.63	1.31	3.81	1.54	.31	.757
	Post-test	3.35	.38	4.42	1.01	3.43	.002*
Triglyceride/HDL Ratio	Pre-test	3.68	1.77	3.38	.98	.51	.616
	Post-test	2.46	1.12	3.55	1.54	1.98	.060
LDL/HDL Ratio	Pre-test	2.22	.72	2.47	.94	.71	.487
	Post-test	2.02	.39	2.68	.95	2.25	.035*
Non-HDL/HDL Ratio	Pre-test	2.96	.65	3.14	.97	.54	.594
	Post-test	2.35	.38	3.42	1.01	3.43	.002*

*Significant at 0.05 level

contributed to significant improvements in biochemical parameters such as total cholesterol, LDL levels, total cholesterol/HDL ratio, LDL/HDL ratio, and non-HDL/HDL ratio. However, no significant changes were observed in other variables, such as triglycerides, VLDL, HDL, and triglyceride/HDL ratio.

Discussions

The data in Table 4 indicate a significant reduction in total cholesterol following a yogic intervention, particularly in the experimental group, observed at both pre-test and post-test stages. This aligns with previous studies highlighting yogic practices role in managing cholesterol levels. For example, a 12-week yogic practices intervention reduced total cholesterol from 244.86 mg/dL to 219.54 mg/dL (Shantakumari et al., 2013), and another study reported a reduction from 213.1 mg/dL to 193.4 mg/dL (Malarvizhi & Elangovan, 2015). A systematic review of 53 studies involving over 13,000 participants revealed a significant reduction of approximately 10.31 mg/dL in total cholesterol (Ghazvineh et al., 2022). These findings suggest that yogic practices may positively impact cholesterol levels through mechanisms like improved liver function, enhanced hepatic lipase activity (Shantakumari et al., 2013; Shradha & Sisodia, 2010), better insulin sensitivity (Sahay, 2007; Dewangani et al., 2020), stress reduction via lower cortisol levels (Bijlani et al., 2005), and weight management (Cramer et al., 2016; Sun et al., 2022).

Several studies further support the notion that regular yogic practices can effectively reduce triglyceride levels in diverse populations, including college students. A study involving urban boys showed significant improvements in triglyceride levels among those who practiced yogic practices compared to a control group (Vidhya & Rani, 2021). Another study with 50 participants revealed that yogic practices for three months lowered triglyceride levels from an average of 151.88 mg/dL to 130.11 mg/dL (Shantakumari et al., 2013). A systematic review and meta-analysis of 53 studies involving 13,191 participants confirmed that yogic practice interventions significantly reduced triglycerides by an average of 13.50 mg/dL (Ghazvineh et al., 2022). These reductions in triglycerides may be attributed to various physiological benefits of yogic practices, such as enhanced lipoprotein lipase activity, improved liver function, and better insulin sensitivity (Shantakumari et al., 2013; Sahay, 2007; Dewangani et al., 2020). Moreover, yogic practice's stress-reducing properties through decreased cortisol levels also play a role in reducing central obesity and insulin resistance, which further contribute to improved lipid profiles (Bijlani et al., 2005; Shantakumari et al., 2013).

In addition to lowering total cholesterol and triglycerides, the study observed a significant increase in high-density lipoprotein (HDL) levels after 12 weeks of yogic practice interventions. This finding is consistent with previous studies demonstrating the positive impact of yogic practices on lipid profiles. For example, a brief yogic practices intervention has been shown to elevate HDL levels from 42.93 mg/dL to 43.52 mg/dL (P = 0.043), particularly in individuals with lower baseline HDL (Yadav et al., 2014). A 12-week study also found that regular yogic practices practice significantly improved HDL levels, further supporting yogic practices' benefits for lipid metabolism (Pandian et al., 2021). Additionally, yogic practices have been linked to improved HDL levels, contributing to better weight management and cardiovascular health (Oza et al., 2019). Yogic practice's impact on HDL levels may be linked to stress reduction through decreased cortisol levels, as well as stimulation of the endocrine system, which regulates cholesterol metabolism and HDL production (The Indian Express, 2023). Additionally, yogic practice's ability to enhance hepatic and lipoprotein lipase activity helps promote triglyceride uptake by adipose tissue and improve lipoprotein metabolism (Shantakumari et al., 2013; Shradha & Sisodia, 2010), which may also support the reverse cholesterol transport mechanism mediated by HDL, helping remove excess cholesterol from peripheral tissues to the liver (Benisek, 2023).

The reduction in LDL cholesterol levels observed in the current study, from a pre-test mean of 90.77 mg/dL to a post-test mean of 87.47 mg/dL, aligns with previous research indicating that yogic practices can positively influence lipid profiles. Although the reduction was modest and not statistically significant at the 0.05 significance level, it is consistent with other studies. For example, Chowdhury (2018) reported a slight decrease in LDL from 126.46 mg/dL to 124.02 mg/dL, and Babu (2018) found a reduction from 165.33 mg/dL to 159.06 mg/dL in college men. Similarly, Chandrashekhar (2012) observed a decrease from 108.9 mg/dL to 104.1 mg/dL, and Dubey et al. (2014) noted a reduction from 118.9 mg/dL to 115.62 mg/dL. The current study's modest reduction in LDL levels may be attributed to factors such as yogic practices' ability to reduce stress and lower cortisol levels, which are linked to elevated LDL (Kumar et al., 2018; Shahnam et al., 2010). Additionally, yogic practices promote weight loss and fat reduction, which can improve cholesterol balance (Oda, 2018; Upadhyah et al., 2019). Enhanced insulin sensitivity from yogic practices also contributes to improved lipid metabolism and better regulation of LDL cholesterol (Alidu et al., 2023; Gowri et al., 2022).

The present study also found a significant reduction in VLDL levels in the experimental group following yogic practices intervention, while no significant change was observed in the control group. This aligns with existing literature suggesting that yogic practices-based interventions can positively influence VLDL levels (Prasad et al., 2006). The decline in VLDL may be attributed to yogic practices's physiological benefits, including improved metabolic function (Doddoli et al., 2017), enhanced lipid oxidation (Promsrisuk et al., 2023), and better insulin sensitivity (Gowri et al., 2022). Furthermore, yogic practices such as asanas, pranayama, and relaxation techniques have been shown to modulate lipid profiles by reducing stress, enhancing cardiac autonomic function (Cramer et al., 2014), and improving circulation (Pal et al., 2011), all of which contribute to better lipid metabolism and reduced cardiovascular risk factors.

The present study demonstrates significant improvements in lipid profile ratios in the experimental group (EG) following yogic practices, while the control group (CG) exhibited minimal or adverse changes. These findings align with previous studies indicating that yogic practice enhances lipid metabolism and cardiovascular health. Research has shown that regular yogic practice reduces total cholesterol (Shantakumari et al., 2013), triglycerides (Vidhya & Rani, 2021), LDL (Chandrashekhar, 2012), and VLDL (Prasad et al., 2006), while increasing HDL (Yadav et al., 2014), leading to favorable changes in lipid ratios such as Cholesterol/HDL, Triglyceride/HDL, LDL/HDL, and Non-HDL/HDL. These results support the role of yogic practice as a non-invasive intervention for optimizing lipid profiles and reducing cardiovascular risk.

Limitations and future of the study

Despite the promising findings, this study has several limitations that warrant consideration. The relatively small sample size (n = 24) may constrain the statistical power and limit the generalizability of the results. The study population was restricted to male college students from a single institution, which may reduce the applicability of the findings to broader populations, including females and individuals of different age groups, socioeconomic statuses, and educational backgrounds. Additionally, key lifestyle variables such as dietary intake, sleep patterns, and psychological stress—which are known to influence lipid profiles—were not controlled or monitored. The absence of follow-up assessments also precludes conclusions about the long-term sustainability of the observed effects. Future research incorporating larger and more diverse cohorts, with comprehensive control of confounding variables and extended follow-up periods, is recommended to validate and extend these findings.

Strength and Implications

The principal strength of this study lies in the methodological rigor with which the intervention was designed and implemented. The use of a randomized controlled design enhanced internal validity, while the clearly defined 12-week yogic protocol—administered consistently in terms of duration, frequency, and content—ensured the systematic delivery of the intervention. The integration of both biochemical assessments, via automated analyzers, enabled a comprehensive assessment of both physiological and functional outcomes. Furthermore, the application of appropriate statistical procedures, including tests for normality and homogeneity of variance, along with paired and independent samples t-tests, strengthened the reliability and interpretability of the findings.

From a practical standpoint, the study offers valuable implications for health promotion among young adult populations. The significant improvements observed in lipid parameters such as HDL, non-HDL/HDL ratio, and triglyceride indices suggest that yogic practices may serve as an effective, non-pharmacological strategy for improving cardiovascular health. Given the accessibility, cost-effectiveness, and cultural relevance of yogic interventions, the findings support their inclusion in health and wellness initiatives within academic institutions. Moreover, the study contributes to the growing body of evidence advocating for holistic, lifestyle-based approaches to disease prevention and health optimization in emerging adults.

Conclusions

This study found that a twelve-week yogic practice significantly improved several biochemical parameters in the experimental group, with no changes observed in the control group. Notable reductions in total cholesterol, triglycerides, VLDL levels, triglyceride/HDL ratio, and non-HDL/HDL ratio were observed, along with a significant increase in HDL levels. The reductions in low-density lipoprotein (LDL), total cholesterol/HDL ratio, and LDL/HDL ratio did not reach statistical significance; however, they demonstrated an improvement from baseline values. The results suggest that yogic practices are an effective non-pharmacological approach for improving lipid. These practices could be beneficial for managing dyslipidemia, and supporting rehabilitation and fitness programs. Future research should explore long-term effects and optimal intervention duration.

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Author Contributions

AR contributed to the conception, design, data collection, and data analysis. He also prepared the tables and figures, drafted the manuscript, and revised and finalized it for publication. TNP contributed to the conception, design, planning, and supervision of the research. He set the goals, provided substantive supervision, and finalized the manuscript for publication.

Approval and Consent to Participate

This study was approved by the Department of Physical Education and Sports Sciences, University of Delhi, following clearance from the Department Research Committee and the Board of Research Studies (Ref. no. SF-1/Ph. D/2023/1481) Informed consent was obtained from all participants after a detailed briefing on the study's objectives, procedures, and their rights, including voluntary participation and the option to withdraw at any stage.

Data Availability Statement

The authors can provide data upon reasonable request.

Conflicts of Interest

The authors state that there is no potential conflict of interests.

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References

Pirillo, A., Casula, M., Olmastroni, E., Norata, G. D., & Catapano, A. L. (2021). Global epidemiology of dyslipidaemias. *Nature reviews. Cardiology, 18*(10), 689-700. https://doi.org/10.1038/s41569-021-00541-4

Murray, C. J., & Lopez, A. D. (1997). Alternative projections of mortality and disability by cause 1990-2020: Global Burden of Disease Study. *Lancet (London, England), 349*(9064), 1498-1504. https://doi.org/10.1016/S0140-6736(96)07492-2

Joshi, P., Islam, S., Pais, P., Reddy, S., Dorairaj, P., Kazmi, K., Pandey, M. R., Haque, S., Mendis, S., Rangarajan, S., & Yusuf, S. (2007). Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. *JAMA, 297*(3), 286-294. https://doi.org/10.1001/jama.297.3.286

Xavier, D., Pais, P., Devereaux, P. J., Xie, C., Prabhakaran, D., Reddy, K. S., Gupta, R., Joshi, P., Kerkar, P., Thanikachalam, S., Haridas, K. K., Jaison, T. M., Naik, S., Maity, A. K., Yusuf, S., & CREATE registry investigators (2008). Treatment and outcomes of acute coronary syndromes in India (CREATE): a prospective analysis of registry data. *Lancet (London, England), 371*(9622), 1435–1442. https://doi.org/10.1016/S0140-6736(08)60623-6

Sharma, K., Basu-Ray, I., Sayal, N., Vora, A., Bammidi, S., Tyagi, R., Modgil, S., Bali, P., Kaur, P., Goyal, A. K., Pal, D. K., Arvind, H., Jindal, K., Garg, V., Matyal, B., Thakur, N., Chhikara, A., Kaur, N., Maanju, P.,…Anand, A. (2022). Yoga as a preventive intervention for cardiovascular diseases and associated comorbidities: Open-label single-arm study. *Frontiers in Public Health,* 10, 843134. https://doi.org/10.3389/fpubh.2022.843134

Harikrishnan, S., Leeder, S., Huffman, M., Jeemon, P., & Prabhakaran, D. A. (2014). *Race against time: The challenge of cardiovascular disease in developing economies* (2nd ed.). New Delhi, India: New Delhi Centre for Chronic Disease Control.

Ali, N., Kathak, R. R., Fariha, K. A., Taher, A., & Islam, F. (2023). Prevalence of dyslipidemia and its associated factors among university academic staff and students in Bangladesh. *BMC Cardiovascular Disorders,* 23, 366. https://doi.org/10.1186/s12872-023-03399-1

Bamba, V., & Rader, D. J. (2007). Obesity and atherogenic dyslipidemia. *Gastroenterology, 132*(6), 2181-2190. https://doi.org/10.1053/j.gastro.2007.03.056

Taye, A. G., Mola, D. W., & Rahman, M. H. (2024). Analyzing the nutritional awareness, dietary practices, attitudes, and performance of U-17 football players in Ethiopia. *Physical Education Theory and Methodology, 24*(1), 110-117. https://doi.org/10.17309/tmfv.2024.1.14

Pikula, A., Beiser, A. S., Wang, J., Himali, J. J., Kelly-Hayes, M., Kase, C. S., Yang, Q., Seshadri, S., & Wolf, P. A. (2015). Lipid and lipoprotein measurements and the risk of ischemic vascular events: Framingham Study. *Neurology, 84*(5), 472-479. https://doi.org/10.1212/WNL.0000000000001202

Huff, T., Boyd, B., & Jialal, I. (2023). *Physiology, cholesterol. In StatPearls.* StatPearls Publishing. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK470561/

Duan, Y., Gong, K., Xu, S., Zhang, F., Meng, X., & Han, J. (2022). Regulation of cholesterol homeostasis in health and diseases: From mechanisms to targeted therapeutics. *Signal Transduction and Targeted Therapy,* 7, 265. https://doi.org/10.1038/s41392-022-01125-5

WHO. (2019). *Indicator metadata registry details. World Health Organization (WHO)*. Retrieved February 3, 2025, from https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3236

Ghazvineh, D., Daneshvar, M., Basirat, V., & Daneshzad, E. (2022). The effect of yoga on the lipid profile: A systematic review and meta-analysis of randomized clinical trials. *Frontiers in Nutrition,* 9, 942702. https://doi.org/10.3389/fnut.2022.942702

Laufs, U., Parhofer, K. G., Ginsberg, H. N., & Hegele, R. A. (2020). Clinical review on triglycerides. *European heart journal, 41*(1), 99-109. https://doi.org/10.1093/eurheartj/ehz785

Zhang, B.-H., Yin, F., Qiao, Y.-N., & Guo, S.-D. (2022). Triglyceride and triglyceride-rich lipoproteins in atherosclerosis. *Frontiers in Molecular Biosciences,* 9, 909151. https://doi.org/10.3389/fmolb.2022.909151

Parhofer, K. G., & Laufs, U. (2019). The diagnosis and treatment of hypertriglyceridemia. *Deutsches Ärzteblatt International, 116*(49), 825-832. https://doi.org/10.3238/arztebl.2019.0825

Shrirang, H., & Surinder, M. (2015). Alteration in Lipid Profile Before and After Yogic Exercises in Patients of Type II Diabetes. *International Journal of Health Sciences and Research, 5*(6), 286-290.

Bailey, A., & Mohiuddin, S. S. (2022). *Biochemistry, high-density lipoprotein.* In StatPearls (Updated September 26, 2022). StatPearls Publishing. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK549802/

Chiesa, S. T., & Charakida, M. (2019). High-Density Lipoprotein Function and Dysfunction in Health and Disease. *Cardiovascular drugs and therapy, 33*(2), 207-219. https://doi.org/10.1007/s10557-018-06846-w

Zhou, L., Li, C., Gao, L., & Wang, A. (2015). High-density lipoprotein synthesis and metabolism (Review). *Molecular medicine reports, 12*(3), 4015-4021. https://doi.org/10.3892/mmr.2015.3930

Kosmas, C. E., Martinez, I., Sourlas, A., Bouza, K. V., Campos, F. N., Torres, V., Montan, P. D., & Guzman, E. (2018). High-density lipoprotein (HDL) functionality and its relevance to atherosclerotic cardiovascular disease. *Drugs in context,* 7, 212525. https://doi.org/10.7573/dic.212525

Liu, Y., Liu, F., Zhang, L., Li, J., Kang, W., Cao, M., Song, F., & Song, F. (2021). Association between low-density lipoprotein cholesterol and all-cause mortality: Results from the NHANES 1999–2014. *Scientific Reports,* 11, 22111. https://doi.org/10.1038/s41598-021-01738-w

Borén, J., Chapman, M. J., Krauss, R. M., Packard, C. J., Bentzon, J. F., Binder, C. J., Daemen, M. J., Demer, L. L., Hegele, R. A., Nicholls, S. J., Nordestgaard, B. G., Watts, G. F., Bruckert, E., Fazio, S., Ference, B. A., Graham, I., Horton, J. D., Landmesser, U., Laufs, U.,…Ginsberg, H. N. (2020). Low-density lipoproteins cause atherosclerotic cardiovascular disease: Pathophysiological, genetic, and therapeutic insights: A consensus statement from the European Atherosclerosis Society Consensus Panel. *European Heart Journal, 41*(24), 2313-2330. https://doi.org/10.1093/eurheartj/ehz962

Venugopal, S. K., Anoruo, M. D., & Jialal, I. (2023). *Biochemistry, low-density lipoprotein.* In StatPearls. StatPearls Publishing. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK500010/

Virani, S. S., Aspry, K., Dixon, D. L., Ferdinand, K. C., Heidenreich, P. A., Jackson, E. J., Jacobson, T. A., McAlister, J. L., Neff, D. R., Gulati, M., & Ballantyne, C. M. (2023). The importance of low-density lipoprotein cholesterol measurement and control as performance measures: A joint clinical perspective from the National Lipid Association and the American Society for Preventive Cardiology. *American journal of preventive cardiology,* 13, 100472. https://doi.org/10.1016/j.ajpc.2023.100472

Huang, J. K., & Lee, H. C. (2022). Emerging Evidence of Pathological Roles of Very-Low-Density Lipoprotein (VLDL). *International journal of molecular sciences, 23*(8), 4300. https://doi.org/10.3390/ijms23084300

Lee, H.-C., Akhmedov, A., & Chen, C.-H. (2022). Spotlight on very-low-density lipoprotein as a driver of cardiometabolic disorders: Implications for disease progression and mechanistic insights. *Frontiers in Cardiovascular Medicine,* 9, 993633. https://doi.org/10.3389/fcvm.2022.993633

Phillips, C. M., & Perry, I. J. (2015). Lipoprotein particle subclass profiles among metabolically healthy and unhealthy obese and non-obese adults: does size matter?. *Atherosclerosis, 242*(2), 399-406. https://doi.org/10.1016/j.atherosclerosis.2015.07.040

Magnifico, M. C., Oberkersch, R. E., Mollo, A., Giambelli, L., Grooten, Y., Sarti, P., Calabrese, G. C., & Arese, M. (2017). VLDL Induced Modulation of Nitric Oxide Signalling and Cell Redox Homeostasis in HUVEC. *Oxidative medicine and cellular longevity,* 2017, 2697364. https://doi.org/10.1155/2017/2697364

Tsai, Y. Y., Rainey, W. E., & Bollag, W. B. (2017). Very low-density lipoprotein (VLDL)-induced signals mediating aldosterone production. *The Journal of endocrinology, 232*(2), R115-R129. https://doi.org/10.1530/JOE-16-0237

Millán, J., Pintó, X., Muñoz, A., Zúñiga, M., Rubiés-Prat, J., Pallardo, L. F., Masana, L., Mangas, A., Hernández-Mijares, A., González-Santos, P., Ascaso, J. F., & Pedro-Botet, J. (2009). Lipoprotein ratios: Physiological significance and clinical usefulness in cardiovascular prevention. *Vascular health and risk management,* 5, 757-765.

Calling, S., Johansson, S. E., Wolff, M., Sundquist, J., & Sundquist, K. (2019). The ratio of total cholesterol to high-density lipoprotein cholesterol and myocardial infarction in Women's Health in the Lund Area (WHILA): A 17-year follow-up cohort study. *BMC Cardiovascular Disorders,* 19, 239. https://doi.org/10.1186/s12872-019-1228-7

Lemieux, I., Lamarche, B., Couillard, C., Pascot, A., Cantin, B., Bergeron, J., Dagenais, G. R., & Després, J.-P. (2001). Total cholesterol/HDL cholesterol ratio vs LDL cholesterol/HDL cholesterol ratio as indices of ischemic heart disease risk in men: The Quebec Cardiovascular Study. *Archives of Internal Medicine, 161*(22), 2685-2692. https://doi.org/10.1001/archinte.161.22.2685

Yu, D., Cai, Y., Qin, R., Graffy, J., Holman, D., Zhao, Z., & Simmons, D. (2018). Total/high-density lipoprotein cholesterol and cardiovascular disease (re)hospitalization nadir in type 2 diabetes. *Journal of Lipid Research, 59*(9), 1745-1750. https://doi.org/10.1194/jlr.P084269

Abera, A., Worede, A., Hirigo, A. T., Alemayehu, R., & Ambachew, S. (2024). Dyslipidemia and associated factors among adult cardiac patients: A hospital-based comparative cross-sectional study. *European Journal of Medical Research,* 29, 237. https://doi.org/10.1186/s40001-024-01802-x

Murguía-Romero, M., Jiménez-Flores, J. R., Sigrist-Flores, S. C., Espinoza-Camacho, M. A., Jiménez-Morales, M., Piña, E., Méndez-Cruz, A. R., Villalobos-Molina, R., & Reaven, G. M. (2013). Plasma triglyceride/HDL-cholesterol ratio, insulin resistance, and cardiometabolic risk in young adults. *Journal of lipid research, 54*(10), 2795-2799. https://doi.org/10.1194/jlr.M040584

Chauhan, A., Singhal, A., & Goyal, P. (2021). TG/HDL Ratio: A marker for insulin resistance and atherosclerosis in prediabetics or not?. *Journal of family medicine and primary care, 10*(10), 3700-3705. https://doi.org/10.4103/jfmpc.jfmpc_165_21

Hermans, M. P., Ahn, S. A., & Rousseau, M. F. (2012). The atherogenic dyslipidemia ratio [log(TG)/HDL-C] is associated with residual vascular risk, beta-cell function loss, and microangiopathy in type 2 diabetes females. *Lipids in Health and Disease,* 11, 132. https://doi.org/10.1186/1476-511X-11-132

Kosmas, C. E., Rodriguez Polanco, S., Bousvarou, M. D., Papakonstantinou, E. J., Peña Genao, E., Guzman, E., & Kostara, C. E. (2023). The Triglyceride/High-Density Lipoprotein Cholesterol (TG/HDL-C) Ratio as a Risk Marker for Metabolic Syndrome and Cardiovascular Disease. *Diagnostics (Basel, Switzerland), 13*(5), 929. https://doi.org/10.3390/diagnostics13050929

Li, Y., Shi, H., Liang, C., Xie, Q., Hu, H., Wang, H., & Li, P. (2024). The relationship between triglyceride to high-density lipoprotein cholesterol ratio and cardiovascular high-risk: A cross-sectional investigation. *medRxiv.* https://doi.org/10.1101/2024.05.08.24307048

Vaduganathan, M., Mensah, G. A., Turco, J. V., Fuster, V., & Roth, G. A. (2022). The Global Burden of Cardiovascular Diseases and Risk: A Compass for Future Health. *Journal of the American College of Cardiology, 80*(25), 2361-2371. https://doi.org/10.1016/j.jacc.2022.11.005

Ghodeshwar, G. K., Dube, A., & Khobragade, D. (2023). Impact of Lifestyle Modifications on Cardiovascular Health: A Narrative Review. *Cureus, 15*(7), e42616. https://doi.org/10.7759/cureus.42616

Tamada, M., Makita, S., Abiko, A., Naganuma, Y., Nagai, M., & Nakamura, M. (2010). Low-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio as a useful marker for early-stage carotid atherosclerosis. *Metabolism: clinical and experimental, 59*(5), 653-657. https://doi.org/10.1016/j.metabol.2009.09.009

Sun, T., Chen, M., Shen, H., PingYin, Fan, L., Chen, X., Wu, J., Xu, Z., & Zhang, J. (2022a). Predictive value of LDL/HDL ratio in coronary atherosclerotic heart disease. *BMC cardiovascular disorders, 22*(1), 273. https://doi.org/10.1186/s12872-022-02706-6

Packard, C. J., & Saito, Y. (2004). Non-HDL cholesterol as a measure of atherosclerotic risk. *Journal of atherosclerosis and thrombosis, 11*(1), 6-14. https://doi.org/10.5551/jat.11.6

Virani S. S. (2011). Non-HDL cholesterol as a metric of good quality of care: opportunities and challenges. *Texas Heart Institute journal, 38*(2), 160-162.

Reddy, S., Rao, R. K., Kashyap, J. R., Kadiyala, V., Kumar, S., Dash, D., Uppal, L., Kaur, J., Kaur, M., Reddy, H., Rather, I. I. G., & Malhotra, S. (2024). Association of non-HDL cholesterol with plaque burden and composition of culprit lesion in acute coronary syndrome: An intravascular ultrasound-virtual histology study. *Indian Heart Journal, 76*(5), 342–348. https://doi.org/10.1016/j.ihj.2024.10.004

Yadav, R., Khapre, M., D, D., & M, A. (2024). Prevalence of Unhealthy Lifestyles and Its Correlates Among College-Going Students in Rishikesh, India: A Cross-Sectional Study. *Cureus, 16*(7), e64713. https://doi.org/10.7759/cureus.64713

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. *Korean journal of family medicine, 41*(6), 365–373. https://doi.org/10.4082/kjfm.20.0165

Fadillah, A. N., Maulang, I., & Hardiyanty, N. (2021).The correlation between sedentary lifestyle and physical fitness level in adolescents. *Enfermería Clínica, 31*(Suppl. 5), S668–S671. https://doi.org/10.1016/j.enfcli.2021.07.015

Verdú, E., Homs, J., & Boadas-Vaello, P. (2021). Physiological Changes and Pathological Pain Associated with Sedentary Lifestyle-Induced Body Systems Fat Accumulation and Their Modulation by Physical Exercise. *International Journal of Environmental Research and Public Health, 18*(24), 13333. https://doi.org/10.3390/ijerph182413333

Kumar, K., Singh, V., kumar, D., Asthana, A. B., & Mishra, D. (2018). Effect of yoga and meditation on serum cortisol level in first-year medical students. *International Journal of Research in Medical Sciences, 6*(5), 1699-1703. https://doi.org/10.18203/2320-6012.ijrms20181762

Shahnam, M., Roohafza, H., Sadeghi, M., Bahonar, A., & Sarrafzadegan, N. (2010). The correlation between lipid profile and stress levels in central iran: isfahan healthy heart program. *ARYA atherosclerosis, 6*(3), 102-106.

Pandian, T., Paulraj, S., & Senthilkumar, K. (2021). Changes on high-density lipoprotein and low-density lipoprotein due to yogic practices among middle-aged hypertensive men. *International Journal of Physiology, Nutrition and Physical Education, 6*(2), 340-341.

Chakraborty, A., & Singh, N. A. (2024). Analysis of the differences in body composition and physiological profiles of professional female sub-junior soccer players of Manipur: An observational study. *Indian Journal of Physiology and Allied Sciences, 76*(1), 40-45. https://doi.org/10.55184/ijpas.v76i01.214

Kang, H. (2021). Sample size determination and power analysis using the G*Power software. *Journal of Educational Evaluation for Health Professions,* 18, 17. https://doi.org/10.3352/jeehp.2021.18.17

Rahaman, A., & Pramanik, N. T. (2025). Yogic practices for modulating hematological indices and inflammatory markers: A non-pharmacological approach. *International Journal of Kinesiology and Sports Science, 13*(2), 101-114. https://doi.org/10.7575/aiac.ijkss.v.13n.2p.101

Govindasamy, K., Kaur, D., Elayaraja, M., Sethi, D., Kalidas, S., Karmakar, D., Orhan, B. E., Astuti, Y., & Parpa, K. (2024). Immediate Effect of Uddiyana Bandha on Heart Rate Variability in Patients with Hypertension: A Randomised Controlled Study. *Annals of neurosciences,* 09727531241299258. Advance online publication. https://doi.org/10.1177/09727531241299258

Rahaman, A., Pramanik, T. N., Rahman, M. H., Shukla, A., Nikita, Kurnaz, M., Monterrosa-Quintero, A., & Konar, N. (2025). Yogic Practices and Their Influence on Hematological Responses: A Physiological Perspective. *Physical Education Theory and Methodology, 25*(5), 1223-1236. https://doi.org/10.17309/tmfv.2025.5.2

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*(3-4), 591–611. https://doi.org/10.1093/biomet/52.3-4.591

Shantakumari, N., Sequeira, S., & El deeb, R. (2013). Effects of a yoga intervention on lipid profiles of diabetes patients with dyslipidemia. *Indian heart journal, 65*(2), 127-131. https://doi.org/10.1016/j.ihj.2013.02.010

Malarvizhi, V., & Elangovan, R. (2015). Effects of yogic practices on total cholesterol and triglyceride among obese women. *Yoga Mimamsa, 47*(1-2), 10-14. https://doi.org/10.4103/0044-0507.195459

Shradha, B., & Sisodia, S. S. (2010). Diabetes, dyslipidemia, antioxidant and status of oxidative stress. *International Journal of Research in Ayurveda and Pharmacy (IJRAP), 1*(1), 33-42.

Sahay B. K. (2007). Role of yoga in diabetes. *The Journal of the Association of Physicians of India,* 55, 121–126.

Dewangani, H. N., Jayawardena, B., & Wijayagunarathne, H. S. (2020). Yoga-based lifestyle intervention for prevention and management of type 2 diabetes mellitus and associated complications: A clinical research review. *Indian Journal of Medical Biochemistry, 24*(3), 125-129. https://doi.org/10.5005/jp-journals-10054-0165

Bijlani, R. L., Vempati, R. P., & Yadav, R. K. (2005). A brief but comprehensive lifestyle education program based on yoga reduces risk factors for cardiovascular disease and diabetes mellitus. *Journal of Alternative and Complementary Medicine, 11*(2), 267–274. https://doi.org/10.1089/acm.2005.11.267

Cramer, H., Thoms, M. S., Anheyer, D., Lauche, R., & Dobos, G. (2016). Yoga in women with abdominal obesity – a randomized controlled trial. *Deutsches Arzteblatt international, 113*(39), 645-652. https://doi.org/10.3238/arztebl.2016.0645

Sun, J., Zhang, Z., Liu, Z., Li, J., & Kang, W. (2022). The correlation of total percent fat with alterations in cholesterol and triglycerides in adults. *Frontiers in nutrition,* 9, 881729. https://doi.org/10.3389/fnut.2022.881729

Vidhya, A., & Rani, K. U. (2021). Effect of yogic practices and physical exercises training on triglycerides of urban obese boy's student. *Psychology and Education Journal, 58*(1), 3161-3164. https://doi.org/10.17762/pae.v58i1.1221

Yadav, R. K., Magan, D., Yadav, R., Sarvottam, K., & Netam, R. (2014). High-density lipoprotein cholesterol increases following a short-term yoga-based lifestyle intervention: a non-pharmacological modulation. *Acta cardiologica, 69*(5), 543-549. https://doi.org/10.1080/ac.69.5.3044881

Oza, D. N., Vadsaria, N., Patel, T. A., & Verma, R. J. (2019). Study of therapeutic role of yoga (Hathyoga) on lipid profile in dyslipidemic individuals of Ahmedabad city. *Indian Journal of Traditional Knowledge, 18*(2), 333-338.

The Indian Express. (2023). *Binge-watching a show? Try these yoga asanas to 'stay fitter and healthier'.* Retrieved September 8, 2024, from https://indianexpress.com/article/lifestyle/fitness/binge-watching-show-try-these-yoga-asanas-to-stay-fitter-and-healthier-anshuka-parwani-7977442/

Benisek, A. (2023). *Yoga and cholesterol.* WebMD. Retrieved September 8, 2024, from https://www.webmd.com/cholesterol-management/features/yoga-and-cholesterol

Chowdhary, B. (2018). Effect of six months practice of suryanamaskar and selected asanas on lipid profile of jangalmahal female tribal students. *Global Journal for Research Analysis, 7*(4), 82-84.

Babu, K. J. (2018). Effect of yogic practices on selected hematological variables and lipid profile among obese college men. *International Journal of Physical Education, Sports and Health, 5*(6), 81-84.

Chandrashekhar, K. (2012). Effect of six weeks yogasana training on hematological parameters and lipid profile. National Journal of Basic Medical Sciences, 3(2), 119-122.

Dubey, N., Kumar, S., Khare, R., & Mishra, S. S. (2014). Effect of yogic exercise on lipid profile of patients of diabetes mellitus type II and its correlation with addiction and family history. *International Journal of Health Sciences & Research, 4*(9), 135-141.

Oda E. (2018). LDL cholesterol was more strongly associated with percent body fat than body mass index and waist circumference in a health screening population. *Obesity research & clinical practice, 12*(2), 195-203. https://doi.org/10.1016/j.orcp.2017.05.005

Upadhyah, A., P. Pandit, D., Goyal, P., & Sharma, D. (2019). Effect of short term yoga on body weight, BMI, body fat percentage & blood pressure. *Indian Journal of Clinical Anatomy and Physiology, 6*(2), 179-182. https://doi.org/10.18231/j.ijcap.2019.040

Alidu, H., Dapare, P. P. M., Quaye, L., Amidu, N., Bani, S. B., & Banyeh, M. (2023). Insulin Resistance in relation to Hypertension and Dyslipidaemia among Men Clinically Diagnosed with Type 2 Diabetes. *BioMed research international,* 2023, 8873226. https://doi.org/10.1155/2023/8873226

Gowri, M., Rajendran, J., Srinivasan, A. R., Bhavanani, A. B., & Meena, R. (2022). Impact of an Integrated Yoga Therapy Protocol on Insulin Resistance and Glycemic Control in Patients with Type 2 Diabetes Mellitus. *Rambam Maimonides medical journal, 13*(1), e0005. https://doi.org/10.5041/RMMJ.10462

Prasad, K. V. V., Sunita, M., Sitarama Raju, P., Venkata Reddy, M., Sahay, B. K., & Murthy, K. J. R. (2006). Impact of pranayama and yoga on lipid profile in normal healthy volunteers. *Journal of Exercise Physiology, 9*(1), 1-6.

Doddoli, S., Shete, S., Kulkarni, D., & Bhogal, R. (2017). Effect of yoga training on lipid metabolism in industrial workers with reference to body constitution (Prakriti). *Journal of Traditional and Complementary Medicine, 7*(3), 322-326. https://doi.org/10.1016/j.jtcme.2016.08.001

Promsrisuk, T., Kongsui, R., Sriraksa, N., Boonla, O., & Srithawong, A. (2023). Elastic band resistance combined with modified Thai yoga exercise to alleviate oxidative stress and airway inflammation in type 2 diabetes mellitus. *Journal of Exercise Rehabilitation, 19*(2), 114-125. https://doi.org/10.12965/jer.2346040.020

Cramer, H., Lauche, R., Haller, H., Steckhan, N., Michalsen, A., & Dobos, G. (2014). Effects of yoga on cardiovascular disease risk factors: a systematic review and meta-analysis. *International journal of cardiology, 173*(2), 170-183. https://doi.org/10.1016/j.ijcard.2014.02.017

Pal, A., Srivastava, N., Tiwari, S., Verma, N. S., Narain, V. S., Agrawal, G. G., Natu, S. M., & Kumar, K. (2011). Effect of yogic practices on lipid profile and body fat composition in patients of coronary artery disease. *Complementary therapies in medicine, 19*(3), 122-127. https://doi.org/10.1016/j.ctim.2011.05.001

Використання йогічної інтервенції знижує рівень ліпідів у сироватці крові та коефіцієнти атерогенності: Комплексне дослідження

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 табл., 2 рис., 87 джерел.

Історія питання. Оптимальна регуляція ліпідів є ключовим визначальним чинником здоров'я серцево-судинної системи. Порушення ліпідного обміну пов'язані з підвищеним ризиком розвитку серцево-судинних захворювань. Йогічні практики демонструють потенціал у модулюванні біохімічних та серцево-судинних параметрів.

Мета дослідження. Метою представленого дослідження було вивчення впливу дванадцятитижневої структуризованої інтервенції з йогічної практики на окремі параметри ліпідного профілю, а саме: загальний холестерин, тригліцериди, ліпопротеїни високої щільності (ЛПВЩ), ліпопротеїни низької щільності (ЛПНЩ), ліпопротеїни дуже низької щільності (ЛПДНЩ), співвідношення холестерин/ЛПВЩ, співвідношення тригліцериди/ЛПВЩ, співвідношення ЛПНЩ/ЛПВЩ та співвідношення не-ЛПВЩ/ЛПВЩ серед студентів чоловічої статі.

Матеріали та методи. Двадцять чотири студенти (віком 17–22 роки) з Державного інституту підготовки вчителів початкової школи в Ш'ямпахарі, Індія, було розподілено за методом рандомізації на експериментальну ($n = 12$) та контрольну ($n = 12$) групи. Учасники експериментальної групи практикували йогу протягом 1 години на день, 6 днів на тиждень, впродовж 12 тижнів, тоді як учасники контрольної групи продовжували займатися стандартними видами діяльності. Зразки венозної крові було зібрано на перед- та постінтервенційному етапах дослідження і проаналізовано за допомогою автоматичного біохімічного аналізатора. Внутрішньогрупові відмінності оцінювали із застосуванням t-критеріїв для парних вибірок, а міжгрупові порівняння — за допомогою t-критеріїв для незалежних вибірок. Статистичну значущість встановлено на рівні $\alpha = 0.05$.

Результати. Експериментальна група показала істотне зниження рівня загального холестерину ($p = .041$), тригліцеридів ($p = .015$), ЛПДНЩ ($p = .021$), співвідношення тригліцеридів/ЛПВЩ ($p = .003$) та співвідношення не-ЛПВЩ/ЛПВЩ ($p = .003$), а також підвищення рівня ЛПВЩ ($p = .045$). Водночас рівень ЛПНЩ ($p = .524$), співвідношення ЛПНЩ/ЛПВЩ ($p = .149$) та співвідношення холестерину/ЛПВЩ ($p = .469$) не зазнали змін. У контрольній групі значних змін не спостерігалося.

Висновки. Результати дослідження свідчать, що структурована програма йоги сприяє покращенню ліпідного обміну і продуктивності серцево-судинної системи, підтверджуючи доцільність застосування йоги як ефективної нефармакологічної інтервенції для молодого дорослого населення.

Ключові слова: йога, ліпіди, серцево-судинні захворювання, холестерин, тригліцериди, ліпопротеїни.

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Original Scientific Article

The Effects of an ad Hoc Stability Training Protocol on Improving Balance in Young Volleyball Players

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Abstract

Objectives. This study aimed to evaluate the effectiveness of a customized training regimen in enhancing balance among young volleyball athletes.

Materials and Methods. A total of 48 athletes (aged 14-16) from four volleyball teams participated, divided into Experimental (EG) and Control Groups (CG). Over six months, the EG adhered to a specialized protocol integrating balance exercises into warm-ups and post-training sessions, encompassing both static and dynamic exercises, while the CG followed a standard program. Balance assessments were conducted using the Leonardo Platform, with tests administered before and after implementing the protocol. Statistical analysis involved paired-samples and independent-samples T-tests to compare within-group changes and between-group differences.

Results. The results obtained revealed significant improvements in the EG, particularly evident in the TanEC test ($p = .00001$), indicating enhanced stability without visual reference. Marked advancements were also noted in single-limb stability tests (1L_EO, $p = .0018$; 1L_EC, $p = .0258$). Conversely, the TanEO test showed no substantial group differences ($p = .107$), suggesting minimal impact on stability under visual conditions.

Conclusions. These findings underscore the efficacy of tailored balance training in enhancing postural stability, motor coordination, and control among young volleyball players, advocating for the integration of targeted exercises in athletic training programs to optimize performance outcomes.

Keywords: motor control, performance, postural testing.

Introduction

Volleyball is a team sport that requires a high combination of technical skill, physical ability and speed. This discipline is based on fundamentals such as dribbling, hitting, walling, serving and receiving, which must be performed with precision and as much coordination as possible (Raiola et al, 2025; D'Elia et al, 2021). Every technical gesture requires a high degree of body control, which is also the result of maximum balance (Altavilla et al., 2022). Volleyball is also a sport that demands excellent reaction skills due to the sudden changes in game situations (Liu, 2022). Therefore, balance is essential to ensure stability during the dynamic movements and sudden shifts required in volleyball (Fuchs et al., 2020). It is divided into static balance, which is necessary to maintain a stable posture in waiting situations, and dynamic balance, which is indispensable for handling changes of direction, landings from take-offs and rapid transitions between phases of play (Pau et al., 2012). This capacity is regulated by the integration of the vestibular, proprioceptive and visual systems, which work in synergy to maintain postural stability and motor efficiency (Esposito et al., 2021). Volleyball is a sport that requires a high level of coordination, as players have to manage ball possession in highly dynamic conditions and often in positions that are not optimal for balance (Hammami et al., 2021). A particularly relevant aspect is the ability to maintain a stable waiting posture, characterised by a posture with flexed and spread legs, accompanied by a forward tilt of the torso, which allows responsiveness and freedom of movement in any direction (Esposito et al., 2024). During the phases of the game in which athletes are in contact with the ground, the control of postural stability and the management of body oscillations are essential to ensure precision of movement and speed of reaction. The ability to constantly adapt posture to different game situations is a key factor in optimising performance and maintaining effective motor readiness (Borzucka et al., 2020). Several studies have shown that good balance control can improve the quality of technical gestures and reduce the risk of injury, particularly when landing from a jump or in high-intensity game situations (Gerberich et al., 1987; Cuñado-González et al., 2019; D'Isanto et al; 2024). Therefore, comprehensive training involving the improvement of these motor qualities is suggested to raise balance levels. However, while strength, speed and endurance training are well-established aspects of athletic preparation programmes, the integration of specific balance protocols in the preparation of volleyball players is still a matter of debate. For this reason, there is a need to measure what effects specific (ad hoc) training protocols for postural stability, motor co-ordination and motor control have on balance. Scientific evidence on the connection of specific training protocols on postural stability, motor co-ordination and motor control underline the importance of further investigation of the effects on balance, highlighting the need for further investigation of a specific protocol.

Purpose of the research – The aim of the study is to measure the effect of an ad hoc training protocol to improve balance in young volleyball athletes.

Materials and Methods

Study Participants

A total of 48 volleyball athletes (24 females, 24 males; age range: 14–16 years) were recruited from four youth teams belonging to local volleyball clubs affiliated with the Albanian Volleyball Federation. Recruitment occurred through voluntary participation after coaches received an official invitation letter describing the aims and procedures of the study.

Inclusion criteria were continuous participation in structured volleyball training for at least two years; absence of musculoskeletal injuries in the previous six months; regular attendance (>90%) during the training season; parental consent for underage athletes.

Exclusion criteria included neurological, vestibular, or postural disorders; participation in additional proprioceptive or balance training programs; failure to complete the post-test evaluation. Participants were divided into two groups using a cluster allocation design based on team membership to preserve the ecological context of training and minimize contamination between programs. Two teams (Superior Female and Partizani 1 Male) formed the Experimental Group (EG), while two other teams (Dinamo Female and Partizani 2 Male) served as the Control Group (CG), which continued their usual training routines.

The a priori primary endpoint was the between-group difference in the pre-to-post change (Δ) on the TanEC test. We therefore based the sample size on a two-tailed independent-samples t-test ($\alpha = .05$, power = .80). Assuming a minimally important between-group effect of Cohen's d = 0.80 (large, in line with previous proprioceptive/balance protocols in youth athletes), the required sample was n = 50 (25 per group). We enrolled n = 48 (24 per group), which is within 4% of the target and provides adequate power for effects of this magnitude. In sensitivity terms, with N = 48 the study is powered at 80% to detect $d \geq 0.81$ for the primary contrast.

Because allocation occurred by team (cluster allocation), we also report a design-effect sensitivity: assuming an intra-cluster correlation ICC = 0.05 and cluster size m = 12, the design effect is $DEFF = 1 + (m-1)\cdot ICC = 1.55$, yielding an effective per-arm size of ≈15.5. Under this conservative scenario, the 80% power threshold corresponds to $d \approx 1.03$ for the primary Δ comparison. We acknowledge this as a limitation and, accordingly, report cluster-robust inferences in the re-analysis.

Study Protocol

The experimental protocol was implemented over 24 weeks, integrated within the athletes' regular training schedule (three sessions per week, each lasting 90 minutes). Balance and postural exercises were added at the beginning (warm-up phase, 15 min) and at the end (cool-down phase, 15 min) of each training session. The control group continued its standard volleyball training program without additional exercises.

The protocol was structured into three progressive phases, each lasting eight weeks, following the principles of progressive overload and specificity. Each session included a warm-up with static and dynamic balance drills, and a cool-down focusing on postural alignment and core stabilization.

Compliance was monitored by the team coaches and verified weekly by the research team. Athletes who completed at least 85% of sessions were included in the post-test analysis.

You can observe the schedule in Table 1.

The intervention was designed as a 24-week stability and postural training program, implemented within the athletes' regular volleyball sessions. Training was performed three times per week, with each session lasting approximately 90 minutes. The experimental group (EG) integrated the stability protocol into two specific segments of their usual training:

(a) the warm-up phase (15 minutes) devoted to balance and proprioceptive exercises, and

(b) the cool-down phase (15 minutes) focused on postural correction and trunk stabilization.

The control group (CG) continued their conventional volleyball training without any modification.

The experimental protocol was developed to progressively improve static balance, dynamic control, and postural alignment, following the principles of specificity, progressive overload, and motor variability. Exercises were selected according to their relevance for volleyball performance—particularly movements involving landing, change of direction, and single-leg stability. The program was divided into three progressive phases of increasing complexity (Table 2).

Table 1. Weekly microcycle and progressive structure of the experimental balance training protocol integrated into regular volleyball practice

Phase	Weeks	Exercises included	Sets × Reps / Duration	Intensity & Progression	Rest intervals	Objective
Phase 1 – Balance foundation & stability	1-6	• One-legged balance (EO/EC) • Tandem stance (EO/EC) • Dynamic balance in motion without ball • General muscle stability exercises (plank, bridge, bird-dog)	3 × 20–30 s or 3 × 8–10 reps	Begin on stable surface; progress to EC; slow controlled time	30 s between drills	Develop static balance and proprioceptive awareness
Phase 2 – Dynamic control & coordination	7-18	• One-legged balance with jump and landing (EO/EC) • Balance exercises in motion with ball (passes, catches, dribbles) • Postural balancing exercises (front/side plank, pelvic control) • Corrective exercises for postural alignment	3 × 10–12 reps or 3 × 20 s	Introduce unstable surfaces (foam, BOSU); increase jump height; progress EC frequency	45 – 60 s	Improve dynamic balance and neuromuscular control
Phase 3 – Postural integration & chest strengthening	19-24	• Balance with direction changes and external perturbation (coach-induced) • Corrective balance exercises combining motion + single-leg support • Chest and scapular strengthening (push-up, theraband rows, wall slides) • Combined proprioceptive tasks with ball	3 × 6–8 reps or 3 × 20–25 s	Increased instability and task complexity; perturbations added progressively	60 – 90 s	Integrate balance and posture control in functional actions
Cool-down (all phases)	2-24	• Postural stretching (spine, shoulder, lower limb) • Breathing and relaxation drills	10 min	Low intensity	none	Promote recovery and postural realignment

Note: EO: eyes open; EC: eyes closed.
Exercises were integrated into the regular training sessions three times per week (90 min per session). Balance drills were included during the warm-up (15 min), while corrective and stability exercises were performed in the final cool-down phase (15 min).
Coaches monitored execution quality and attendance, and only athletes with ≥ 85 % compliance were included in post-test analysis.

During Phase 1 (weeks 1–6), the focus was on developing fundamental balance and proprioceptive awareness. Athletes performed one-legged and tandem stance exercises with eyes open and closed on stable surfaces, along with general stability drills such as planks, bridges, and bird-dogs. The aim was to consolidate control of the center of pressure and initiate proprioceptive adaptation under stable conditions.

In Phase 2 (weeks 7–18), exercises evolved toward dynamic balance and neuromuscular coordination. The progression included single-leg jumps and landings, balance tasks involving a volleyball (passes and catches while maintaining stance), and corrective postural exercises targeting the trunk and pelvis. Unstable surfaces (foam pads, BOSU balls) and eyes-closed conditions were introduced gradually to increase proprioceptive challenge and vestibular involvement.

Phase 3 (weeks 19–24) emphasized postural integration and functional stability. Exercises simulated game-like conditions and external perturbations (e.g., partner pushes, sudden direction changes), combining dynamic balance with upper-body strength work such as push-ups, theraband rows, and wall slides for scapular and chest stabilization. The inclusion of compound proprioceptive drills with the ball aimed to enhance coordination between balance control and volleyball-specific movements.

Each exercise was executed under direct supervision by qualified coaches, ensuring correct technique, progressive difficulty, and safety. Athletes advanced to more complex variants only after successfully maintaining proper posture for at least 30 seconds without compensatory movements. Rest intervals ranged from 30 to 90 seconds depending on exercise intensity.

All participants' attendance and compliance were recorded weekly; only those who completed at least 85 % of sessions were included in the post-test analysis. Coaches were instructed to document any deviations, absences, or injuries throughout the intervention.

This structured, phase-based program allowed for a gradual yet continuous improvement in postural control, aligning proprioceptive and neuromuscular adaptations with the technical and physical demands of volleyball performance.

The exercises used within the protocol follow a cognitive approach, based on a structured organisation of the exercises, with a defined number of repetitions, execution times and a clear methodical progression (Esposito et al., 2024).

Test Applications

Balance performance was assessed using the Leonardo Mechanograph® Force Platform (Novotec Medical GmbH, Germany), an instrument widely validated for the quantitative evaluation of postural stability and neuromuscular control in youth populations. The platform records center of pressure (COP) displacements at a sampling frequency of 800 Hz, providing time- and position-based metrics of postural control.

The primary outcome was the time (s) the subject was able to maintain the prescribed balance position during each test, as automatically recorded by the Leonardo software. This metric was selected because it represents a functional indicator of static and dynamic stability and allows easy interpretation and comparison between conditions.

Moreover, time maintained is a direct measure of functional balance endurance, reflecting the athlete's ability to stabilize posture over a given period, a relevant skill in volleyball actions such as landing and directional changes.

Secondary analyses focused on COP-derived parameters provided by the platform's software for each trial:

1. Sway Path Length (mm): total displacement of COP during the test, representing overall postural oscillation.
2. Sway Velocity (mm/s): mean velocity of COP movement, reflecting efficiency of postural control.
3. Mean COP Deviation (mm): average distance of COP from the center, quantifying steadiness.

These indicators were used to complement time-based results and describe qualitative changes in balance strategy (static vs. dynamic control).

Four standardized postural tests were administered before and after the 24-week intervention:

1. Tangent stance, eyes open (TanEO) arms at sides.

In this test, the subject stands with feet in contact with the Leonardo platform, arms at the sides of the body and eyes open. The aim is to assess the subject's static balance while maintaining a stable position without the additional visual support of closed vision.

2. Tangent Stand, Eyes Closed (TanEC) arms to the sides. Similar to the previous test, but in this case the subject keeps their eyes closed. This test assesses balance without visual input, which makes the test more challenging as the subject must rely on other sensors to maintain balance.

3. One-Leg Stand, Eyes Open (1L_EO) arms to the sides.

In this test, the subject is standing on one leg, with the other leg raised off the ground. The arms are at the sides of the body and the eyes are open. This test measures the subject's ability to maintain balance on a reduced support base (one leg) with the help of visual input.

4. One-Leg Stand, Eyes Closed (1L_EC) arms to the sides.

Similar to the previous test, but with eyes closed. This is the most challenging test of the four, as the subject has to balance on one leg without visual input. This is done using the Leonardo Platform. The latter consists of two platforms with four sensors each. Its software contains a protocol with 17 different tests.

Each test was performed three times, with 30-second rest between trials, and the best value was used for analysis. Measurements were performed under identical environmental conditions (quiet room, no visual distractions).

Before testing, athletes completed a standardized familiarization trial to ensure correct posture and understanding of instructions.

The Leonardo platform demonstrates high test–retest reliability for static and dynamic balance tasks (ICC = 0.86–0.94). All measurements were conducted by the same operator to reduce inter-rater variability.

Ethical Committee

The study was conducted in accordance with the Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects (6 September 2022 revision) and the guidelines of the Ethics Committee for Scientific Research of Tirana Sports University.

Ethical approval was obtained under protocol number 2385/2, approved on 20 September 2024.

Written informed consent was obtained from all participants and their legal guardians prior to participation.

Statistical Analysis

Primary analysis was the between-group comparison of Δ (pre→post) using independent-samples t-tests with Hedges' g and 95% CIs; cluster-robust standard errors (teams as clusters) are also reported. Within-group changes were tested with paired t-tests. To analyse the effectiveness of the experimental protocol, the collected data were subjected to a statistical analysis. Prior to inferential testing, the assumptions of normality and homogeneity of variances were verified using the Shapiro–Wilk and Levene's tests, respectively. Descriptive statistics (mean ± standard deviation, SD) were computed for all variables at pre- and post-test stages.

Specifically, a paired-samples T-Test was applied to compare pre- and post-measurements within each group and an independent-samples T-Test to compare improvements between EG and CG. This allowed us to test whether the experimental protocol resulted in significant postural improvements compared to the traditional training programme.

To assess changes induced by the training protocol within each group, paired-samples t-tests were performed on pre–post data for each balance variable (TanEO, TanEC, 1L_EO, 1L_EC). For each comparison, the effect size was calculated as Cohen's d for paired samples, with accompanying 95% confidence intervals (CI). Effect magnitudes were interpreted according to Cohen's benchmarks: d = 0.20 (small), 0.50 (medium), 0.80 (large).

To evaluate differential improvements between the experimental (EG) and control (CG) groups, independent-samples t-tests were conducted on the Δ values (post–pre). Each test reported p-values, Hedges' g (corrected for small sample bias), and 95% CI.

Given that athletes were nested within four teams, a sensitivity check was also performed using a cluster-robust approach (teams as random units) to confirm the stability of results under potential intra-team correlation.

Because four outcome tests were analyzed, the Benjamini–Hochberg false discovery rate (FDR) correction was applied to control the expected proportion of false positives. Adjusted p-values are reported alongside uncorrected ones.

For each variable, both within-group (d) and between-group (g) effect sizes were reported with 95% CI.

The primary outcome (TanEC test) was interpreted as the main indicator of protocol effectiveness.

Secondary outcomes (1L_EO, 1L_EC, TanEO) were used to explore transfer effects on static and dynamic balance under different visual conditions.

All data visualizations (Δ mean ± 95% CI) were produced using SPSS Chart Builder and verified for consistency with tabular data.

Effect sizes were computed as Cohen's d for paired samples (within-group) and Hedges' g for between-group comparisons of Δ (post–pre), both with 95% confidence intervals. As the monitored parameter decreases with improved stability, negative Δ and effect size values indicate enhancement of postural control.

The analysis was conducted using the Statistical Package for Social Science software (IBM SPSS Statistics for Windows, version 25.0, IBM, SPSS Inc., Armonk, NY, USA).

Results

Following the use of the Leonardo Platform, pre- and post-intervention results were collected for the CG in the four tests applied (Tan EO, Tan EC, 1L EO, 1L EC). The data, shown in Table 2, describe the subjects' performance in terms of balance time maintained on the platform, measured in seconds (s), in line with what was previously described.

The same was done for the EG, where the test results are shown in Table 3.

The T-Test for dependent samples was applied to understand any significant improvements in EG due to the proposed training protocol.

Table 2. Control Group Results

No.	Balance Test (BT)							
	Tan EO (s)		Tan EC (s)		1L EO (s)		1L EC (s)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	3.05	3.06	11.80	11.82	7.03	7.01	17.78	67.67
2	1.68	1.57	19.25	19.27	4.29	4.28	8.27	7.89
3	3.02	3.04	10.14	10.12	3.40	3.39	9.75	9.12
4	4.54	4.52	32.50	32.52	3.66	3.90	22.57	20.55
5	6.79	6.74	17.83	17.81	6.77	6.78	67.11	52.45
6	0.43	0.43	2.25	2.29	2.19	2.47	11.41	10.99
7	2.07	2.11	10.60	10.49	6.02	6.05	16.86	18.34
8	1.19	1.17	18.35	18.37	3.29	3.38	7.72	7.21
9	2.47	2.45	9.41	9.38	2.41	2.38	3.75	3.70
10	4.23	4.20	31.40	30.40	2.76	2.64	21.93	20.65
11	2.54	2.51	13.10	12.10	6.29	5.79	15.65	14.37
12	1.55	1.53	3.47	3.93	3.61	3.17	20.18	28.58
1	3.71	3.70	16.55	16.52	8.71	7.01	10.68	67.67
2	3.38	1.57	44.33	44.35	4.83	3.56	7.79	7.89
3	1.89	2.67	6.47	6.51	3.54	3.11	10.26	9.12
4	4.00	4.07	14.45	14.51	12.02	12.04	14.34	20.55
5	6.78	6.22	6.63	6.65	7.59	6.21	5.88	52.45
6	5.53	0.43	7.66	3.59	8.09	8.07	19.63	10.99
7	1.28	1.31	14.37	14.49	6.65	6.67	20.45	18.34
8	1.12	1.11	14.69	14.70	9.78	9.76	24.73	7.21
9	1.03	1.05	8.99	8.21	3.47	3.45	17.88	3.70
10	3.85	3.78	45.40	45.42	6.76	6.77	12.46	20.65
11	2.60	2.51	15.75	15.73	5.74	5.79	10.16	14.37
12	1.60	1.53	12.01	12.03	7.67	7.65	16.23	28.58

Table 3. Exeperimental Group Results

No.	Balance Test (BT)							
	Tan EO (s)		Tan EC (s)		1L EO (s)		1L EC (s)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	1.51	1.50	2.78	2.15	4.97	3.98	24.02	24.02
2	4.63	4.63	5.23	4.20	6.59	5.21	38.05	21.05
3	1.30	1.20	19.42	10.24	18.98	10.97	49.43	28.32
4	0.92	0.90	3.78	2.76	3.19	2.28	8.64	8.12
5	5.51	3.46	4.57	3.57	5.21	4.78	14.72	14.23
6	2.17	2.20	5.28	3.82	5.04	4.14	14.43	11.49
7	0.76	0.77	3.75	1.77	5.03	3.13	10.32	7.56
8	1.88	1.11	9.63	7.34	2.31	1.76	12.45	10.45
9	0.40	0.40	7.42	1.89	2.69	3.69	8.32	9.72
10	1.06	1.30	5.22	4.38	6.07	4.18	16.68	14.34
11	31.31	10.33	15.45	11.54	7.46	7.13	13.36	11.39
12	2.43	1.49	15.93	11.24	2.17	1.87	12.37	11.78
1	1.92	0.79	14.52	10.55	5.96	4.78	29.88	15.89
2	1.16	1.01	9.76	7.28	15.88	13.88	19.67	14.76
3	2.86	1.24	8.73	6.78	5.45	4.58	18.75	13.72
4	15.92	10.88	14.50	11.53	7.82	5.89	9.62	8.32
5	2.26	1.78	7.33	5.68	3.73	2.37	6.73	6.11
6	3.99	1.98	13.58	9.74	16.07	11.35	20.00	12.88
7	1.71	1.12	6.36	4.54	2.83	2.14	10.03	8.27
8	4.00	3.11	15.37	7.57	13.02	9.57	14.72	10.73
9	5.35	1.95	4.63	2.54	8.31	6.33	4.80	5.82
10	6.64	5.63	8.44	7.43	9.08	8.08	20.56	15.55
11	1.29	1.30	14.02	13.96	1.98	2.19	21.45	19.32
12	5.88	3.67	12.48	9.68	7.88	6.65	22.78	17.87

Table 4. Change scores (Δ), effect sizes with 95% CI, and between-group p on Δ

Test	Group	Δ (Post–Pre, mean ± SD)	p	Effect size	95% CI
TanEO	EG	−1.80 ± 2.10	.051	d = −0.42	[−0.84, −0.00]
	CG	−0.29 ± 1.11	.107	d = −0.26	[−0.67, 0.14]
TanEC	EG	−2.75 ± 1.93	<.001	d = −1.23	[−1.76, −0.70]
	CG	−0.26 ± 0.88	<.001	d = −0.29	[−0.70, 0.12]
1L_EO	EG	−1.53 ± 1.79	<.001	d = −0.86	[−1.32, −0.39]
	CG	−0.22 ± 0.92	.001	d = −0.43	[−0.84, −0.01]
1L_EC	EG	−4.17 ± 3.13	.001	d = −0.74	[−1.20, −0.29]
	CG	+5.40 ± 6.92	.026	d = +0.28	[−0.13, 0.69]

Results show that for Tan EO there is no significance difference, as P=.051. For Tan Ec the P-value is P=.00000688; for 1L EO the P-value is P=.0003; for 1L EC the P-value is P=.0013; thus, for these three tests, significance was verified. To compare the CG and EG results, it is necessary to use the T-test for independent samples. To proceed, the Delta for each group must be calculated and compared using the previously mentioned test, establishing significance with a value of P < 0.05. In The Results shown that for Tan EO there is no significance in the comparison between CG and EG, as P=.107. For Tan EC, the P-value is P=.000019; for 1L EO, the P-value is P=.0018; for 1L EC, the P-value is P=.025; thus, for these three tests, there is significance in the comparison between CG and EG.

The comparison of change scores (Δ = post–pre) revealed significant advantages for the Experimental Group (EG) in three of the four balance tests. Large effects were observed in TanEC (Hedges' g = −1.44; 95% CI [−2.08, −0.80]) and 1L_EO (g = −0.98; 95% CI [−1.58, −0.38]), and a moderate effect in 1L_EC (g = −0.67; 95% CI [−1.25, −0.09]). The TanEO test showed a small, non-significant effect (g = −0.47; 95% CI [−1.05, 0.10]). Negative values indicate greater reduction (improvement) in the EG compared with the CG.

Paired-sample analyses revealed large improvements in the EG for TanEC (d_p = −1.23; 95% CI [−1.76, −0.70]), and moderate-to-large effects for 1L_EO (d_p = −0.86; 95% CI [−1.32, −0.39]) and 1L_EC (d_p = −0.74; 95% CI [−1.20, −0.29]). The TanEO test showed a small effect (d_p = −0.42; 95% CI [−0.84, −0.00]).

Conversely, the CG showed only small or trivial changes, with most confidence intervals crossing zero.

These findings confirm that the experimental stability training protocol effectively enhanced postural control, particularly under more demanding conditions (eyes closed or single-leg stance).

Discussion

The results of the study showed significant improvements in balance for the EG, compared to the CG. Specifically, the Tan EC, 1L EO and 1L EC tests showed statistically significant improvements with P=.0019; P=.0018 and P=.02, respectively, suggesting that the specific balance training protocol had a significant impact on the balance of the volleyball athletes considered for the study. Previous studies have shown that better postural control correlates with better sports performance and a reduced risk of injury (Hrysomallis, 2011). In particular, the ability to maintain stability in high-intensity game situations is crucial for optimising movement efficiency and motor co-ordination (Andreeva et al., 2021). Reduced reliance on the visual system suggests an improvement in proprioceptive and vestibular integration, which are crucial for volleyball athletes. Another study by Gioftsidou et al. (2012) showed that proprioceptive training, integrated into warm-up programmes, can improve postural stability in team sports players, confirming the effectiveness of the method used in our study. The improvement observed in EG compared to CG can be attributed to the specific nature of the protocol, which included single-leg balance exercises, dynamic exercises with and without a ball, and a postural stabilisation programme. Increasing the difficulty of the exercises over time may have contributed to better neuromuscular adaptation, as suggested by Gribble et al. (2012), who demonstrated that progressive protocols were more effective in improving postural stability than isolated static exercises. The result of the Tan EO test, which did not show significant improvements, suggests that static stability with visual input already present was not a limiting factor for athletes, while more challenging conditions (visual occlusion or balancing on one limb) showed more room for improvement.

Practical Implications

The results of the study suggest that integrating specific balance exercises into volleyball training programmes can improve athletes' postural stability and reaction ability. Coaches and athletic trainers can implement similar protocols in the warm-up and cool-down phase to improve postural stability, motor co-ordination and motor control. Furthermore, training focused on postural stability could contribute to injury prevention, especially in the landing phases after a jump, where balance control is essential to avoid lower limb injuries. The application of such protocols can also be extended to other sports that require high dynamic stability, such as basketball and gymnastics, suggesting their potential cross-disciplinary utility.

Limitations of the Study

Despite the significant results, the study has some limitations. The sample is relatively small and limited to a specific age group (14-16 years), which might influence the generalisability of the results to other categories of athletes. Furthermore, the six-month intervention period, although sufficient to observe significant changes, may not have captured any long-term effects of the training protocol. Another limitation is the absence of a detailed biomechanical analysis that could have provided more in-depth data on training-induced neuromuscular adaptations. Finally, the experimental protocol focused exclusively on balance exercises, without integrating other components of athletic training such as explosive strength and quickness, which could further influence the athletes' performance.

Conclusion

The results confirm the effectiveness of the proposed ad hoc balance protocol in improving postural stability, motor coordination and motor control in volleyball athletes. Comparison with the literature suggests that such protocols may have significant implications for both sports performance and injury prevention, supporting the integration of balance exercises into training programmes. These findings emphasise the importance of incorporating balance-specific training protocols into the training of volleyball athletes. The inclusion of stability exercises in the warm-up and defatigue phase may be an effective strategy to improve proprioceptive skills and reduce the risk of injury. Future research could examine the effect of different types of proprioceptive exercises (e.g., training on unstable surfaces or exercises under conditions of external perturbation) and evaluate the transfer of these improvements to volleyball-specific performance, such as jumping, landing and reactivity in changes of direction.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author AI and Writing Assistance Statement

Artificial intelligence tools were not used in the generation, analysis, or interpretation of data, nor in the conception or revision of the scientific content.

The only use of AI-based tools (DeepL) was limited to language editing and stylistic refinement of the English text.

The authors have carefully reviewed and verified all content to ensure full accuracy, integrity, and consistency with the original data and analyses.

References

Raiola, G., Esposito, G., Aliberti, S., & D'Elia, F. (2025). Effects on performance, perception and awareness of plyometric training in youth volleyball: A novel methodological approach to training. *Applied Sciences,15*(3), 1581 https://doi.org/10.3390/app15031581

D'Elia, F., D'Isanto, T., Altavilla, G., & Raiola, G. (2021). Evolution of explosive strength data in youth volleyball players before and after pandemic. *Physical Education Theory and Methodology, 21*(4), 375-380. https://doi.org/10.17309/tmfv.2021.4.13

Altavilla, G., Esposito, G., Ceruso, R., Di Domenico, F., & D'Isanto, T. (2022). Profile and differences in anthropometric data and jumping ability performance between elite and amateur U16 volleyball players. *Physical Education Theory and Methodology, 22*(2), 237-241. https://doi.org/10.17309/tmfv.2022.2.13

Liu, Y. (2022). Athletes' reaction capacity in the performance during a volleyball competition. *Revista Brasileira de Medicina do Esporte,* 29, e2022_0375. https://doi.org/10.1590/1517-8692202329012022_0375

Fuchs, P. X., Fusco, A., Cortis, C., & Wagner, H. (2020). Effects of differential jump training on balance performance in female volleyball players. *Applied Sciences, 10*(17), 5921. https://doi.org/10.3390/app10175921

Pau, M., Loi, A., & Pezzotta, M. C. (2012). Does sensorimotor training improve the static balance of young volleyball players?. *Sports Biomechanics, 11*(1), 97-107. https://doi.org/10.1080/14763141.2011.637126

Esposito, G., Altavilla, G., Di Domenico, F., Aliberti, S., D'Isanto, T., & D'Elia, F. (2021). Proprioceptive training to improve static and dynamic balance in elderly. *International Journal of Statistics in Medical Research,* 10, 194-199. https://doi.org/10.6000/1929-6029.2021.10.18

Hammami, R., Chaabene, H., Kharrat, F., Werfelli, H., Duncan, M., Rebai, H., & Granacher, U. (2021). Acute effects of different balance exercise types on selected measures of physical fitness in youth female volleyball players. *BMC Sports Science, Medicine and Rehabilitation,* 13, 1-8. https://doi.org/10.1186/s13102-021-00249-5

Esposito, G., Altavilla, G., Giardullo, G., Ceruso, R., & D'Isanto, T. (2024). The effects of the use of plyometric exercises with and without the ball in the development of explosive strength in volleyball. *Journal of Functional Morphology and Kinesiology, 9*(3), 126. https://doi.org/10.3390/jfmk9030126

Borzucka, D., Kręcisz, K., Rektor, Z., & Kuczyński, M. (2020). Postural control in top-level female volleyball players. BMC Sports Science, *Medicine and Rehabilitation,* 12, 1-6. https://doi.org/10.1186/s13102-020-00213-9

Gerberich, S. G., Luhmann, S., Finke, C., Priest, J. D., & Beard, B. J. (1987). Analysis of severe injuries associated with volleyball activities. *The Physician and Sportsmedicine, 15*(8), 75-79. https://doi.org/10.1080/00913847.1987.11702055

Cuñado-González, Á., Martín-Pintado-Zugasti, A., & Rodríguez-Fernández, Á. L. (2019). Prevalence and factors associated with injuries in elite Spanish volleyball. *Journal of Sport Rehabilitation, 28*(8), 796-802. https://doi.org/10.1123/jsr.2018-0044

D'Isanto, T., Esposito, G., Ceruso, R., D'Elia, F., & Raiola, G. (2024). The role of the sports kinesiologist to prevent grade II ankle sprains in volleyball. *European Journal of Human Movement,* 53, 101-113. https://doi.org/10.21134/eurjhm.2024.53.10

Esposito, G., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Ecological-dynamic approach vs. traditional prescriptive approach in improving technical skills of young soccer players. *Journal of Functional Morphology and Kinesiology, 9*(3), 162. https://doi.org/10.3390/jfmk9030162

Hrysomallis, C. (2011). Balance ability and athletic performance. *Sports Medicine,* 41, 221-232. https://doi.org/10.2165/11538560-000000000-00000

Andreeva, A., Melnikov, A., Skvortsov, D., Akhmerova, K., Vavaev, A., Golov, A., Draugelite, V., Nikolaev, R., Chechelnickaia, S., Zhuk, D., Bayerbakh, A., Nikulin, V., & Zemková, E. (2021). Postural stability in athletes: The role of sport direction. *Gait & Posture,* 89, 120-125. https://doi.org/10.1016/j.gaitpost.2021.07.005

Gioftsidou, A., Malliou, P., Pafis, G., Beneka, A., Tsapralis, K., & Godolias, G. (2012). Balance training programs for soccer injuries prevention. *Journal of Human Sport and Exercise, 7*(3), 639-647. https://doi.org/10.4100/jhse.2012.73.04

Gribble, P. A., Hertel, J., & Plisky, P. (2012). Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: A literature and systematic review. J*ournal of Athletic Training, 47*(3), 339-357. https://doi.org/10.4085/1062-6050-47.3.08

Вплив спеціального протоколу тренування стабільності на поліпшення рівноваги юних волейболістів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 4 табл., 18 джерел.

Мета дослідження. Мета цього дослідження полягала в оцінці ефективності індивідуалізованої програми тренувань у покращенні рівноваги серед юних спортсменів-волейболістів.

Матеріали та методи. У дослідженні взяли участь 48 спортсменів (віком 14-16 років) з чотирьох волейбольних команд, розділених на експериментальну (ЕГ) та контрольну (КГ) групи. Протягом шести місяців ЕГ дотримувалася спеціалізованого протоколу, що передбачав інтеграцію вправ на рівновагу до програми розминок та посттренувальних сесій, які охоплювали як статичні, так і динамічні вправи, тоді як КГ займалася за стандартною програмою. Оцінювання рівноваги проводилося за допомогою платформи Leonardo із використанням тестів перед та після впровадження протоколу. Статистичний аналіз включав використання Т-критеріїв для парних та незалежних вибірок з метою порівняння внутрішньогрупових змін та міжгрупових відмінностей.

Результати. Отримані результати виявили значне поліпшення показників в ЕГ, що особливо помітно у виконанні тесту TanEC (p = .00001), вказуючи на підвищення стабільності без візуального орієнтира. Виражені покращення також були відзначені у виконанні тестів стабільності на одній кінцівці (1L_EO, P = .0018; 1L_EC, P = .0258). Натомість тест TanEO не показав істотних групових відмінностей (p = .107), що свідчить про мінімальний вплив на стабільність за візуальних умов.

Висновки. Представлені результати підкреслюють ефективність застосування адаптованих тренувань рівноваги у покращенні постуральної стабільності, координації рухів та контролю серед юних волейболістів, що свідчить на користь інтеграції цільових вправ до програм спортивного тренування з метою оптимізації результатів.

Ключові слова: контроль рухів, результативність, постуральне тестування.

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Original Scientific Article

Analyzing the Effects of a 12-Week Yoga and Elastic-Band Resistance Training Program on Functional Fitness in Intermediate-Level Male Tennis Athletes: A Randomised Controlled Trial

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Abstract

Background. Yoga and elastic-band resistance training (EBRT) are cost-effective methods to enhance physical function, yet their combined effects on competitive young tennis athletes remain underexplored.

Objectives. This study aimed to examine the impact of a 12-week yoga + EBRT program on functional fitness in intermediate-level male tennis players.

Materials and Methods. Thirty-four athletes (age 20.3 ± 1.5 years) were randomly assigned to an experimental group (yoga + EBRT, n = 17) or control group (regular tennis training, n = 17). Functional outcomes were assessed at baseline, week 6, and week 12 using the Chair Stand, Arm Curl, Chair Sit-and-Reach, Single-Leg Stance, and Timed Up-and-Go (TUG) tests. A 2 × 3 repeated-measures ANOVA evaluated group × time effects, with effect sizes reported as Cohen's d and partial eta squared (η^2_p) with 95% confidence intervals (CIs).

Results. Significant group × time interactions were found for all outcomes ($p < 0.01$). At post-test, the experimental group showed superior performance compared with controls in arm curl (+4.2 reps, 95% CI [1.77, 6.63], d = 1.16), chair stand (+2.3 reps, 95% CI [−0.23, 4.83], d = 0.61), sit-and-reach (+6.2 cm, 95% CI [3.12, 9.28], d = 1.35), and TUG (−1.0 s, 95% CI [−1.44, −0.56], d = −1.53). Improvements in single-leg stance were small and non-significant (+1.2 s, 95% CI [−2.03, 4.43], d = 0.25). Attendance averaged 88%, with no adverse events reported.

Conclusions. A 12-week yoga and EBRT program significantly improved muscular endurance, flexibility, and mobility compared with regular training, with large effect sizes observed for upper-body endurance, flexibility, and dynamic agility. These findings support the use of combined yoga and elastic-band protocols as a practical conditioning option for young tennis athletes. Further studies should integrate tennis-specific performance metrics to confirm sport transferability.

Keywords: yoga, elastic-band resistance training, tennis athletes, functional fitness, balance, flexibility.

Introduction

Participation in sports and physical activity extends far beyond physical training; it serves as a vital driver of holistic growth, enhancing not only physical fitness but also psychological health and overall well-being (Choudhary & Dubey, 2024; Choudhary et al., 2024). Tennis is a physically demanding sport that places high and varied demands on the musculoskeletal and neuromuscular systems, requiring repeated explosive actions, rapid change-of-direction, unilateral stability, and reliable recovery between high-intensity efforts (Fernandez-Fernandez et al., 2013; Koya et al., 2022). Tennis performance requires a unique blend of explosive strength, endurance, flexibility, and repeated high-intensity efforts (Kovacs, 2006), underscoring the relevance of conditioning programs that target multiple functional domains. Conditioning programs for tennis, therefore, commonly combine strength, power, plyometric, and neuromuscular training to optimise on-court performance and reduce injury risk (Guo, 2024; Ramirez-Campillo et al., 2023). However, practical constraints (time, equipment availability, and athlete schedules) and the need to preserve movement quality have driven interest in hybrid, low-cost modalities such as elastic-band resistance and mind-body practices (e.g., yoga) that can be integrated into athletes' routines while targeting complementary physiological and sensorimotor systems (Lopes et al., 2019; Hernandez-Martinez, 2024). Recent intervention studies have demonstrated that integrated conditioning approaches can meaningfully enhance tennis-related capacities such as skill, agility, strength, and balance. For instance, Bangari et al. (2025) reported significant improvements in tennis skills, agility, strength, and balance following a 12-week integrated core and plyometric program in adolescent players. Parallel evidence shows that high-intensity interval training elicits substantial performance gains in adolescent tennis athletes (Choudhary & Choudhary, 2025), while a 12-week structured yoga intervention produced notable improvements in flexibility, balance, and joint kinematics in university athletes (Choudhary, S., et al., 2025). Shorter yoga-based protocols, such as a six-week Surya Namaskar program, have also been shown to enhance back flexibility and lumbar flexion in young females (Dubey & Choudhary, 2024), supporting the inclusion of yoga-derived mobility work within multimodal conditioning for tennis. Recent perspectives highlight yoga's neurophysiological benefits and its potential role in clinical neurology, supporting the idea that mind-body practices can produce central nervous system adaptations beneficial for motor control and sensorimotor integration (Choudhary & Choudhary, 2025).

Yoga and elastic-band resistance each have a growing evidence base for improving functional fitness components relevant to sport. Yoga interventions have been shown to increase joint range of motion, balance, and movement control in athletic and non-athletic populations (Amin & Goodman, 2014; Gothe & McAuley, 2016; Polsgrove et al., 2016), and athlete-targeted trials report improvements in flexibility and postural stability after short to moderate training blocks (Polsgrove et al., 2016). Elastic-band resistance training (EBRT) produces strength gains comparable to conventional resistance training, while offering low equipment cost, portability, and high exercise specificity when arranged in functional, multiplanar patterns (Lopes et al., 2019; Hernandez-Martinez, 2024). Elastic resistance bands have been shown to acutely enhance jump performance via post-activation potentiation, highlighting their capacity to improve explosive neuromuscular function (Chaware & Lum, 2024). Importantly, combinations of yoga and elastic-band exercise have been trialled in clinical and older-adult samples with positive effects on mobility, balance, and functional capacity, supporting the face validity of coupling these modalities for broader populations (Akbar et al., 2022; Buttichak et al., 2023). From a mechanistic standpoint, combined yoga + EBRT is plausibly suited to address both peripheral and central contributors to tennis performance. Peripheral adaptations include improvements in musculotendinous extensibility and joint range of motion through sustained stretch and soft-tissue remodelling, which support larger and more efficient movement arcs (Amin & Goodman, 2014; Polsgrove et al., 2016). EBRT offers progressive overload to muscular and tendinous structures in sport-specific directions (e.g., resisted rows, lateral lunges, rotational chops), translating to improved force production and muscular endurance relevant to serving and repeated groundstrokes (Lopes et al., 2019; Fernandez-Fernandez et al., 2013). Central adaptations include enhanced neural drive, motor unit recruitment, and inter-muscular coordination that appear early in resistance programs and underpin rapid gains in strength and power (Aagaard, 2003). In parallel, the attentional and sensorimotor training elements of yoga are associated with improved proprioception and movement consistency, possibly augmenting motor learning and movement economy when paired with resistance stimuli (Cotman et al., 2007; Lim, 2019). Evidence from tennis-specific and athlete-focused research supports the transfer potential of multimodal programs. Short-term tennis conditioning that combined elastic resistance, medicine-ball work, and core training produced measurable increases in serve velocity in juniors (Fernandez-Fernandez et al., 2013), and resisted sprint interventions improved acceleration and horizontal power in young tennis players (Moya-Ramon et al., 2020). Systematic reviews and recent meta-analyses of neuromuscular training indicate significant benefits for serve speed, sprint, and change-of-direction performance, and muscular strength when balance, plyometric, and resistance components are combined (Zhou et al., 2025; Deng et al., 2025). Thus, a hybrid program that mixes yoga's mobility and balance emphasis with EBRT's progressive, sport-specific overload is theoretically capable of producing both the physical capacities and motor control improvements that are meaningful for tennis performance.

Balance and proprioception are particularly important in tennis because the sport demands rapid transitions from dynamic movement to stable stroke platforms and frequent unilateral loading (Jacquier-Bret et al., 2024). Contemporary reviews demonstrate that targeted proprioceptive and sensorimotor training produce robust improvements in balance, postural control, and explosive strength across athletic cohorts (Winter, 2022; Yilmaz, 2024; Sluga & Kozinc, 2024). These adaptations reduce movement variability, speed reactive stabilisation, and likely contribute to injury risk reduction when implemented alongside strength work (Winter, 2022; Sluga et al., 2024). Therefore, integrating balance-centric yoga poses (e.g., Tree, Warrior III) and unilateral EBRT progressions (e.g., single-leg Romanian deadlifts, lateral band walks) creates a coherent training stimulus for tennis athletes.

Despite promising theoretical and empirical foundations, gaps remain. Much of the prior work on yoga + band combinations has been conducted in older or clinical populations (Akbar et al., 2022; Muangritdech, 2023), leaving a relative paucity of randomised, sport-specific trials in young competitive athletes. Similarly, while elastic resistance and neuromuscular training are supported individually by systematic reviews and meta-analyses (Lopes et al., 2019; Ma, 2025; Rong, 2025), clear evidence on the dose, progression, and periodisation of combined yoga + EBRT programs for maximal transfer to tennis performance is limited. Additionally, many tennis conditioning studies focus narrowly on isolated outcomes (e.g., serve speed), whereas coaches require evidence that interventions improve a constellation of functional qualities (strength, flexibility, balance) that together underpin court performance and injury resilience (Fernandez-Fernandez et al., 2013; Koya et al., 2022).

While previous research has shown that yoga can improve flexibility and balance (Dubey & Choudhary, 2024) and that elastic-band resistance training effectively develops muscular strength (Lopes et al., 2019; Choudhary et al., 2025; Hernández-Martínez et al., 2024), there is limited evidence on their combined effects in competitive sport contexts. Most yoga + resistance interventions have been applied to older or clinical populations (Muangritdech et al., 2023), while tennis-specific conditioning studies have primarily focused on isolated modalities such as plyometrics, high-intensity interval training, or traditional strength training (Bangari et al., 2025; Choudhary et al., 2025). Thus, it remains unclear whether integrating yoga with elastic-band resistance can yield complementary neuromuscular, flexibility, and balance adaptations in young, competitive tennis athletes.

Although both yoga and elastic-band resistance training have independently demonstrated positive effects on flexibility, balance, muscular strength, and overall functional fitness, the majority of combined interventions have been tested primarily in clinical or elderly populations (Akbar et al., 2022; Muangritdech et al., 2023; Jangphonak et al., 2025). These studies consistently report improvements in mobility, joint stability, and quality of life, but they provide limited insight into the transferability of such programs to young, competitive athletes engaged in high-intensity, sport-specific training. Previous research has demonstrated that a yoga combined elastic band program can significantly improve balance and functional fitness in older adults (Jangphonak et al., 2025). However, evidence in competitive young athletes remains scarce. To date, evidence on yoga combined with resistance band training in athletic contexts remains scarce, and randomised controlled trials (RCTs) in tennis players are virtually nonexistent. This gap highlights the need to investigate whether the synergistic benefits observed in clinical samples can extend to sports populations where explosiveness, endurance, and balance are critical to performance.

Equally important are the practical considerations faced by coaches and athletes. Traditional resistance training often requires access to gyms, heavy equipment, and structured supervision, which may not always be feasible in resource-limited tennis academies or during travel for tournaments. In contrast, elastic-band resistance training and yoga are cost-effective, portable, and highly adaptable methods that can be implemented with minimal equipment. When integrated, they provide both peripheral benefits (musculoskeletal strength, extensibility) and central adaptations (neuromuscular coordination, proprioceptive control). This makes the hybrid program not only scientifically promising but also practically viable, offering coaches a conditioning approach that supports performance while reducing logistical barriers.

Therefore, the present study aimed to evaluate the effects of a 12-week structured yoga combined with an elastic-band resistance training program on functional performance, muscular endurance, flexibility, balance, and mobility among intermediate-level male tennis athletes compared with a control group engaged in regular training. It was hypothesised that the intervention group would demonstrate significantly greater improvements across all outcomes, with particularly pronounced gains in flexibility and balance due to the synergistic effects of yoga and proprioceptive resistance.

Materials and Methods

Study Design

This study employed a two-arm, parallel-group randomised controlled trial (RCT) design with repeated measures at three time points: baseline (T0), mid-test at week six (T1), and post-test at week twelve (T2) to examine the effects of a yoga combined elastic band training program on functional performance and balance among competitive young tennis athletes. Participants were randomly assigned in a 1:1 allocation ratio using computer-generated randomisation, with 17 athletes allocated to the experimental group and 17 to the control group. The intervention group received the structured training protocol, whereas the control group continued with their regular tennis training routines (table 1). To minimise bias, both outcome assessors and data analysts were blinded to group allocation.

Table 1. Yoga + Elastic Band Training Protocol (12 Weeks, Experimental Group)

Week	Warm-Up (10 min)	Elastic Band Training (Sets × Reps, Tempo, Band Colour)	Yoga Poses (Sets × Hold Time)	Cool-Down (10 min)
1–2	Light jog, mobility drills	Squats (2×12, yellow), Lateral walks (2×8, yellow), Rows (2×10, red)	Tree (2×20s), Forward bend (2×20s)	Static stretches, breathing
3–4	Skipping, side shuffles	Squats (3×10, red), Push press (2×10, red), RDL (2×8, red)	Warrior II (2×30s), Knee-to-chest (2×20s)	Spinal twists, stretches
5–6	Ladder drills, lunges	Single-leg squats (3×8, green), Hip thrusts (3×10, green), Rows (3×10, green)	Pigeon (2×20s), Tree with band (2×25s)	Guided breathing, long stretches
7–8	High knees, planks	Lateral lunges (3×10, green), Overhead press (3×10, green), Face pulls (3×12, green)	Warrior III (2×25s), Cow face (2×25s)	Yoga Nidra, stretches
9–10	Skipping + agility cones	Single-leg RDL (3×8, blue), Band squat jumps (3×8, blue), Resisted push-ups (3×10, blue)	Balance flow (Tree → Warrior III)	Hamstring/hip stretches
11–12	Sport-specific footwork	Resisted sprints (4×15m, blue), Rotational chops (3×8, blue), Rows (3×10, blue)	Combined sequence (Tree, Warrior II, Leg lift) (2×30s each)	Dead Body Pose, static stretches

Notes: Tempo = 2s concentric, 1s pause, 2s eccentric; RPE = 6–8/10 depending on week; band colors increased progressively (yellow → blue). Yoga pose holds increased from 20 to 40s over 12 weeks.

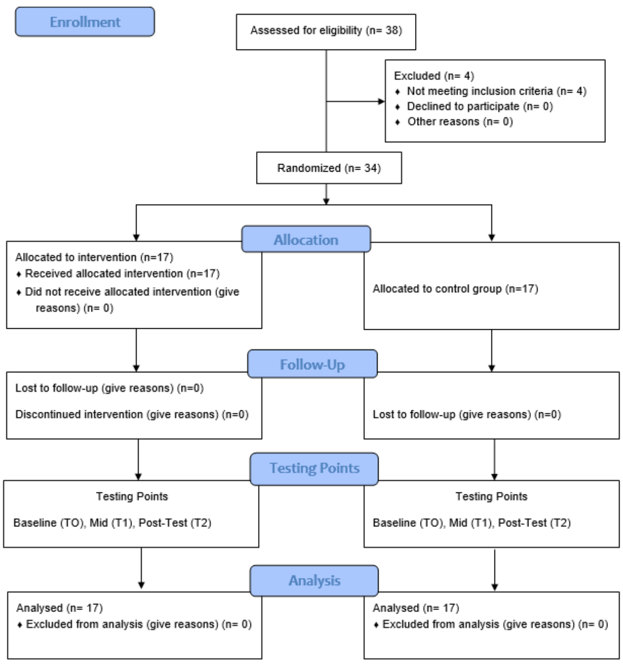

Fig. 1. CONSORT flow diagram of participant recruitment, allocation, follow-up, and analysis

Participants

A total of thirty-four male tennis athletes classified in the Eclipse category, aged between 18 and 23 years, were recruited for the study. Inclusion criteria required athletes to be male, within the specified age range, and to demonstrate an intermediate playing level. The intermediate level was operationally defined as engaging in regular tennis training three to six times per week, sustaining practice sessions of 60-90 minutes, and demonstrating fundamental tennis competencies such as consistent groundstrokes, reliable serving ability, and verified match experience as confirmed by both the coach and athlete.

Table 2. Demographic characteristics of participants

Variable	Control Group (n = 17) M ± SD	Experimental Group (n = 17) M ± SD	Total (N = 34) M ± SD
Age (years)	20.2 ± 1.5	20.4 ± 1.6	20.3 ± 1.5
Height (cm)	176.8 ± 6.2	177.3 ± 5.9	177.0 ±6.0
Weight (kg)	69.5 ± 7.8	70.2 ± 8.1	69.8 ± 7.9
BMI (kg/m²)	22.1 ± 1.9	22.4 ± 2.0	22.2 ± 1.9
Playing experience (years)	6.2 ± 1.4	6.4 ± 1.5	6.3 ± 1.4
Weekly training frequency (sessions)	4.1 ± 0.8	4.3 ± 0.9	4.2 ± 0.8

All participants were medically cleared for exercise, provided written informed consent, and committed to attending at least 80% of the scheduled training sessions.

Ethics Consideration

The study was conducted in accordance with the principles of the Declaration of Helsinki. It was approved by a local ethics committee, and written informed consent was obtained from all participants before data collection.. All procedures were non-invasive, posed minimal risk to participants, and involved standard training and fitness assessments commonly used in sport science research. All participants were fully informed about the study objectives, procedures, potential risks, and benefits, and provided written informed consent before participation. Confidentiality and anonymity were strictly maintained throughout the study.

Exclusion Criteria

Exclusion criteria included any current musculoskeletal injuries that could impair training or performance, diagnosed cardiovascular, respiratory, or neurological disorders that contraindicate moderate-intensity exercise, current or recent use of performance-enhancing substances, and concurrent participation in other structured training interventions that could confound the study outcomes. These criteria were implemented to ensure homogeneity in playing level and to minimise extraneous variability that could bias the results.

Sample Size and Power Analysis

The final sample size of thirty-four athletes was primarily determined by practical considerations of athlete availability; however, it was cross-validated against established statistical power requirements. According to Cohen's power analysis framework, using G*Power software for a repeated-measures ANOVA with a within-between interaction, an alpha level of 0.05, a statistical power of 0.80, and a medium effect size ($f = 0.25$), the recommended sample size is approximately 34–40 participants. Therefore, the inclusion of 34 athletes in this study was considered adequate to achieve sufficient statistical power for detecting meaningful changes while maintaining a feasible recruitment target within the specific population of young competitive tennis athletes.

Intervention Fidelity

To ensure consistency and accuracy in the delivery of the training program, all yoga and elastic-band sessions were supervised by certified instructors with expertise in strength and conditioning and yoga practice. Athlete attendance was recorded, and participants were required to complete at least 80% of sessions to remain eligible for analysis. Instructors provided live corrections to maintain proper exercise technique, while research assistants monitored adherence and documented any deviations. This process ensured that the intervention was implemented as designed and reduced the likelihood of performance bias.

Randomisation, Allocation Concealment, and Blinding

Participants were randomly assigned to either the experimental group (yoga + elastic-band training) or the control group (regular tennis training) using a computer-generated random number sequence (1:1 allocation). Allocation concealment was ensured through the use of sealed, opaque, sequentially numbered envelopes, which were prepared by an independent researcher not involved in participant recruitment or outcome assessment. To minimise bias, outcome assessors and data analysts were blinded to group assignments throughout the study. Assessors who administered and recorded the functional fitness tests were not informed of participant allocation, and raw data were coded before statistical analysis to maintain objectivity.

Outcome Measures

The assessments were conducted following standardised procedures established by Jones and Rikli (2013), which provide validated field-based measures of functional fitness commonly applied in exercise science research. The following tests were selected for this study: All outcome assessments were conducted at three time points: baseline (T0), mid-test at week six (T1), and post-test at week twelve (T2) using standardised and validated physical fitness tests adapted from Rikli and Jones' Senior Fitness Test battery. Five primary measures were employed:

Chair Stand Test (lower-body strength): Participants were instructed to stand up and sit down from a standard chair as many times as possible in 30 seconds, with arms crossed over the chest. The total number of repetitions was recorded.

Arm Curl Test (upper-body strength): Using an 8-pound (3.6 kg) dumbbell, participants performed as many bicep curls as possible within 30 seconds. The number of completed repetitions was recorded.

Chair Sit-and-Reach Test (flexibility): Participants sat on the edge of a chair with one leg extended and attempted to reach toward their toes using both hands. The distance between the fingertips and toes was measured in centimetres, with positive values for overlap and negative values for shortfall.

Single-Leg Stance Test (static balance): Participants were timed while standing on one leg with arms at the side and eyes open, until balance was lost or the foot touched the floor. The best attempt was recorded in seconds.

Time Up-and-Go Test (dynamic balance and agility): Participants were timed while standing from a chair, walking three meters, turning, and returning to sit. The total time to complete the task was measured in seconds.

All tests were administered by trained assessors blinded to group allocation, and each participant was given a familiarisation trial before data collection. To minimise variability, testing was conducted at the same time of day (±1 hour) across all time points, and participants were instructed to avoid strenuous exercise 24 hours before assessment. The primary outcomes were changes in muscular strength, flexibility, and balance across the three testing intervals.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA), with the significance level set at $p < 0.05$. Descriptive statistics, including mean and standard deviation (M ± SD), were calculated for all variables at each measurement point. Prior to inferential analysis, the dataset was screened for missing values, outliers, and entry errors. Assumptions of normality were evaluated using the Shapiro–Wilk test along with visual inspection of Q–Q plots, while homogeneity of variance was assessed through Levene's test. For repeated-measures analyses, Mauchly's test of sphericity was performed, and in cases where sphericity was violated, the Greenhouse–Geisser correction was applied.

To examine changes in performance over time and differences between groups, a 2 (Group: Experimental vs. Control) × 3 (Time: T0 baseline, T1 mid-test, T2 post-test) repeated-measures analysis of variance (RM-ANOVA) was performed for each outcome measure (Arm Curl, Chair Stand, Chair Sit-and-Reach, Single-Leg Stance, and Time Up-and-Go). The analysis provided main effects for time, main effects for group, and group × time interaction effects. When significant interactions were observed, post hoc pairwise comparisons with Bonferroni adjustments were conducted to identify the source of differences across time points within each group and between groups at each measurement interval.

Effect sizes were reported as partial eta squared (η^2_p) for the ANOVA outcomes, interpreted as small (0.01), medium (0.06), or large (0.14). For post hoc comparisons, Cohen's d was calculated to quantify the magnitude of between-group and within-group differences. In addition, baseline equivalence between groups was examined using independent-samples t-tests for continuous variables (age, height, weight, BMI, and test scores) and chi-square tests for categorical variables. Missing data were handled using a complete-case approach if ≤5% of values were absent; if more extensive missingness occurred, SPSS's multiple imputation procedure (Fully Conditional Specification) was applied, and pooled results were reported.

Results

The present study evaluated the effects of a 12-week yoga program combined with an elastic band training program on functional performance outcomes in young male tennis athletes. Descriptive statistics are first presented to summarize participant characteristics, followed by assumption checks to ensure compliance with parametric test requirements. The main findings are then reported from repeated-measures ANOVA, highlighting group, time, and interaction effects. Finally, detailed within-group comparisons with effect sizes are provided to illustrate the magnitude of changes across the intervention period.

Table 7 presents descriptive statistics and within-group changes across baseline, mid-test, and post-test.The experimental group showed consistent improvements in all outcomes, with large gains in arm curl, chair stand, sit-and-reach, single-leg stance, and reduced TUG times.

Control group values remained largely unchanged, with negligible or negative changes across the 12 weeks. Significant within-group improvements were evident only in the intervention group ($p < 0.001$). These results confirm the progressive and sustained benefits of yoga combined with elastic-band resistance training.

Table 8 compares post-test outcomes between the experimental and control groups with mean differences, 95% confidence intervals, and effect sizes. The intervention group outperformed controls in all measures, with large effects in arm curl, sit-and-reach, and TUG time.

Table 3. Shapiro–Wilk test for normality of outcome measures

Outcome Measure	Group	Baseline (T0) (p)	Mid-Test (T1) (p)	Post-Test (T2) (p)
Arm Curl Test	Control	0.214	0.311	0.268
	Experimental	0.356	0.284	0.227
Chair Stand Test	Control	0.189	0.241	0.198
	Experimental	0.254	0.336	0.298
Chair Sit-and-Reach	Control	0.227	0.302	0.310
	Experimental	0.241	0.290	0.331
Single-Leg Stance	Control	0.218	0.254	0.279
	Experimental	0.276	0.325	0.298
Time Up-and-Go	Control	0.243	0.289	0.301
	Experimental	0.266	0.313	0.286

Note. Shapiro–Wilk tests indicated that all outcome measures were normally distributed at baseline, mid-test, and post-test ($p > 0.05$), satisfying the assumption of normality for parametric analyses

Moderate improvements were seen in chair stand repetitions, while single-leg stance showed small, non-significant differences. Negative values for TUG mean difference favour the experimental group, as lower times indicate better performance. Overall, the between-group analysis confirms the practical significance of the intervention beyond statistical improvements.

Discussion

This 12-week yoga plus elastic-band program produced consistent, meaningful improvements in functional performance, upper- and lower-body muscular endurance, flexibility, static and dynamic balance among intermediate male tennis athletes, while the control group (regular tennis training) showed minimal change. These findings mirror and extend the work of Jangphonak et al. (2025), who reported significant gains in strength, flexibility, and balance following a shorter (6-week) yoga + elastic-band program in older adults. Translating those mechanisms to a younger, sport-specific population helps explain why the experimental group here exhibited larger improvements: the combined regimen targets both peripheral tissue adaptations (flexibility,

Table 4. Levene's Test of Homogeneity of Variances for outcome measures at baseline, mid-test, and post-test

Outcome Measure	Time Point	F-value	p-value
Arm Curl Test	Baseline (T0)	0.84	0.37
	Mid-Test (T1)	0.92	0.34
	Post-Test (T2)	1.12	0.29
Chair Stand Test	Baseline (T0)	0.78	0.38
	Mid-Test (T1)	0.91	0.34
	Post-Test (T2)	1.03	0.31
Chair Sit-and-Reach	Baseline (T0)	0.69	0.41
	Mid-Test (T1)	0.87	0.36
	Post-Test (T2)	1.08	0.30
Single-Leg Stance	Baseline (T0)	0.74	0.40
	Mid-Test (T1)	0.96	0.33
	Post-Test (T2)	1.15	0.28
Time Up-and-Go	Baseline (T0)	0.88	0.36
	Mid-Test (T1)	1.02	0.31
	Post-Test (T2)	1.09	0.29

Note. Levene's Test for equality of variances indicated no significant differences in variance between groups across all outcome measures at baseline, mid-test, and post-test ($p > 0.05$)

Table 5. Mauchly's Test of Sphericity for Time (T0, T1, T2)

Outcome Measure	Mauchly's W	χ^2 (df=2)	Sig. (p)	Greenhouse–Geisser ε	Huynh–Feldt ε
Arm Curl Test	0.920	3.40	0.18	0.96	0.98
Chair Stand Test	0.880	5.60	0.06	0.86	0.92
Chair Sit-and-Reach	0.750	16.20	<0.001	0.68	0.79
Single-Leg Stance	0.810	8.50	0.014	0.72	0.82
Time Up-and-Go	0.950	2.10	0.35	0.98	0.99

Note. Mauchly's test evaluates the sphericity assumption for the within-subject factor (Time)

Table 6. Repeated-measures ANOVA results for time, group, and interaction effects across functional outcome measures

Outcome Measure	Time Effect (F, p, η^2_p)	Group Effect (F, p, η^2_p)	Group × Time Interaction (F, p, η^2_p)
Arm Curl Test	$F(2,64) = 18.4, p < 0.001, \eta^2_p = 0.36$	$F(1,32) = 4.5, p = 0.041, \eta^2_p = 0.12$	$F(2,64) = 9.3, p < 0.001, \eta^2_p = 0.22$
Chair Stand Test	$F(2,64) = 15.2, p < 0.001, \eta^2_p = 0.32$	$F(1,32) = 5.2, p = 0.029, \eta^2_p = 0.14$	$F(2,64) = 8.1, p = 0.001, \eta^2_p = 0.20$
Chair Sit-and-Reach	$F(2,64) = 21.5, p < 0.001, \eta^2_p = 0.40$	$F(1,32) = 6.1, p = 0.019, \eta^2_p = 0.16$	$F(2,64) = 11.5, p < 0.001, \eta^2_p = 0.26$
Single-Leg Stance	$F(2,64) = 10.7, p < 0.001, \eta^2_p = 0.25$	$F(1,32) = 3.8, p = 0.058, \eta^2_p = 0.11$	$F(2,64) = 6.4, p = 0.003, \eta^2_p = 0.17$
Time Up-and-Go	$F(2,64) = 12.9, p < 0.001, \eta^2_p = 0.29$	$F(1,32) = 4.9, p = 0.034, \eta^2_p = 0.13$	$F(2,64) = 7.8, p = 0.001, \eta^2_p = 0.20$

Note. All outcome measures demonstrated significant main effects of time ($p < 0.001$), indicating performance changes across the 12 weeks

Table 7. Descriptive statistics and within-group changes

Outcome Measure	Group	Baseline (T0) Mean ± SD	Mid-Test (T1) Mean ± SD	Post-Test (T2) Mean ± SD	Δ T0–T2	p (within)
Arm Curl (reps/30 s)	Control	14.8 ± 3.5	15.0 ± 3.6	15.1 ± 3.4	+0.3	0.62
	Experimental	15.2 ± 3.6	17.8 ± 3.7	19.3 ± 3.8	+4.1	<0.001
Chair Stand (reps/30 s)	Control	14.2 ± 3.6	14.0 ± 3.5	13.9 ± 3.4	−0.3	0.59
	Experimental	14.3 ± 3.9	15.5 ± 4.0	16.2 ± 4.1	+1.9	<0.001
Chair Sit-and-Reach (cm)†	Control	1.2 ± 6.0	1.1 ± 5.2	1.1 ± 5.1	−0.1	0.92
	Experimental	1.5 ± 2.7	4.9 ± 3.6	7.3 ± 4.0	+5.8	<0.001
Single-Leg Stance (s)	Control	11.4 ± 5.0	11.3 ± 4.6	11.2 ± 4.5	−0.2	0.40
	Experimental	10.4 ± 3.9	11.8 ± 4.7	12.4 ± 5.1	+2.0	<0.001
Timed Up-and-Go (s)‡	Control	8.8 ± 0.6	9.0 ± 0.7	8.9 ± 0.7	+0.1	0.06
	Experimental	8.9 ± 0.7	8.3 ± 0.6	7.9 ± 0.6	−1.0	<0.001

Descriptive statistics and within-group changes in functional performance outcomes across baseline (T0), mid-test (T1), and post-test (T2). Values are mean ± standard deviation (SD). Δ T0–T2 represents the net change from baseline to post-test. Positive values indicate improvement, except for Timed Up-and-Go (TUG), where a negative change reflects better performance. Within-group significance (p) and effect sizes (Cohen's d) are reported

Table 8. Post-test (T2) between-group differences with 95% CIs and Cohen's d

Test	N (Exp)	Mean ± SD (Exp)	N (Ctrl)	Mean ± SD (Ctrl)	Mean Diff (Exp–Ctrl)	95% CI (Diff)	Cohen's d	95% CI (d)
Arm Curl (reps/30 s)	17	19.3 ± 3.8	17	15.1 ± 3.4	+4.2	+1.77 to +6.63	1.16	0.43 to 1.89
Chair Stand (reps/30 s)	17	16.2 ± 4.1	17	13.9 ± 3.4	+2.3	−0.23 to +4.83	0.61	−0.08 to 1.30
Chair Sit-and-Reach (cm)	17	7.3 ± 4.0	17	1.1 ± 5.1	+6.2	+3.12 to +9.28	1.35	0.60 to 2.10
Single-Leg Stance (s)	17	12.4 ± 5.1	17	11.2 ± 4.5	+1.2	−2.03 to +4.43	0.25	−0.43 to 0.93
Timed Up-and-Go (s)§	17	7.9 ± 0.6	17	8.9 ± 0.7	−1.0	−1.44 to −0.56	−1.53	−2.30 to −0.76

Post-test (T2) between-group comparisons of functional performance outcomes following a 12-week yoga and elastic-band resistance training program. Values are mean ± standard deviation (SD). Mean difference (Exp–Ctrl), 95% confidence intervals (CI), and effect sizes (Cohen's d with 95% CI) are shown. Negative values for Timed Up-and-Go (TUG) indicate faster completion times and thus superior performance in the experimental group

connective tissue compliance) and central neuromuscular adaptations (motor unit recruitment, coordination) that are especially relevant to athletic performance.

Improvements in flexibility in the present study are consistent with prior yoga investigations demonstrating that targeted asanas increase joint range of motion and muscle extensibility (Amin & Goodman, 2014; Gothe & McAuley, 2016). The progressive stretching and sustained holds used in our yoga sequences likely promoted increased tolerance to stretch and viscoelastic changes in musculotendinous units (Amin & Goodman, 2014). Greater hamstring and lumbar flexibility (chair sit-and-reach improvements) can directly benefit groundstrokes and court coverage by allowing larger, more economical ranges of motion during dynamic lunges and rotations, and they may reduce injury risk during high-velocity movements (Gothe & McAuley, 2016; Ni et al., 2014). Given the high prevalence of overuse and musculoskeletal injuries in tennis players, there is a need for conditioning approaches that simultaneously improve performance and reduce injury risk (Rodríguez-González et al., 2024).

Elastic-band training produced clinically relevant strength gains in both upper- and lower-body tests (arm curl, chair stand) (Stojanović et al., 2021). Meta-analytic evidence indicates elastic (band) resistance training yields strength improvements comparable to conventional resistance training across populations (Lopes et al., 2019). For tennis athletes, band-based exercises produce functional, multiplanar loading (rotational chops, resisted rows, single-leg Romanian deadlifts) that transfers well to stroke production and rapid court movements (Fernandez-Fernandez et al., 2013; Koya et al., 2022). The large effect sizes observed in arm curl and chair stand measures in our experimental group suggest elastic resistance served as an effective, low-cost, joint-friendly stimulus to increase muscular endurance and force capacity attributes linked to serve speed and repeated explosive actions in tennis (Fernandez-Fernandez et al., 2013; Moya-Ramon et al., 2020).

Beyond peripheral changes, neuromuscular adaptations help explain rapid performance gains. Early strength improvements, particularly over 6-12 weeks, are often mediated by neural mechanisms including increased motor unit recruitment, firing rate, synchronisation, and reduced antagonist co-contraction (Aagaard, 2003; Aslam et al., 2025). The combined modality in this study (yoga + band work + proprioceptive balance tasks) likely augmented both feedforward and feedback motor control processes. Yoga's emphasis on posture, balance, and mindful control complements resistance work by enhancing proprioceptive acuity and intermuscular coordination; systematic reviews of proprioceptive and balance training document improvements in motor control, reduced injury risk, and better sport-specific performance (Winter et al., 2022; Yılmaz et al., 2024). The balance and agility improvements (single-leg stance and faster TUG scores) are particularly meaningful for tennis, a sport characterised by unilateral demands, sudden changes of direction, and rapid stabilisation after groundstrokes. The yoga balance poses (Tree, Warrior III) combined with unilateral band-loading likely challenged both ankle/hip strategies and trunk control, producing improved static and dynamic stability (Ergin & Arslan, 2020). These results align with meta-analytic and RCT evidence showing that balance and mind–body exercises (yoga, tai chi) improve postural control and reduce fall risk in clinical and older populations (Ni et al., 2014; Howe et al., 2011), and more recent athlete-focused research confirms proprioceptive training benefits rapid change-of-direction and stability (Winter et al., 2022; Francavilla et al., 2025). For tennis players, improved postural control translates into better shot recovery, more stable stroke platforms, and potentially fewer lower-limb injuries (Manojlović et al., 2020).

The cognitive and sensorimotor aspects of yoga breath control, attentional focus, and slow controlled movement likely contributed to enhanced motor planning and decreased movement variability. Neurobiological work has repeatedly shown that physical training stimulates neurotrophic factors and improves sensorimotor integration, which supports learning and coordination (Cotman et al., 2007). Thus, pairing yoga's mindfulness elements with dynamic resistance exercises may foster both physical and central adaptations necessary for fine-tuned athletic skills.

Importantly, the integrated program's sport-specific progressions (weeks 9–12, emphasising resisted sprints and rotational power) were intended to maximise transfer to tennis performance. Evidence suggests that combining strength, power, and neuromuscular training yields greater improvements in explosive tasks (sprint, jump) than isolated modalities (Ma et al., 2025; Rong et al., 2025). While the present investigation focused on functional fitness tests rather than direct tennis performance metrics (e.g., serve velocity or match statistics), previous studies show that improvements in strength, rotational power, and balance relate positively to serve speed and on-court explosive actions (Fernandez-Fernandez et al., 2013; Koya et al., 2022). Future work should therefore include tennis-specific outcomes (serve velocity, sprint times, change-of-direction tests) to confirm transfer.

Study strengths include a randomised, parallel-group design, sport-specific participant selection (Eclipse-category intermediate male players), and rigorous repeated measures across three time points: baseline, mid, and post, which allowed us to capture trajectories of adaptation and demonstrated that meaningful improvements continued after mid-test. The use of widely validated field tests, Rikli & Jones (2013)-derived measures, enhances reproducibility and comparability with other studies, and the requirement for ≥80% attendance preserved intervention fidelity.

The observed improvements in flexibility, balance, and muscular endurance provide plausible pathways to on-court performance. Increased hip and thoracolumbar range of motion (Chair Sit-and-Reach) can facilitate greater trunk–pelvis separation and elastic energy storage during the serve's cocking and acceleration phases, mechanics linked to higher ball velocity (Jacquier-Bret & Gorce, 2024; Gorce & Jacquier-Bret, 2024). Gains in single-leg stance reflect better neuromuscular control at the ankle–knee–hip, which underpins stable stroke platforms after split-steps and during wide-base groundstrokes, thereby reducing compensatory motions that dissipate force. Enhanced lower-body endurance and repeated 30-s chair stands imply improved force maintenance across points and games, contributing to consistent first-step quickness and late-rally agility. Together, yoga's postural control and extensibility plus elastic-band resistance's multiplanar loading likely improved feedforward stabilisation and segmental sequencing both prerequisites for faster serves, sharper change-of-direction, and lower cumulative joint stress.

Our findings align with Guo et al. (2024), who highlight the need for integrated neuromuscular conditioning in adolescent tennis, and extend Deng et al. (2025), showing strength & conditioning interventions improve serve speed by demonstrating parallel gains in flexibility and balance capacities often omitted in serve-centric trials. They also complement Zhou et al. (2025), where neuromuscular training improved service velocity, sprint, and COD, by providing randomised evidence that coupling mobility/balance (yoga) with resistance (bands) produces large effects across multiple functional domains. Compared with device-dependent or lab-based protocols, our elastic-band approach mirrors the practicality emphasised by Hernandez-Martinez et al. (2024), for portable resistance in field settings. Mechanistically, the present pattern of early-to-mid block gains resonates with neural adaptation timelines summarised by Aagaard (2003). To our knowledge, this is among the first RCTs in competitive tennis players testing a yoga + elastic-band hybrid, moving beyond single-modality programs (e.g., plyometrics alone; Fernandez-Fernandez et al., 2013; Moya-Ramon et al., 2020) and addressing calls for multimodal, low-cost interventions.

Stretching-induced flexibility gains are particularly valuable in tennis, as they enhance tendon compliance and reduce injury risk in high SSC movements (Witvrouw et al., 2004). Developing muscular strength through heavy-load and eccentric-based methods underpins power and resilience (Suchomel et al., 2018), while tennis-specific conditioning demands structured resistance programs to sustain performance in the modern game (Reid & Schneiker, 2008). Resistance and plyometric training both benefit youth athletes, with plyometrics effective pre-PHV and resistance training more impactful around/post-PHV (Peitz et al., 2018). Yoga interventions have shown improvements in flexibility, vitality, and overall fitness (Noradechanunt et al., 2017), and when combined with resistance elements, further enhance balance and strength (Jangphonak et al., 2025). Plyometric training also directly improves tennis serve velocity without affecting precision (Behringer et al., 2013). Finally, speed, power, and dominant-side strength strongly correlate with competitive performance, highlighting the need for balanced conditioning in youth players (Girard & Millet, 2009).

Limitations and Future Directions

A key limitation of this study is the use of the Senior Fitness Test (SFT) battery, which was originally validated for older adults. We selected these measures due to their practicality, reproducibility, and minimal equipment requirements, making them suitable for field-based sport science interventions. Previous research has also demonstrated that SFT components can detect meaningful changes in flexibility, balance, and muscular endurance among younger and athletic populations (Polsgrove et al., 2016; Gothe & McAuley, 2016). Nonetheless, the SFT lacks ecological specificity to tennis. Future studies should therefore complement functional assessments with athlete-validated, tennis-specific measures, such as the countermovement jump (CMJ) for explosive lower-body power, the 5-0-5 change-of-direction test for agility and footwork, radar-measured serve speed as a direct sport performance outcome, short sprints (10–20 m) for acceleration and first-step quickness, and the Y-Balance Test for dynamic balance and injury-risk profiling (Fernandez-Fernandez et al., 2013; Moya-Ramon et al., 2020; Zhou et al., 2025). Integrating these outcomes will provide a more comprehensive evaluation of training effects, linking functional fitness improvements to direct tennis performance indicators.

Practical Applications for Coaches and Practitioners

The full protocol requires only elastic bands, floor space, and a mat. Sessions (≈60 min) can be slotted 3×/week in pre-season or 2×/week in-season as maintenance. Start with foundational mobility and bilateral band patterns (weeks 1-4), progress to unilateral and balance-challenging sequences (weeks 5–8), and add tennis-specific rotational/chop and band-assisted footwork (weeks 9-12). Minimal equipment and easy transport make it feasible for academies with limited budgets and for travel blocks. Use simple field markers, a 30-s chair stand, a sit-and-reach, and a single-leg stance to track adaptation and adjust band tension/hold durations.

Pair mobility blocks before on-court sessions (movement quality priming) and use band work on strength/conditioning days to maintain load while limiting joint stress. "The practical value of hybrid yoga–elastic band interventions is reinforced by evidence emphasizing the benefits of portable and low-cost training technologies in sports science (Jaén-Carrillo et al., 2024).

Conclusion

The present randomised controlled trial demonstrated that a 12-week yoga program combined with elastic-band resistance training produced significant improvements in muscular endurance, flexibility, and dynamic mobility among intermediate-level male tennis athletes, compared with regular training alone. Large effect sizes were observed for arm curl repetitions, sit-and-reach flexibility, and Timed Up-and-Go performance, while gains in chair stand repetitions were moderate and improvements in single-leg balance were small and not statistically significant. These findings suggest that integrating yoga with elastic-band training offers a practical, low-cost approach to enhance selected domains of functional fitness relevant to tennis. However, the absence of direct tennis-specific performance metrics (e.g., serve velocity, sprint times, change-of-direction ability) limits conclusions regarding sport-specific transfer. Future research with larger and more diverse cohorts, inclusion of female players, and the use of athlete-validated outcome measures is recommended to confirm and extend these findings.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

AI Transparency Statement

The authors declare that no artificial intelligence (AI) tools were used in the collection, analysis, or interpretation of study data. AI-assisted software (ChatGPT, OpenAI, USA) was employed only for language editing and grammar refinement during manuscript preparation. All scientific content, study design, statistical analysis, and interpretation were performed solely by the authors.

References

Choudhary, P. K., & Dubey, S. (2024). Physiological effects of Zumba exercise on male college students: An intervention study. *Physical Education Theory and Methodology, 24*(3), 404-410. https://doi.org/10.17309/tmfv.2024.3.08

Choudhary, P. K., Dubey, S., Rawat, B., Kumar, S., Pratap, B., Bangari, D., Kumar, S., Prasad, S., & Kaunteya, D. S. (2024). Assessing Strength Effort in Pre-Adolescent Girls: Insights into Effort Accuracy at Different Strength Thresholds. *Physical Education Theory and Methodology, 24*(6), 873-880. https://doi.org/10.17309/tmfv.2024.6.03

Fernandez-Fernandez, J., Ellenbecker, T., Sanz-Rivas, D., Ulbricht, A., & Ferrautia, A. (2013). Effects of a 6-week junior tennis conditioning program on service velocity. *Journal of sports science & medicine, 12*(2), 232-239.

Koya, N., Kitamura, T., & Takahashi, H. (2022). Prediction of Service Performance Based on Physical Strength in Elite Junior Tennis Players. *Frontiers in psychology,* 13, 898224. https://doi.org/10.3389/fpsyg.2022.898224

Kovacs M. S. (2006). Applied physiology of tennis performance. *British journal of sports medicine, 40*(5), 381-386. https://doi.org/10.1136/bjsm.2005.023309

Guo, Y., Xie, J., Dong, G., & Bao, D. (2024). A comprehensive review of training methods for physical demands in adolescent tennis players: a systematic review. *Frontiers in physiology,* 15, 1449149. https://doi.org/10.3389/fphys.2024.1449149

Ramirez-Campillo, R., Thapa, R. K., Afonso, J., Perez-Castilla, A., Bishop, C., Byrne, P. J., & Granacher, U. (2023). Effects of Plyometric Jump Training on the Reactive Strength Index in Healthy Individuals Across the Lifespan: A Systematic Review with Meta-analysis. *Sports medicine (Auckland, N.Z.), 53*(5), 1029-1053. https://doi.org/10.1007/s40279-023-01825-0

Lopes, J. S. S., Machado, A. F., Micheletti, J. K., de Almeida, A. C., Cavina, A. P., & Pastre, C. M. (2019). Effects of training with elastic resistance versus conventional resistance on muscular strength: A systematic review and meta-analysis. *SAGE open medicine,* 7, 2050312119831116. https://doi.org/10.1177/2050312119831116

Hernandez-Martinez, J., Guzmán-Muñoz, E., Cid-Calfucura, I., Villalobos-Fuentes, F., Diaz-Saldaña, D., Alvarez-Martinez, I., Castillo-Cerda, M., Herrera-Valenzuela, T., Branco, B. H. M., & Valdés-Badilla, P. (2024). Elastic Band Training Versus Multicomponent Training and Group-Based Dance on Morphological Variables and Physical Performance in Older Women: A Randomized Controlled Trial. *Life, 14*(11), 1362. https://doi.org/10.3390/life14111362

Bangari, D., Choudhary, P. K., Choudhary, S., Kandpal, A., Singh, H., & Mohit. (2025). Effects of a 12-week integrated core and plyometric training program on tennis skills, agility, strength, and balance in adolescent tennis players. *Pedagogy of Physical Culture and Sports, 29*(4), 308-319. https://doi.org/10.15561/26649837.2025.0408

Choudhary, S., & Choudhary, P. K. (2025). Reframing Mind–Body Medicine: A Case for Integrating Yoga into Neurology Clinics. *Annals of Neurosciences.* https://doi.org/10.1177/09727531251362022

Choudhary, S., Choudhary, P. K., Sahu, K. K., Rajpoot, Y. S., Karmakar, D., & Saha, S. (2025). The impact of a 12-week structured yoga intervention on flexibility, balance, and joint kinematics in university athletes: A quasi-experimental study. *Physical Education Theory and Methodology, 25*(4), 927-937. https://doi.org/10.17309/tmfv.2025.4.22

Dubey, S., & Choudhary, P. K. (2024). Analyzing musculoskeletal flexibility in young females: The impact of a six-week Surya Namaskar intervention on back flexibility and lumbar flexion. *Physical Education Theory and Methodology, 24*(4), 554-561. https://doi.org/10.17309/tmfv.2024.4.06

Amin, D. J., & Goodman, M. (2014). The effects of selected asanas in Iyengar yoga on flexibility: pilot study. *Journal of bodywork and movement therapies, 18*(3), 399-404. https://doi.org/10.1016/j.jbmt.2013.11.008

Gothe, N. P., & McAuley, E. (2016). Yoga Is as Good as Stretching-Strengthening Exercises in Improving Functional Fitness Outcomes: Results From a Randomized Controlled Trial. *The journals of gerontology. Series A, Biological sciences and medical sciences, 71*(3), 406-411. https://doi.org/10.1093/gerona/glv127

Polsgrove, M. J., Eggleston, B. M., & Lockyer, R. J. (2016). Impact of 10-weeks of yoga practice on flexibility and balance of college athletes. *International journal of yoga, 9*(1), 27-34. https://doi.org/10.4103/0973-6131.171710

Chaware, U., & Lum, D. (2024). Effect of Post-Activation potentiation enhancement induced using elastic resistance bands on female track and field jumpers. *Sport Mont, 22*(3), 61-66. https://doi.org/10.26773/smj.241010

Akbar, S., Soh, K. G., Jazaily Mohd Nasiruddin, N., Bashir, M., Cao, S., & Soh, K. L. (2022). Effects of neuromuscular training on athletes physical fitness in sports: A systematic review. *Frontiers in physiology,* 13, 939042. https://doi.org/10.3389/fphys.2022.939042

Buttichak, A., Namboonlue, S., Muangritdech, N., Sriwiset, P., & Namboonlue, C. (2023). Effects of Fitball Exercise on Body Composition, Flexibility, Muscular Strength-Endurance and Aerobic Capacity in Obese Working-Age Women. *Physical Education Theory and Methodology, 23*(5), 707-715. https://doi.org/10.17309/tmfv.2023.5.08

Aagaard P. (2003). Training-induced changes in neural function. *Exercise and Sport Sciences Reviews, 31*(2), 61-67. https://doi.org/10.1097/00003677-200304000-00002

Cotman, C. W., Berchtold, N. C., & Christie, L. A. (2007). Exercise builds brain health: key roles of growth factor cascades and inflammation. *Trends in neurosciences, 30*(9), 464-472. https://doi.org/10.1016/j.tins.2007.06.011

Lim, C. (2019). Multi-Sensorimotor training improves proprioception and balance in subacute stroke patients: a randomized controlled pilot trial. *Frontiers in Neurology,* 10. https://doi.org/10.3389/fneur.2019.00157

Moya-Ramon, M., Nakamura, F. Y., Teixeira, A. S., Granacher, U., Santos-Rosa, F. J., Sanz-Rivas, D., & Fernandez-Fernandez, J. (2020). Effects of Resisted Vs. Conventional Sprint Training on Physical Fitness in Young Elite Tennis Players. *Journal of human kinetics,* 73, 181-192. https://doi.org/10.2478/hukin-2019-0142

Zhou, Y., Bai, Y., Liang, Y., Yang, K., & Yang, Y. (2025). Effects of neuromuscular training on tennis players: A systematic review and meta-analysis. *BMC Sports Science, Medicine and Rehabilitation, 17*(1), 172. https://doi.org/10.1186/s13102-025-01219-x

Deng, N., Soh, K. G., Xu, F., & Yang, X. (2025). The effects of strength and conditioning interventions on serve speed in tennis players: a systematic review and meta-analysis. *Frontiers in physiology,* 15, 1469965. https://doi.org/10.3389/fphys.2024.1469965

Jacquier-Bret, J., & Gorce, P. (2024). Kinematics characteristics of key point of interest during tennis serve among tennis players: a systematic review and meta-analysis. *Frontiers in sports and active living,* 6, 1432030. https://doi.org/10.3389/fspor.2024.1432030

Winter, L., Huang, Q., Sertic, J. V. L., & Konczak, J. (2022). The Effectiveness of proprioceptive Training for Improving Motor performance and Motor Dysfunction: A Systematic review. *Frontiers in Rehabilitation Sciences,* 3. https://doi.org/10.3389/fresc.2022.830166

Yılmaz, O., Soylu, Y., Erkmen, N., Kaplan, T., & Batalik, L. (2024). Effects of proprioceptive training on sports performance: a systematic review. *BMC sports science, medicine & rehabilitation, 16*(1), 149. https://doi.org/10.1186/s13102-024-00936-z

Pšeničnik Sluga, S., & Kozinc, Z. (2024). Sensorimotor and proprioceptive exercise programs to improve balance in older adults: a systematic review with meta-analysis. *European journal of translational myology, 34*(1), 12010. https://doi.org/10.4081/ejtm.2024.12010

Muangritdech, N., Promsrisuk, T., Kongsui, R., Sriraksa, N., Thongrong, S., & Srithawong, A. (2023). Exploring the Impact of Combined Thai Yoga and Elastic Band Exercise on Physical Fitness and Exercise Capacity in Older Patients with Type 2 Diabetes. *Physical Education Theory and Methodology, 23*(6), 894-901. https://doi.org/10.17309/tmfv.2023.6.11

Ma, S., Xu, Y., & Xu, S. (2025). Effects of Physical Training Programs on Healthy Athletes' Vertical Jump Height: A Systematic Review With Meta-Analysis. *Journal of sports science & medicine, 24*(2), 236-257. https://doi.org/10.52082/jssm.2025.236

Rong, W., Soh, K. G., Samsudin, S., Zhao, Y., Wang, X., Zhang, X., & Cao, L. (2025). Effect of resistance training on kinetic and kinematic indicators in jump athletes: A systematic review. *BMC Sports Science, Medicine and Rehabilitation, 17*(1), 210. https://doi.org/10.1186/s13102-025-01249-5

Choudhary, P. K., Choudhary, S., Saha, S., Karmakar, D., Rajpoot, Y. S., Sharma, A., Prasad, S., Pratap, B., Dharam, D. S., Sisodiya, K., & Prajapati, P. (2025). The transformative impact of high-intensity interval training on performance indicators among adolescent tennis players. *Retos,* 69, 799-810. https://doi.org/10.47197/retos.v69.114111

Jangphonak, P., Bussamonkol, P., Suksong, P., & Thonglong, T. (2025). Effect of yoga combined elastic band program on health-physical fitness and balance in older adults. *Physical Rehabilitation and Recreational Health Technologies, 10*(1), 42-48. https://doi.org/10.15391/prrht.2025-10(1).06

Rikli, R. E., Jones, C.J. (2013). *Senior Fitness Test Manual - 2nd Edition*. Human Kinetics

Ni, M., Mooney, K., Richards, L., Balachandran, A., Sun, M., Harriell, K., Potiaumpai, M., & Signorile, J. F. (2014). Comparative impacts of Tai Chi, balance training, and a specially-designed yoga program on balance in older fallers. *Archives of physical medicine and rehabilitation, 95*(9), 1620-1628.e30. https://doi.org/10.1016/j.apmr.2014.04.022

Rodríguez-González, E. M., Amor-Salamanca, M. S., Rosselló, D., de Lluc-Bauza, M., Hermosilla-Perona, F., Martín-Castellanos, A., & Herrera-Peco, I. (2024). Exploring prevalent injuries among tennis players and optimal rehabilitation approaches: A systematic review protocol. *PloS one, 19*(11), e0309232. https://doi.org/10.1371/journal.pone.0309232

Stojanović, M. D. M., Mikić, M. J., Milošević, Z., Vuković, J., Jezdimirović, T., & Vučetić, V. (2021). Effects of Chair-Based, Low-Load Elastic Band Resistance Training on Functional Fitness and Metabolic Biomarkers in Older Women. *Journal of sports science & medicine, 20*(1), 133-141. https://doi.org/10.52082/jssm.2021.133

Aslam, S., Habyarimana, J. D., & Bin, S. Y. (2025). Neuromuscular adaptations to resistance training in elite versus recreational athletes. *Frontiers in physiology,* 16, 1598149. https://doi.org/10.3389/fphys.2025.1598149

Ergin, E., & Arslan, E. (2020). The effect of 8-Week balance training on the agility, strength, balance performance and tennis skills of 10-14 Year-Old tennis players. *Journal of Educational Issues, 6*(2), 170. https://doi.org/10.5296/jei.v6i2.17450

Howe, T. E., Rochester, L., Neil, F., Skelton, D. A., & Ballinger, C. (2011). Exercise for improving balance in older people. *The Cochrane database of systematic reviews, 2011*(11), CD004963. https://doi.org/10.1002/14651858.CD004963.pub3

Francavilla, V. C., Messina, G., Mingrino, O., Parisi, M. C., & Di Corrado, D. (2025). Effects of a Specific Proprioceptive Training Program on Injury Prevention and Stress in Basketball Players: A Pilot Study. *Journal of functional morphology and kinesiology, 10*(2), 226. https://doi.org/10.3390/jfmk10020226

Manojlović, M. (2020). The efficiency of proprioceptive training in preventing injuries to team athletes: A systematic review. *Exercise and Quality of Life, 13*(2), 37-46. https://doi.org/10.31382/eqol.211205

Gorce, P., & Jacquier-Bret, J. (2024). Are there kinematic and kinetic parameters correlated with racket velocity during the tennis serve? A preliminary comparison between a slow and a fast serve for performance improvement. *Frontiers in Sports and Active Living,* 6. https://doi.org/10.3389/fspor.2024.1451174

Witvrouw, E., Mahieu, N., Danneels, L., & McNair, P. (2004). Stretching and injury prevention. *Sports Medicine, 34*(7), 443-449. https://doi.org/10.2165/00007256-200434070-00003

Suchomel, T. J., Nimphius, S., Bellon, C. R., & Stone, M. H. (2018). The Importance of Muscular Strength: Training Considerations. *Sports medicine (Auckland, N.Z.), 48*(4), 765-785. https://doi.org/10.1007/s40279-018-0862-z

Reid, M., & Schneiker, K. (2008). Strength and conditioning in tennis: current research and practice. *Journal of science and medicine in sport, 11*(3), 248-256. https://doi.org/10.1016/j.jsams.2007.05.002

Peitz, M., Behringer, M., & Granacher, U. (2018). A systematic review on the effects of resistance and plyometric training on physical fitness in youth- What do comparative studies tell us? *PloS one, 13*(10), e0205525. https://doi.org/10.1371/journal.pone.0205525

Noradechanunt, C., Worsley, A., & Groeller, H. (2017). Thai Yoga improves physical function and well-being in older adults: A randomised controlled trial. *Journal of science and medicine in sport, 20*(5), 494-501. https://doi.org/10.1016/j.jsams.2016.10.007

Behringer, M., Neuerburg, S., Matthews, M., & Mester, J. (2013). Effects of two different resistance-training programs on mean tennis-serve velocity in adolescents. *Pediatric exercise science, 25*(3), 370-384. https://doi.org/10.1123/pes.25.3.370

Girard, O., & Millet, G. P. (2009). Physical determinants of tennis performance in competitive teenage players. *Journal of strength and conditioning research, 23*(6), 1867-1872. https://doi.org/10.1519/JSC.0b013e3181b3df89

Jaén-Carrillo, D., Pérez-Castilla, A., & García-Pinillos, F. (2024). Wearable and Portable Devices in Sport Biomechanics and Training Science. *Sensors (Basel, Switzerland), 24*(14), 4616. https://doi.org/10.3390/s24144616

Appendix Table

Table A1. Comparison of Functional Fitness Tests with Tennis-Specific Alternatives

Functional Test Used	Fitness Component	Tennis-Specific Alternative	Relevance to Tennis Performance
Chair Stand (30 s)	Lower-body muscular endurance	Countermovement Jump (CMJ)	Explosive power for serves, jumps, and rapid recovery steps
Arm Curl (30 s)	Upper-body muscular endurance	Serve speed (radar gun)	Direct indicator of stroke power and effectiveness
Chair Sit-and-Reach	Flexibility (hamstrings/ lower back)	Hip and shoulder range of motion (ROM) tests	Greater reach in strokes, improved trunk rotation, reduced injury risk
Single-Leg Stance	Static balance	Y-Balance Test	Dynamic balance, asymmetry detection, injury prevention in unilateral tennis movements
Timed Up-and-Go (TUG)	Agility, mobility	5-0-5 Change of Direction (COD), 10–20 m sprint	Court coverage, first-step quickness, rapid directional changes

Note: Functional tests were chosen for their field-friendliness and reproducibility. Tennis-specific tests are recommended for future trials to enhance ecological validity.

Table A2. Elastic-Band Resistance Calibration and Progression

Band Color	Resistance at 100% elongation (kg)	Resistance at 200% elongation (kg)	Weeks Applied	Progression Notes
Yellow	~1.4	~2.6	Weeks 1–2	Initial familiarisation, low-load adaptation
Red	~2.3	~4.1	Weeks 3–4	Introduced moderate resistance, bilateral focus
Green	~3.2	~5.7	Weeks 5–8	Transition to higher resistance, unilateral balance emphasis
Blue	~4.5	~8.0	Weeks 9–12	Peak training block, resisted sprints and rotational power drills

Note: Resistance values approximate manufacturer calibration (TheraBand®, Hygenic Corp., USA). Band tension was increased progressively to maintain target RPE 6–8/10.

Аналіз впливу 12-тижневої програми йоги та силових тренувань з еластичними стрічками на функціональну підготовленість тенісистів-чоловіків середнього рівня кваліфікації: Рандомізоване контрольоване дослідження

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – стataналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 13 с., 8 табл., 1 рис., 52 джерела.

Історія питання. Йога та силові тренування з еластичними стрічками (СТЕС) є економічно ефективними методами поліпшення фізичної функції, проте їхній сукупний вплив на молодих спортсменів-тенісистів, які беруть участь у змаганнях, залишається недостатньо дослідженим.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу 12-тижневої програми йоги та СТЕС на функціональну фізичну підготовленість тенісистів-чоловіків середнього рівня кваліфікації.

Матеріали та методи. Тридцять чотири спортсмени (вік 20.3 ± 1.5 років) було розподілено за методом рандомізації на експериментальну групу (йога + СТЕС, n = 17) та контрольну групу (регулярні тренування з тенісу, n = 17). Оцінювання функціональних результатів проводилося на початку дослідження, на 6-му та 12-му тижні за допомогою наступних тестів: вставання зі стільця і сідання назад, не використовуючи рук, згинання рук із підйомом ваги на біцепс, вимірювання гнучкості шляхом сидіння на стільці та спроби дотягнутися рукою до пальців витягнутої ноги, стояння на одній нозі та тесту «Встань та йди» (TUG). Із застосуванням дисперсійного аналізу з 2 × 3 повторними вимірами оцінювали ефекти групи × часу, причому розміри ефекту повідомлялися як коефіцієнт d Коена та частковий ета-квадрат (η^2_p) з 95% довірчими інтервалами (ДІ).

Результати. Встановлено значущі взаємодії між групою та часом для всіх показників ($p < 0.01$). На етапі посттесту експериментальна група продемонструвала кращу результативність порівняно з контрольною групою у виконанні тестів на згинання рук із підйомом ваги на біцепс (+4.2 повторення, 95% ДІ [1.77, 6.63], d = 1.16), вставання зі стільця і сідання назад, не використовуючи рук (+2.3 повторення, 95% ДІ [−0.23, 4.83], d = 0.61), сидіння на стільці та спроби дотягнутися рукою до пальців витягнутої ноги (+6.2 см, 95% ДІ [3.12, 9.28], d = 1.35) і TUG (−1.0 с, 95% ДІ [−1.44, −0.56], d = −1.53). Поліпшення в утриманні рівноваги на одній нозі були незначними і неістотними (+1.2 с, 95% ДІ [−2.03, 4.43], d = 0.25). Рівень відвідуваності становив в середньому 88%, побічних реакцій не зафіксовано.

Висновки. 12-тижнева програма йоги та СТЕС значно покращила м'язову витривалість, гнучкість та рухливість, порівнюючи з регулярними тренуваннями, причому великі розміри ефекту спостерігалися для витривалості верхньої частини тіла, гнучкості та динамічної спритності. Зазначені результати підтверджують доцільність використання комбінованих протоколів йоги та тренувань з еластичними стрічками як практичного варіанту підготовки молодих спортсменів-тенісистів. Подальші дослідження повинні включати специфічні для тенісу метрики результативності з метою підтвердження спортивної трансферабельності.

Ключові слова: йога, силові тренування з еластичними стрічками, спортсмени-тенісисти, функціональна підготовленість, рівновага, гнучкість.

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Original Scientific Article

Enhancing Skill Performing Competency among Handball Players: Comparative Effects of Mental Imagery, Self-Talk, and Their Combination

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Abstract
Objectives. The objective of this study was to examine the comparative and combined effects of mental imagery and self-talk training on handball players' jump-shoot skill performing competency. The study aimed to determine whether integrating both psychological techniques leads to greater improvement in motor performance than using either strategy alone or traditional practice.
Materials and Methods. Forty male handball players were randomly assigned to four groups (n = 10 each): Mental Imagery and Self-Talk, Mental Imagery, Self-Talk, and Control. The experimental groups received a six-week psychological skills training intervention, while the control group participated only in regular handball practice. The Handball Jump-Shoot Skill Performing Competency test was administered before and after the intervention. Data were analyzed using Analysis of Covariance (ANCOVA) to control for pre-test differences, followed by Bonferroni post-hoc tests for pairwise comparisons.
Results. The ANCOVA revealed a significant group effect on post-test scores, $F_{(3, 35)} = 18.18$, $p < .001$, with an adjusted $R^2 = .665$. The Mental Imagery and Self-Talk group demonstrated the highest improvement (pre-mean = 13.90; post-mean = 17.70), followed by the Mental Imagery and Self-Talk groups, while the Control group showed minimal gain. Post-hoc analysis confirmed that the combined intervention produced significantly better results than all other groups ($p < .05$).
Conclusions. The findings suggest that the combined application of mental imagery and self-talk was the most effective psychological intervention for enhancing handball jump-shoot skill performance, emphasizing the synergistic value of integrating cognitive and motivational training strategies in sport performance improvement.
Keywords: mental imagery, self-talk, psychological skills training, handball performance, jump-shoot competency.

Introduction

Psychological skills play a vital role in enhancing athletic performance, particularly when athletes compete under pressure where physical preparation alone may not suffice. In recent years, mental training techniques such as mental imagery and self-talk have gained recognition as powerful tools to optimize skill execution, regulate emotion, and improve focus during performance (Rupprecht, Tran, & Groepel, 2024). Mental imagery involves the cognitive rehearsal of movements without physical execution, stimulating neural patterns similar to those activated during actual performance (Guillot & Collet, 2020). In contrast, self-talk refers to the verbal or internal dialogue athletes use to direct attention, enhance confidence, and control anxiety (Hatzigeorgiadis, Zourbanos, Galanis, & Theodorakis, 2011). Both techniques have demonstrated performance benefits in a wide range of sports, including basketball, tennis, and swimming (Tod et al., 2011; Slimani et al., 2016). In performance psychology, visualization technique has been a standardized training method contributes to improving athletic performance in a wide range of sports (Sharma et.al., 2024).

Despite strong evidence supporting both interventions, the main controversy in current literature concerns whether combining mental imagery and self-talk produces superior effects compared to using either technique alone. Some studies suggest that integrating both methods may create synergistic benefits, enhancing motivation, focus, and motor coordination more effectively than either intervention independently (Slimani et al., 2016). Others argue that since each technique already targets similar cognitive mechanisms—such as attentional control and self-efficacy—their combination may not yield additional improvements (Hatzigeorgiadis et al., 2020). This debate remains unresolved, particularly in handball, where rapid decision-making and precise execution are critical to performance outcomes.

Handball jump-shooting represents one of the most essential and complex offensive skills, requiring accurate timing, motor coordination, and confidence under defensive pressure. Research indicates that mental imagery can significantly improve throwing accuracy and goal-scoring ability in handball (Muluken & Konka, 2019), while self-talk interventions have enhanced motor performance, motivation, and error correction (Zourbanos et al., 2013; Theodorakis et al., 2012). Yet, the comparative and combined effects of these two interventions on jump-shoot skill competency remain inadequately studied. Recent findings in similar sports, such as badminton and basketball, suggest that combining self-talk and imagery training can yield higher improvements in skill learning and execution (Hidayat et al., 2023). However, limited evidence exists for handball players, creating a research gap that this study aims to address.

An analysis of recent research and publications shows increasing interest in psychological training programs in sports. For example, meta-analyses reveal that mental imagery interventions yield moderate-to-large effects on performance (Cumming & Williams, 2012; Guillot & Collet, 2020), while self-talk interventions have also been shown to significantly enhance focus and reduce anxiety (Hatzigeorgiadis et al., 2011). Despite these advances, only a few studies have systematically compared the effects of these techniques in a controlled experimental framework or tested their combined influence on handball-specific motor skills (Slimani et al., 2016; Hidayat et al., 2023). This lack of comparative evidence limits the practical understanding of how coaches should prioritize or integrate psychological training into handball practice routines.

Hypothesis: Based on this theoretical and empirical background, the hypothesis of the present study states that the combined Mental Imagery and Self-Talk training will produce greater improvements in Handball Jump Shoot Skill Performing Competency than either Mental Imagery or Self-Talk alone, and that both individual interventions will outperform the Control group.

Purpose of the Study: Therefore, the purpose of the study is to critically examine and compare the effects of Mental Imagery, Self-Talk, and Combined Mental Imagery with Self-Talk interventions on Handball Jump Shoot Skill Performing Competency among secondary school athletes. This study seeks to determine whether the combined approach produces a statistically significant improvement over the single-method interventions, thereby contributing to the optimization of psychological training strategies in handball and potentially across similar team sports.

Materials and Methods

Study Participants

Forty (N = 40) male handball players were selected as participants for this study from Lakshmibai National Institute of Physical Education (LNIPE), India. The participants' age ranged from 18 to 27 years. All players had prior competitive handball experience and were free from injury or illness during the experimental period. The participants were randomly divided into four groups of ten members each to ensure equal representation and control of individual differences. The four groups included: Mental Imagery, Self-Talk, Combined Mental Imagery and Self-Talk, and Control Group. Each participant provided voluntary consent to participate in the study, and ethical approval was obtained from the concerned institutional authority.

Study Organization

The research followed a true experimental pre-test post-test randomized group design. This design was selected to assess the effect of different psychological training interventions—Mental Imagery, Self-Talk, and their combination—on the improvement of handball players' jump shoot skill performing competency.

The study was organized in three phases:

1. Pre-Test Phase:

All participants underwent a baseline assessment of Handball Jump Shoot Skill Performing Competency using the standardized Zinn Team Handball Skills Battery Test. This pre-test established the initial skill levels of the players before any intervention.

2. Intervention Phase:

The experimental groups participated in distinct psychological skill training programs for eight weeks, conducted three times per week. Each session lasted 20 to 50 minutes, increasing gradually in duration as the participants adapted to the training.

The Mental Imagery group practiced guided visualization of jump shooting techniques, incorporating sensory and situational elements. The Self-Talk group used structured instructional and motivational phrases to enhance focus and emotional regulation during performance. The Combined Mental Imagery and Self-Talk group integrated both techniques in a synchronized manner, involving relaxation, visualization, and verbal cueing. The Control group continued with their regular handball training without any additional psychological interventions.

The training progression followed a planned pedagogical sequence to ensure gradual development of cognitive and emotional control, beginning with basic relaxation and imagery practice, and advancing to performance under simulated pressure conditions.

3. Post-Test Phase:

After completing the eight-week intervention, all participants were reassessed using the same Handball Jump Shoot Skill Performing Competency test to measure performance improvement.

This structured and progressive organization allowed a systematic evaluation of the effects of psychological skill training on handball performance.

Administration of the Test

Zinn team handball skills battery test from which handball jump shoot skill performing competency:

The Handball Shooting Ability Test is designed to measure the shooting proficiency of players in team handball. The test requires a marked level floor or ground with a smooth surface, a stopwatch, a standard handball, rope or string, measuring tape, marking tape, and scorecards or recording sheets along with a pencil for recording the results. The front surface area of the team handball goal is divided using rope or string into eight distinct sections, each assigned a specific number of points that correspond to the difficulty of successfully shooting the ball into that particular area.

During the test, each player is given five opportunities to perform a jump throw. Players are allowed to take three steps before releasing the ball, ensuring that the final step occurs outside the free-throw line (9-meter line). If the ball touches the ground before reaching the goal, no points are awarded for that attempt. All shots must be executed from behind the 9-meter line, and adherence to this rule is essential for maintaining the validity of the attempt.

Scoring is based on the difficulty level of the target zones within the goal. Players earn points for each successful throw according to the designated value of the section hit. Throws that hit the court surface before reaching the goal are awarded zero points. The final score for each player is calculated by summing the points earned across all five throws, with a maximum possible score of 20 points representing optimal shooting accuracy and consistency.

Description of Exercise

The psychological skills training program was conducted three times per week for eight weeks. Session duration progressed gradually, starting from 20–30 minutes in the initial weeks and extending to 50 minutes by the 8th week to allow adaptation and deeper practice.

Combined Mental Imagery + Self-talk (Group A): Sessions included relaxation, visualization of jump shots, and synchronized instructional/motivational cues. Training progressed from basic imagery and simple cues to complex, pressure-based scenarios.

Mental Imagery (Group B): Athletes practiced relaxation, guided and independent visualization of jump shots, integrating sensory detail and correcting errors. Progression moved from simple technical rehearsal to situational imagery under time or defensive pressure.

Self-talk (Group C): Training focused on relaxation, structured instructional and motivational phrases, and their application in simulated match conditions. Progression advanced from practicing cue words to automatic use under pressure.

Control Group (Group D): Continued regular handball training without additional intervention.

This progressive schedule ensured consistent psychological skill development, with each intervention tailored to improve focus, confidence, and accuracy in handball jump shots.

Research Design

The study adopted a true experimental pre-test post-test randomized group design. Participants were randomly assigned to four groups of ten athletes each: Group I (Mental Imagery), Group II (Self-talk), Group III (Mental Imagery and Self-talk combined), and Group IV (Control group). Pre-tests were conducted using the Zinn Team Handball Skills Battery Test from which Handball Jump Shoot Skill Performing Competency was chosen as the primary skill performing variable to assess Handballers Skill Performance. Following this, the three experimental groups underwent an eight-week psychological skills training program, with each group practicing their respective intervention. The Control group continued with their routine practice sessions without additional intervention. At the end of the eight weeks, the Handball Jump Shoot Skill Performing Competency was again administered as a post-test measure. The pre-test and post-test scores of the Handball Jump Shoot Skill Performing Competency was used for statistical analysis to determine the effectiveness of the interventions.

Statistical Analysis

The collected data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics, including mean and standard deviation, were used to summarize the performance scores of each group.

Inferential statistics were applied to determine the significance of the observed differences between pre-test and post-test scores. Analysis of Covariance (ANCOVA) was used to compare post-test means among the four groups while controlling for pre-test differences. This helped to accurately estimate the true effect of the interventions. When significant differences were detected, Bonferroni post hoc tests were performed to identify specific group-wise comparisons.

The level of statistical significance was set at $p < 0.05$, indicating a 95% confidence level. The use of ANCOVA and Bonferroni tests provided a robust approach to determining which intervention—Mental Imagery, Self-Talk, or their combination—had the most significant effect on improving handball jump shoot skill performing competency.

Result

Table 1 presents the overall Handball Jump Shoot Skill Performing Competency Scores for all four groups—Mental Imagery and Self-Talk, Mental Imagery, Self-Talk, and Control. The results indicate a noticeable improvement in the post-test mean scores across all experimental groups compared to their pre-test scores, whereas the Control group showed minimal change. The Mental Imagery and Self-Talk group demonstrated the highest improvement, with the mean score increasing from 13.90 to 17.70, accompanied by a reduction in standard deviation from 2.02 to 1.41, suggesting more consistent performance among participants. The Mental Imagery group also showed a substantial improvement, with the mean score rising

Table 1. Overall Handball Jump Shoot Skill Performing Competency Score

Groups	N	Pre-Mean	Post Mean	Pre SD	Post SD
Mental Imagery and Self-Talk	10	13.9	17.7	2.02485	1.41814
Mental Imagery	10	12.0	15.0	2.05480	2.05480
Self-Talk	10	10.9	12.9	2.33095	2.46982
Control Group	10	8.9	9.2	1.91195	2.65832

from 12.00 to 15.00, while the Self-Talk group recorded an increase from 10.90 to 12.90. In contrast, the Control group exhibited a marginal increase in mean score from 8.90 to 9.20, indicating that regular handball practice without psychological intervention had minimal influence on performance enhancement. Overall, the data suggest that psychological skills training interventions, particularly the combined use of Mental Imagery and Self-Talk, were more effective in enhancing handball players' jump shoot skill performing competency than either technique alone or no intervention at all.

Table 2. Inferential Statistical Analysis Using ANCOVA for Overall Handball Jump Shoot Skill Performing Competency Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	392.012[a]	4	98.003	20.370	.000
Intercept	297.430	1	297.430	61.822	.000
Handball Accuracy Pre	6.212	1	6.212	1.291	.264
Groups	262.440	3	87.480	18.183	.000
Error	168.388	35	4.811		
Total	8068.000	40			
Corrected Total	560.400	39			

a. R Squared = .700 (Adjusted R Squared = .665)

Table 2 presents the inferential statistical analysis using ANCOVA for the Overall Handball Jump Shoot Skill Performing Competency Scores among the four groups—Mental Imagery and Self-Talk, Mental Imagery, Self-Talk, and Control. The analysis aimed to determine the effectiveness of the psychological training interventions while controlling for the influence of pre-test scores. The results indicate that the model was statistically significant ($F = 20.370$, $p < .001$), suggesting that the interventions had a meaningful impact on post-test performance scores. The R Squared value of .700 (Adjusted $R^2 = .665$) reveals that approximately 70% of the variance in post-test performance can be explained by the independent variables included in the model, indicating a strong effect of the training interventions. The covariate, Handball Accuracy Pre-test, was found to be non-significant ($F = 1.291$, $p = .264$), showing that the pre-test scores did not significantly influence the post-test results. However, a significant main effect of Groups was observed ($F = 18.183$, $p < .001$), confirming that the differences among the four training conditions were statistically significant. Overall, the ANCOVA results demonstrate that the psychological training programs—particularly the combined Mental Imagery and Self-Talk intervention—produced a significant improvement in handball players' jump shoot skill performing competency compared to the other groups and the control condition.

Table 3. Pairwise Comparison done for critical analysis for the Post hoc test using Bonferroni for Handball Jump Shoot Skill Performing Competency Score

(I) Groups	(J) Groups	Mean Difference (I-J)	Sig.[b]
Mental Imagery and Self-Talk	Mental Imagery	3.078*	.032
	Self-Talk	5.397*	.000
	Control Group	9.496*	.000
Mental Imagery	Mental Imagery and Self-Talk	-3.078*	.032
	Self-Talk	2.319	.158
	Control Group	6.417*	.000
Self-Talk	Mental Imagery and Self-Talk	-5.397*	.000
	Mental Imagery	-2.319	.158
	Control Group	4.098*	.002
Control Group	Mental Imagery and Self-Talk	-9.496*	.000
	Mental Imagery	6.417*	.000
	Self-Talk	-4.098*	.002

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 3 presents the results of the pairwise comparison conducted through a Post Hoc test using the Bonferroni adjustment for the Handball Jump Shoot Skill Performing Competency Scores. The analysis was performed to identify specific differences among the four groups—Mental Imagery and Self-Talk, Mental Imagery, Self-Talk, and Control—following the significant ANCOVA results. The findings indicate that the Mental Imagery and Self-Talk group demonstrated significantly higher post-test scores compared to all other groups. Specifically, significant differences were observed when compared with the Mental Imagery group (Mean Difference = 3.078, $p = .032$), Self-Talk group (Mean Difference = 5.397, $p < .001$), and Control group (Mean Difference = 9.496, $p < .001$). These results suggest that the combined intervention of Mental Imagery and Self-Talk was the most effective psychological training approach for enhancing handball skill performance. Additionally, the Mental Imagery group also showed a significant improvement over the Control group (Mean Difference = 6.417, $p < .001$), though the difference between Mental Imagery and Self-Talk groups was not statistically significant ($p = .158$). Similarly, the Self-Talk group outperformed the Control group (Mean Difference = 4.098, $p = .002$). Overall, the Bonferroni post hoc results reveal a clear hierarchical pattern in intervention effectiveness: Mental Imagery and Self-Talk > Mental Imagery > Self-Talk > Control. This demonstrates that integrating both psychological strategies leads to superior performance gains in Handball Jump Shoot Skill Performing Competency compared to using either strategy alone.

Discussion

Overview of the Main Hypothesis

The main hypothesis of this study proposed that the combined practice of Mental Imagery and Self-Talk would significantly enhance Handball Jump Shoot Skill Performing Competency compared to the use of either technique individually or the absence of psychological intervention. The results from ANCOVA and post hoc analysis clearly supported this hypothesis, revealing that athletes who engaged in both Mental Imagery and Self-Talk training exhibited the highest post-test mean scores. This suggests a synergistic interaction between cognitive visualization and verbal cueing, where the integration of both methods amplifies focus, accuracy, and self-regulation. The findings are consistent with contemporary research emphasizing the efficacy of psychological skill integration in sports training (Hidayat et al., 2023; Theodorakis et al., 2001).

Discussion of Conclusions (Comparison with Previous Studies)

The results of this study align with prior findings that combined psychological interventions lead to greater improvements in sport-specific skills than single-method approaches. The Mental Imagery and Self-Talk group demonstrated the highest mean improvement, suggesting a synergistic effect between visualization and verbal regulation techniques. This finding is consistent with Holmes and Collins (2001), who noted that imagery coupled with cognitive cues enhances motor learning and performance consistency. Similarly, Hardy et al. (2001) emphasized that self-talk improves focus and self-regulation during performance execution. In contrast, while the Mental Imagery and Self-Talk groups individually improved compared to the control group, their combined use appeared to integrate both the cognitive and motivational components necessary for optimal performance outcomes (Tod, Hardy, & Oliver, 2011). Comparable trends have been observed in basketball and football training, where integrating imagery and verbal strategies produced superior skill retention (Hatzigeorgiadis et al., 2009; Munroe-Chandler, Hall, & Fishburne, 2008).

Justifications and Importance of the Results

The findings underscore the growing recognition that psychological interventions are not merely supplementary but essential components of athletic training programs. In Handball, where rapid decision-making and precise motor coordination are vital, the ability to mentally rehearse actions before physical execution can significantly enhance performance accuracy (Moran, Guillot, & MacIntyre, 2012). The present study confirms that structured psychological training cultivates self-efficacy and reduces performance anxiety—factors directly influencing skill acquisition (Behncke, 2004; Birrer & Morgan, 2010). Furthermore, these results hold pedagogical importance for sports educators, demonstrating that incorporating psychological conditioning alongside technical drills can lead to comprehensive athlete development (Vealey & Greenleaf, 2010).

Practical Application of the Results

From a practical standpoint, the application of combined Mental Imagery and Self-Talk techniques offers coaches and trainers an accessible, low-cost, and scientifically supported tool to improve performance outcomes. Implementing guided imagery sessions before practice and employing constructive self-talk scripts during skill rehearsal can strengthen focus and motor execution in young athletes (Gould et al., 2014). These methods can be easily adapted into existing training curricula without extensive infrastructural resources, making them feasible for school-level sports programs. The integration of psychological training also helps in developing resilience, coping mechanisms, and motivation—key attributes for sustaining high-level performance in competitive Handball environments (Thelwell & Greenlees, 2003; Hatzigeorgiadis et al., 2011).

Prospects for Further Research

The outcomes of this study open new avenues for exploring the long-term and sport-specific implications of combined psychological training methods. Future research may investigate how varying durations, intensities, or modalities of mental skills training affect performance across different age groups and genders. Moreover, integrating neurophysiological measures such as EEG or EMG responses could provide objective evidence of how cognitive interventions influence motor activation patterns. Expanding this line of inquiry will deepen the understanding of the mind–performance relationship, ultimately contributing to more effective, evidence-based training models in Handball and other skill-dominant sports.

Conclusion

The present study demonstrates that psychological skills training interventions, particularly the combination of Mental Imagery and Self-Talk, significantly enhance Handball Jump Shoot Skill Performing Competency among secondary school athletes. The findings indicate that while both Mental Imagery and Self-Talk individually improve skill performance compared to standard training, their combined application produces superior results, reflecting a synergistic effect. This supports the primary purpose of the study, which was to evaluate the comparative effectiveness of different psychological interventions in improving handball-specific skill performance. The results provide empirical evidence that integrating cognitive visualization with motivational and instructional self-talk can optimize both motor execution and mental readiness in competitive scenarios.

Furthermore, the study underscores the practical value of psychological training as an integral component of sports education and coaching. Coaches and trainers can implement structured mental imagery and self-talk protocols to enhance athletes' focus, accuracy, and confidence, without requiring additional physical training time. The results also highlight the potential for these interventions to reduce performance variability and enhance consistency across different athletes. In conclusion, the study not only confirms the effectiveness of combined mental training strategies but also offers a foundation for future research to explore long-term effects, variations across age and skill levels, and integration with other sport-specific psychological techniques to maximize overall athletic performance.

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Conflict of Interest

Authors declare no conflict of interest.

References

Rupprecht, A. G., Tran, U. S., & Groepel, P. (2024). The effectiveness of pre-performance routines in sports: a meta-analysis. *International Review of Sport and Exercise Psychology, 17*(1), 39-64. https://doi.org/10.1080/1750984X.2021.1944271

Guillot, A., & Collet, C. (2020). The neuroscience of motor imagery: New perspectives for sport psychology. *Frontiers in Human Neuroscience,* 14, 36.

Hatzigeorgiadis, A., Zourbanos, N., Galanis, E., & Theodorakis, Y. (2011). Self-talk and sports performance: A meta-analysis. *Perspectives on Psychological Science, 6*(4), 348-356. https://doi.org/10.1177/1745691611413136

Tod, D., Hardy, J., & Oliver, E. (2011). Effects of self-talk: A systematic review. *Journal of Sport & Exercise Psychology, 33*(5), 666-687. https://doi.org/10.1123/jsep.33.5.666

Slimani, M., Tod, D., Chaabene, H., Miarka, B., & Chamari, K. (2016). Effects of Mental Imagery on Muscular Strength in Healthy and Patient Participants: A Systematic Review. *Journal of sports science & medicine, 15*(3), 434-450.

Sharma, A., Prasad, B. K., Das, R., Sharma, A., Karmakar, D., & Choudhary, P. K. (2024). Analyzing the Impact of VMBR Training on Table Tennis Players' Competence in Performing Alternate Counter and Forehand Drive Shots with Precision. *Physical Education Theory and Methodology, 24*(3), 382-387. https://doi.org/10.17309/tmfv.2024.3.05

Hatzigeorgiadis, A., Galanis, E., & Theodorakis, Y. (2020). *Strategic Self-talk Interventions.* In Self-talk in Sport. Routledge.

Muluken, D., & Konka, S.K. (2019). The effect of imagery skills training in handball game penalty shooting. *IOSR Journal of Humanities and Social Science, 24*(2), 31-35.

Zourbanos, N., Hatzigeorgiadis, A., Bardas, D., & Theodorakis, Y. (2013). The effects of self-talk on dominant and non-dominant arm performance on a handball task. *Perceptual and Motor Skills, 116*(1), 150-162.

Theodorakis, Y., Weinberg, R., Natsis, P., Douma, I., & Kazakas, P. (2012). The effects of motivational versus instructional self-talk on improving motor performance. *The Sport Psychologist, 26*(2), 212-226. https://doi.org/10.1123/tsp.14.3.253

Hidayat, Y., Yudiana, Y., Hambali, B., Sultoni, K., Ustun, U.D., & Singnoy, C. (2023). The effect of the combined self-talk and mental imagery program on the badminton motor skills and self-confidence of youth beginner student-athletes. *BMC Psychology, 11*(1), 35.

Cumming, J., & Williams, S. E. (2012). *The role of imagery in performance.* In S. Murphy (Ed.), The Oxford handbook of sport and performance psychology (pp. 213-232). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199731763.013.0011

Theodorakis, Y., Chroni, S., Laparidis, K., Bebetsos, V., & Douma, I. (2001). Self-talk in a basketball-shooting task. *Perceptual and Motor Skills, 92*(1), 309-315. https://doi.org/10.2466/pms.2001.92.1.309

Holmes, P.S., & Collins, D.J. (2001). The PETTLEP approach to motor imagery: A functional equivalence model for sport psychologists. *Journal of Applied Sport Psychology, 13*(1), 60-83. https://doi.org/10.1080/10413200109339004

Hardy, J., Hall, C. R., & Hardy, L. (2001). Quantifying athlete self-talk. *Journal of Sports Sciences, 19*(12), 861-873. https://doi.org/10.1080/02640410500130706

Hatzigeorgiadis, A., Zourbanos, N., Mpoumpaki, S., & Theodorakis, Y. (2009). Mechanisms underlying the self-talk-performance relationship: The effects of motivational self-talk on self-confidence and anxiety. *Psychology of Sport and Exercise, 10*(1), 186-192. https://doi.org/10.1016/j.psychsport.2008.07.009

Munroe-Chandler, K., Hall, C., & Fishburne, G. (2008). Playing with confidence: The relationship between imagery use and self-confidence and self-efficacy in youth soccer players. *Journal of Sports Sciences, 26*(14), 1539-1546. https://doi.org/10.1080/02640410802315419

Moran, A., Guillot, A., & MacIntyre, T. (2012). Mental imagery in sport and exercise: Theoretical perspectives. *Sport and Exercise Psychology Research,* 91-115. https://doi.org/10.1016/B978-0-12-381460-9.00005-2

Behncke, L. (2004). Mental skills training for sports: A brief review. *Athletic Insight: The Online Journal of Sport Psychology, 6*(1).

Birrer, D., & Morgan, G. (2010). Psychological skills training as a way to enhance an athlete's performance in high-intensity sports. *Scandinavian Journal of Medicine & Science in Sports, 20*(S2), 78-87. https://doi.org/10.1111/j.1600-0838.2010.01188.x

Vealey, R. S., & Greenleaf, C. A. (2010). *Seeing is believing: Understanding and using imagery in sport.* In J. M. Williams (Ed.), Applied sport psychology: Personal growth to peak performance (6th ed., pp. 267–304). New York, NY: McGraw-Hill.

Gould, D., Voelker, D. K., Damarjian, N., & Greenleaf, C. (2014). *Imagery training for peak performance.* https://doi.org/10.1037/14251-004

Thelwell, R.C., & Greenlees, I.A. (2003). Developing competitive endurance performance using mental skills training. *The Sport Psychologist, 17*(3), 318-337. https://doi.org/10.1123/tsp.17.3.318

Підвищення компетенції виконавської майстерності серед гандболістів: Порівняльний вплив ментальних образів, внутрішнього діалогу та їхнього поєднання

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 3 табл., 23 джерела.

Мета дослідження. Метою цього дослідження було вивчення порівняльних та комбінованих впливів тренувань з використанням ментальних образів та внутрішнього діалогу на навички майстерності виконання кидків у стрибку гандболістів. Дослідження мало на меті визначити, чи призводить інтеграція обох психологічних методів до значного покращення рухової результативності, ніж використання кожної із зазначених стратегій окремо або традиційної практики.

Матеріали та методи. Сорок гандболістів чоловічої статі було розподілено за методом рандомізації на чотири групи (по 10 осіб у кожній): «Ментальні образи та внутрішній діалог», «Ментальні образи», «Внутрішній діалог» та «Контрольна». Експериментальні групи отримали шеститижневий інтервенційний курс з тренування психологічних навичок, тоді як контрольна група продовжувала займатися стандартними тренуваннями з гандболу. На перед- та постінтервенційному етапах дослідження проведено тест на визначення рівня майстерності з виконання кидків у стрибку з гандболу. Дані були проаналізовані за допомогою коваріаційного аналізу з метою контролю передтестових відмінностей, з подальшим проведенням post-hoc тестів Бонферроні для парних порівнянь.

Результати. Коваріаційний аналіз виявив значний груповий ефект на посттестові показники, $F_{(3, 35)} = 18.18$, $p < .001$, з скоригованим $R^2 = .665$. Група «Ментальні образи та внутрішній діалог» продемонструвала максимальне поліпшення (середній передтестовий показник = 13.90; середній посттестовий показник = 17.70), за якою слідували групи «Ментальні образи» та «Внутрішній діалог», тоді як контрольна група показала мінімальний приріст. Post-hoc аналіз підтвердив, що комбінована інтервенція призвела до значно кращих результатів, ніж у решти груп ($p < .05$).

Висновки. Результати дослідження свідчать, що комбіноване застосування ментальних образів та внутрішнього діалогу виявилося найефективнішою психологічною інтервенцією для підвищення навичок майстерності виконання кидків у стрибку в гандболі, підкреслюючи синергетичну цінність інтеграції когнітивних та мотиваційних стратегій тренування у покращенні спортивної результативності.

Ключові слова: ментальні образи, внутрішній діалог, тренування психологічних навичок, результативність у гандболі, майстерність виконання кидків у стрибку.

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A Comparative Analysis of Male and Female Complex I Skill Performance in Beach Volleyball

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Abstract

Objectives. The objective of this study was to analyse and evaluate the performance of skill types among male and female players in Complex I.

Materials and Methods. The study comprised 28 men's and 26 women's matches, representing the 32 national teams that participated in the FIVB World Tour Finals 2019. A total of 3624 Complex I sequences were recorded and assessed. Passing skills (reception and setting) were evaluated using a four-level tactical rating quality scale, while attacking hits were assessed using a five-level scale. The observer's reliability test demonstrated a high correlation coefficient.

Results. Male beach volleyball players generally exhibited higher quality (Quality Level–QL3) in serve reception and setting, as well as greater effectiveness (QL4) in attacking hits compared to women. Males used more frequently the basic forearm pass technique in reception ($p = 0.001$), the overhead set ($p = 0.001$) in setting, and the hard-driven ball ($p = 0.001$) in attacking compared to females. In contrast, females used more frequently the side forearm pass and other techniques in reception ($p = 0.001$ and $p = 0.001$, respectively), the forearm setting ($p=0.001$), and the driven ball and poke shot techniques in attacking ($p = 0.001$ and $p = 0.001$, respectively). Furthermore, the higher the quality of serve reception, the better the quality of the setting ($p < 0.001$), and the higher the quality of the setting, the more effective the attack ($p<0.001$) for both genders. Finally, the results showed that male athletes executed excellent settings more frequently than female athletes ($p = 0.02$, $p = 0.001$, and $p = 0.001$, respectively), regardless of the quality level of the received serve.

Conclusions. Male players were more effective than female players, as they primarily used the frontal reception technique, overhead setting, and powerful attacking hits, which enhanced the overall quality of their game. To generalize these findings, further research is recommended at different competitive and age levels.

Keywords: performance, technical skills, complex I, beach volleyball, gender.

Introduction

Beach volleyball (BV) is a popular and continuously evolving sport that attracts athletes of all ages from around the world. The nature of the sport requires a combination of exceptional physiological abilities, technical skills, and tactical intelligence. These demands make BV a sport that requires high specialization and adaptation to the unique conditions of sand and the often-challenging outdoor environment (Casanova, 2015).

One of the most important factors affecting performance in the sport is the physiological characteristics of male and female athletes. These include anthropometric characteristics such as height, weight, and body composition, as well as cardiorespiratory variables such as heart rate and maximal oxygen consumption (VO_2 max). Particularly important is the additional burden of movement on the sand, which, as an unstable and variable surface, requires greater energy expenditure compared to hard surfaces. According to existing literature, walking is 1.8–2.7 times more energy-demanding on sand than on a hard surface, running is 1.2–1.6 times more costly, and jumping is 1.2 times more demanding on a sandy surface (Hank et al., 2016; Kumar, 2015; Pinnington & Dawson, 2001).These findings indicate that BV requires high levels of endurance and physical fitness from athletes, regardless of their gender.

When it comes to anthropometric characteristics, body height particularly plays a crucial role in jump performance and overall BV performance. Athletes aim to reach as high as possible to surpass the net height, allowing for better offensive (attacks) and defensive actions (blocks) to gain points and ultimately win the set and match. A study by Palao et al. (2008) that analyzed male and female BV athletes from World Tour events and the Olympic Games (2000–2006), found that male players had an average height of 193 cm, weight of 88–89 kg, body mass index (BMI) of 23.8–24.1, and an average age of 29–31 years. Female players had an average height of 177–179 cm, weight of 66–68 kg, BMI of 19.2–21.1, and average age of 27–29 years. Specialization-wise, blockers were found to be taller than defenders, while teams without specialized roles had intermediate values (Palao et al., 2008). Freire et al. (2023) further found that BV athletes were slightly shorter, lighter, and had lower fat mass than indoor volleyball players.

According to Tilp et al. (2006) volleyball and BV are characterized by six fundamental technical skills: serving, serve reception, setting (pass to the attacker), attacking (spiking), blocking, and defense. These skills are categorized into scoring skills (e.g., attacking, serving, blocking) that can directly earn points and transition skills (e.g., reception, setting, defense) that do not directly earn points. Medeiros et al. (2017) studied BV skills in relation to team performance and found that the game has a hierarchical structure, divided into attack after reception and attack after defense. They also distinguished volleyball gameplay into defensive and offensive phases, where each phase consists of 3–4 successive technical actions. Similarly, Eom & Schutz (1992) defined Complex I as serve reception, setting, and attack after reception, and Complex II as serve, block, defense, setting, and attack after defense. These sequences involve chained skills that influence one another. From this, it follows that performance in volleyball and BV cannot be assessed solely through the effectiveness of individual skills but rather holistically through all six skills to serve as a reliable performance criterion for researchers and coaches.

This study hypothesized significant performance differences between genders, with male teams showing higher effectiveness in serve reception, setting quality, and attack efficacy due to physiological factors. Also, greater skill variation within female teams and a strong dependence on the quality of each Complex I component for both genders were expected.

The purpose of this study was to analyze and evaluate the performance of male and female skill types in Complex I among the top 32 national teams participating in the FIVB Beach Volleyball World Tour Finals 2019, held in Rome in September 2019.

Materials and Methods

Study Participants

The research sample consisted of 28 matches from the top 32 men's and 26 women's national teams that participated in the finals of the Beach Volleyball World Championship, held in Rome in September 2019 (FIVB World Tour Finals 2019). A total of N = 3624 Complex I sequences were recorded and evaluated.

Study Organization

To carry out the study, data was collected using the observation method and a Microsoft Office Excel spreadsheet, through which an observation protocol was created, containing the following variables (in the parentheses the categories of each variable): gender (Male, Female); reception type (Basic forearm pass, Side forearm pass, Tomahawk, Other, such as with a dive, kneeling, one-handed reception); setting type (Overhead, Forearm); and attack type [the hard-driven ball, the driven ball (slow deep placement shot), the roll shot (rotational close-range placement shot), and the poke shot (placement hit using the knuckles)].

The evaluation criteria for the non-scoring skills of reception and setting consisted of four quality levels (QL) based on Coleman et al. (1969). Regarding reception, the levels were: incorrect reception execution (QL0, missed point), poor-quality reception (QL1), moderate-quality reception (QL2), and excellent reception (QL3). Regarding the setting, they were incorrect technique/error (QL0, missed point), poor quality setting (QL1, not pinned), moderate/ good quality setting, (QL2, attack manifestation) and excellent setting (QL3, attack with good conditions). The evaluation criteria for the scoring skill of attack consisted of 5 levels which according to (Eom & Schutz, 1992b) were: incorrect attack (QL0), poor execution of attack (QL1), moderate execution of attack (QL2), very good attack (QL3, the ball is returned under favourable conditions by the opponent for counterattack) and excellent attack (QL4, point).

Data Collection

Data collection was conducted using observation. Specifically, the researcher observed 54 matches, gathering data related to Complex I, as well as their respective types. The procedure followed to ensure the researcher's reliability was a test-retest, which was performed within a 15-day interval, on 10% of the games (6 matches, 3 from each gender), meeting the minimum value recommended in the literature (Tabachnick et al., 2019). This procedure was designed to control negative influences that may have arisen as a consequence of the researcher's memory. The researcher's intra-observer reliability was assessed using Cohen's Kappa index (Cohen, 1988), which showed values of > .85, indicating a high reliability (Altman, 1991).

Statistical Analysis

Initially, a descriptive analysis of the variables was conducted, to calculate the frequencies of each study variable. The statistical analysis used included a chi-square (χ^2) test of independence between the variables "type per skill" and "performance," which was performed using the chi-square test and Fisher's exact test when the expected count per cell was less than 5. The same procedure was followed for the remaining variables. For the comparison of proportions and frequencies, the z-test was used. To examine the relationship between the quality of the previous and the next game action (reception-setting and setting-attack) a chi-square (χ^2) test of independence was employed. Cramer's V was calculated to quantify the effect size, with values of 0.1, 0.2, 0.4, 0.6, 0.8 and 1 representing negligible, weak, moderate, relatively strong, strong and very strong association, respectively (Kortlik & Williams, 2003). Two-way contingency tables were visualised using mosaic plots to examine the combinations of variable categories that contributed most to the association after rejecting the null hypothesis of independence. In these plots, the width and height of the tiles represent the relative frequencies of the variables being studied. Color coding and tile edges indicate each cell's standardised residual's absolute size and sign. Additionally, fixed cutoffs of ±2 and ±4 were used to shade cells that were individually significant at approximately $\alpha = 0.05$ and $\alpha = 0.001$ levels, respectively. The analyses of two-way contingency tables were performed using the R statistical software, with the vcd package (Meyer et al., 2020; Zeileis et al., 2007) utilised. The statistical analysis was performed using SPSS v.25 and Statgraphics v.5.1 (the latter was used for percentage testing as SPSS was not as descriptive in this regard). The significance level for all measurements was set at $p < 0.05$.

Results

The performance of serve reception in BV regarding its type, as well as its comparison between genders

A total of 3.624 reception actions were recorded. Of these, 1.798 were performed by men and 1.826 by women Table 1. The recorded types of reception were the basic forearm pass, the side forearm pass, the Tomahawk technique, and any other technique (such as with a dive, kneeling, or one-handed reception).

In general, the comparison of ratios and frequencies regarding reception performance revealed significant differences between genders. Men were of higher quality (QL3) compared to women (z = 9.52, p = 0.001) and performed more frequent moderate reception actions (QL1) (z = 4.05, p = 0.001), while women performed more frequent good receptions (QL2) (z = -12.6, p = 0.001) (Table 1). From the comparison of ratios and frequencies, the results showed that male beach volleyball players more frequently used the basic forearm pass technique compared to female players (z = 13.3, p = 0.001), while female players more frequently used the side forearm pass and other techniques (z = -4.18, p = 0.001 and z = -14.7, p = 0.001, respectively). The Tomahawk technique was rarely used by the players (Figure 1).

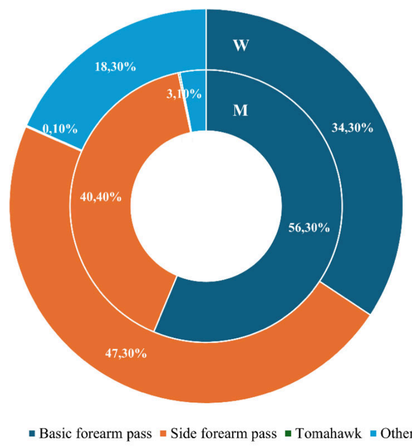

Fig. 1. Percentages of reception type occurrences by gender in BV performance

Table 1. The performance of the reception of men and women by type of reception in BV

Reception type	Gender	Reception Performance				Total	χ^2
		QL0	QL1	QL2	QL3		Value
		%(N)	%(N)	%(N)	%(N)		Sig.
Basic forearm pass	M	1.1(11)	6.1(62)	18.1(183)	74.7(756)	1012	51.184
	F	3.2(20)	2.6(16)	30.3(190)	64(401)	627	0.001
	z	-3.02	3.23	-5.72	4.62		
	p	0.002	0.001	0.001	0.001		
Side forearm pass	M	5.1(37)	10.5(76)	30.6(222)	53.9(391)	726	57.999
	F	2.3(20)	4.4(38)	46.5(401)	46.8(404)	863	0.001
	z	2.99	4.69	-6.47	2.82		
	p	0.003	0.001	0.001	0.005		
Tomahawk	M	75(3)	0.0(0)	0.0(0)	25.1(1)	4	5.000
	F	0.0(0)	0.0(0)	100(1)	0.0(0)	1	0.082
	z	-	-	-	-		
	p	ns	ns	ns	ns		
Other	M	66.1(37)	12.5(7)	10.7(6)	10.7(6)	56	100.36
	F	11(37)	9.9(33)	55.5(186)	23.6(79)	335	0.001
	z	9.75	0.59	-6.21	-2.17		
	p	0.001	ns	0.001	0.03		
Total	M	4.9(88)	8.1(145)	22.9(411)	64.1(1154)	1798	164.08
	F	4.2(77)	4.8(87)	42.6(778)	48.4(884)	1826	0.001
	z	1.01	4.05	-12.6	9.52		
	p	ns	0.001	0.001	0.001		

Table 2. The performance of setting in BV, according to its type by gender

Setting type	Gender	Setting Performance QL0 %(N)	QL1 %(N)	QL2 %(N)	QL3 %(N)	Total	χ^2 Value Sig.
Overhead	M	0.8(8)	0.9(9)	7.2(72)	91.1(908)	997	2.084
	F	1.1(4)	0.3(1)	6.2(22)	92.4(326)	353	0.555
	z	-0.52	1.13	0.64	-0.75		
	p	ns	ns	ns	ns		
Forearm	M	1.4(8)	2.6(15)	18.1(104)	78(449)	576	14.027
	F	1.2(15)	3(37)	25.9(317)	69.9(857)	1226	0.003
	z	0.35	-0.47	-3.65	3.59		
	p	ns	0.05	0.001	0.001		
Total	M	1.0(16)	1.5(24)	11.2(176)	86.3(1357)	1573	66.917
	F	1.2(19)	2.4(38)	21.5(339)	74.9(1183)	1579	0.001
	z	-0.54	-1.83	-7.82	8.09		
	p	ns	ns	0.001	0.001		

Regarding the performance of reception by type, the results showed that men were more efficient (QL3) in the types of forearms and side forearm reception (z = 4.62, p = 0.001 and z = 2.82, p = 0.005, respectively), while women performed better in the other techniques (z = -2.17, p = 0.03). Additionally, women displayed QL2 more frequently than men in all types of reception, excluding the tomahawk technique. Specifically, women showed QL2 more frequently in the basic forearm pass, side forearm pass, and other techniques (z = -5.72, p = 0.001, z = -6.47, p = 0.001 and z = -6.21, p = 0.001, respectively). On the other hand, men exhibited QL1 more frequently in the basic forearm pass and side forearm pass techniques (z = 3.23, p = 0.001, z = 4.69, p = 0.001, respectively). Finally, it was found that men made more errors when using the side forearm pass and other techniques (z = 2.99, p = 0.003, z = 9.75, p = 0.001, respectively), while women made more errors when using the Basic forearm pass (z = -3.02, p = 0.002).

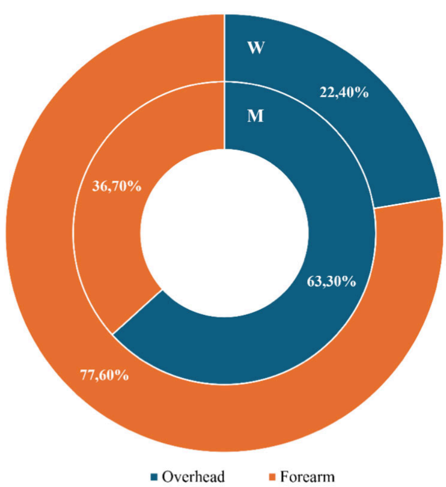

Fig. 2. Percentage of setting types by gender in BV

The performance of setting in BV concerning its type and gender comparison

A total of 3.152 setting actions were recorded (M = 1.573 and W = 1.579) (Table 2). The types of setting recorded were overhead (M: N = 997 and W: N = 353) and forearm (M: N = 576 and W: N = 1226). The highest frequency and the highest percentages for both genders were seen in QL3, that is, in excellent settings regardless of their type. Specifically, for the overhead technique: for men (N = 908) it was 91.1%, and for women (N = 326) it was 92.4%. Similarly, for the forearm technique: for men (N = 449) it was 78%, and for women (N = 857) it was 69.9%.

In general, the comparison of the ratios and frequencies regarding the performance of setting, by setting type revealed significant differences between the genders. Men were more proficient in their passes (QL3) compared to women (z = 8.09, p = 0.001), while women more frequently performed good (QL2) passes (z = -7.82, p = 0.001) (Table 2). Additionally, it was found that male BV players used the overhead technique more often than female players (z = 23.2, p = 0.001), who, in turn, used the forearm technique more frequently (z = -23.2, p = 0.001).

Regarding the performance of setting by type, the results showed that there were no significant differences between genders in the overhead technique. However, differences were found in the forearm technique, where men were of higher quality (QL3) (z = 3.59, p = 0.001), while women were more frequently in QL2 (z = -3.65, p = 0.001).

The performance of setting in BV regarding the quality of the serve reception and the comparison between genders

A total of 3.151 setting actions were recorded (M = 1.571 and F = 1.580) (Table 3). The serve reception quality percentages, based on which settings were performed, were as follows: for men, 5.4% for QL1, 24.4% for QL2, and 70.2% for QL3, while for women, 2.7% for QL1, 45.1% for QL2, and 52.3% for QL3. A comparison of proportions and frequencies showed that men performed their settings

Table 3. The Performance of setting in BV regarding the quality of serve reception by gender

Reception Performance	Gender	Setting Performance				Total	χ^2 Value Sig.
		QL0	QL1	QL2	QL3		
		%(N)	%(N)	%(N)	%(N)		
QL1	M	8.3(7)	17.9(15)	53.6(45)	20.2(17)	84	30.045
	F	35.7(15)	40.5(17)	19(8)	4.8(2)	42	0.001
	z	-3.82	-2.75	3.65	2.28		
	p	0.001	0.006	0.001	0.02		
QL2	M	1.3(5)	1.3(5)	25.6(98)	71.8(275)	383	24.258
	F	0.3(2)	2.2(16)	38.6(275)	58.8(419)	712	0.001
	z	1.96	-1.04	-4.33	4.26		
	p	0.05	ns	0.001	0.001		
QL3	M	0.4(4)	0.4(4)	2.9(32)	96.4(1064)	1104	17.227
	F	0.2(2)	0.6(5)	6.8(56)	92.4(763)	826	0.001
	z	0.78	-0.63	-4.06	3.88		
	p	ns	ns	0.001	0.001		
Total	M	1.0(16)	1.5(24)	11.1(175)	86.3(1356)	1571	67.367
	F	1.2(19)	2.4(38)	21.5(339)	74.9(1184)	1580	0.001
	z	-0.54	-1.83	-7.9	8.09		
	p	ns	0.06	0.001	0.001		

more frequently than women after excellent (QL3) and moderate (QL1) serve receptions ($z = 10.3$, $p = 0.001$, and $z = 3.84$, $p = 0.001$, respectively). On the other hand, women performed their settings more frequently than men after good serve receptions ($z = -12.2$, $p = 0.001$). The results also indicated that regardless of gender, as serve reception performance increased, setting performance was also improved. Overall, as previously observed, men executed higher-quality settings (QL3) compared to women ($z = 8.09$, $p = 0.001$), while women more frequently performed good-quality settings (QL2) ($z = -7.9$, $p = 0.001$) (Table 3).

Independence tests revealed a significant association between the quality of reception and the quality of setting for men ($\chi^2 = 542.299$, df = 6, $p < 0.001$, Cramer V = 0.417, large effect) and women ($\chi^2 = 958.214$, df = 6, $p < 0.001$, Cramer V = 0.551, large effect). The mosaic plots in Figure 3 (left plot for men, right plot for women) reveal the structure of the relationships between the quality of reception and the quality of setting per gender. Concerning men, standardized residuals (StRes) showed a discrepancy between observed and expected frequencies (Figure 1). These quality levels, implicated in variable interdependence, were: QL1 reception and all levels of setting (StRes = 6.6 for QL0, 12.1 for QL1, 11.7 for QL2 and -6.5 for QL3), QL2 reception and QL2 and QL3 setting (StRes = 8.5 and -3.1), QL3 reception for all levels of setting (StRes = -2.2, -3.1, -8.2 and 3.6,). Concerning women standardized residuals (StRes) showed a discrepancy between observed and expected frequencies (Figure 1). These quality levels, implicated in variable interdependence, were: QL1 reception and various levels of setting (StRes = 20.4 for QL0, 15.9 for QL1, and -5.3 for QL3), QL2 reception and various levels of setting (StRes = -2.2 for QL0, 9.9 for QL2, and -5.0 for QL3), QL3 reception for all levels of setting (StRes = -2.5, -3.3, -9.1 and 5.8).

In addition, significant gender differences were identified. Regardless of the quality of the reception (QL1-3),

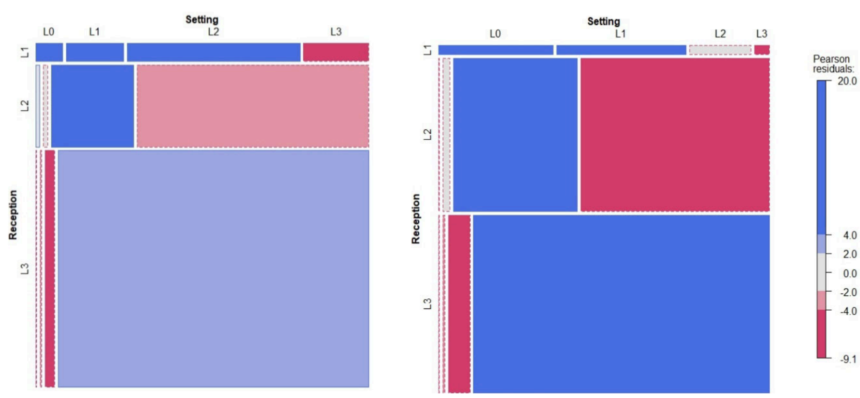

Fig. 3. Mosaic plots of men (left) and women (right)

Table 4. The performance of the attacking hits in BV concerning its type by gender

Attack type	Gender	Attacking Performance					Total	χ^2 Value Sig.
		QL0	QL1	QL2	QL3	QL4		
		%(N)	%(N)	%(N)	%(N)	%(N)		
Hard driven ball	M	19.8(195)	5.7(56)	8.8(87)	6.3(62)	59.5(587)	987	13.472
	F	16.4(91)	8.8(49)	11.4(63)	8.5(47)	54.9(304)	554	0.009
	z	1.65	-2.32	-1.65	-1.61	1.75		
	p	ns	0.02	ns	ns	ns		
Driven ball	M	11.7(47)	14.9(60)	15.9(64)	5(20)	52.6(212)	403	5.738
	F	16.2(119)	16.2(119)	15.7(115)	4(29)	48(352)	734	0.220
	z	-2.05	-0.57	0.09	0.79	1.48		
	p	0.04	ns	ns	ns	ns		
Roll shot	M	9.1(18)	11.7(23)	16.2(32)	5.6(11)	57.4(113)	197	0.830
	F	7.2(14)	13.8(27)	15.9(31)	5.6(11)	57.4(112)	195	0.934
	z	0.69	-0.62	0.08	0.0	0.0		
	p	ns	ns	ns	ns	ns		
Poke shot	M	21.4(18)	13.1(11)	14.3(12)	6(5)	45.2(38)	84	6.517
	F	10.8(23)	18.3(39)	15.5(33)	4.7(10)	50.7(108)	213	0.164
	z	2.38	-1.08	-0.26	-0.46	-0.85		
	p	0.02	ns	ns	ns	ns		
Total	M	16.6(278)	9(150)	11.7(195)	5.9(98)	56.9(950)	1671	28.080
	F	14.6(247)	13.8(234)	14.3(242)	5.7(97)	51.7(876)	1696	0.001
	z	1.6	-4.38	-2.24	0.25	3.03		
	p	ns	0.001	0.02	ns	0.002		

men performed excellent (QL3) settings more frequently than women (z = 2.28, p = 0.02; z = 4.26; p = 0.001, and z = 3.88, p = 0.001, respectively). Men also executed good (QL2) settings more often after a QL1 reception (z = 3.65, p = 0.001) and made more errors following a good (QL2) reception compared to women (z = 1.96, p = 0.05). On the other hand, women performed good (QL2) settings more frequently than men after good (QL2) and excellent (QL3) serve receptions (z = -4.33, p = 0.001 and z = -4.06, p = 0.001, respectively). However, they also made more errors when the reception was of good quality (QL1) (z = -3.82, p = 0.001).

The performance of the attacking hit in BV concerning its type and the comparison between genders

A total of 3.367 attacking hits were recorded, with 1.671 performed by men and 1.696 by women (Table 4). From the comparison of ratios and frequencies between genders regarding the type of attacking type used, the results showed that men used the hard-driven ball more frequently than women (z = 15.1, p = 0.001), while women used the driven ball and poke shot more frequently than men (z = -11.8, p = 0.001 and z = -7.52, p = 0.001, respectively). No significant differences were found between genders in the use of the roll shot (Figure 4).

Overall, the comparison of proportions and frequencies regarding the performance of the attacking hit revealed significant differences between genders. As shown in Table 4, men demonstrated higher quality (QL4) attacks compared to women (z = 3.03, p = 0.002), while women executed good (QL2) and moderate (QL1) attacking hits more frequently (z = -2.24, p = 0.001 and z = -4.38, p = 0.001, respectively).

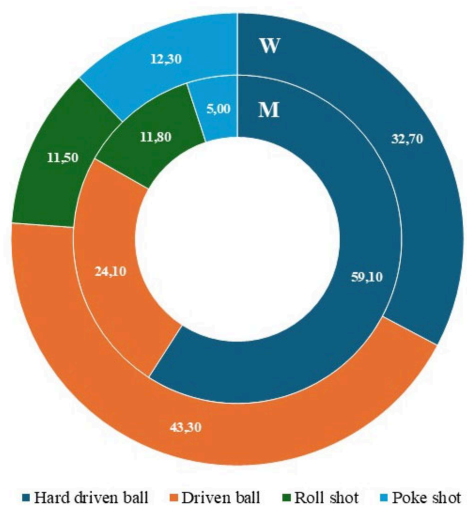

Fig. 4. Frequency percentage of attack hit types by gender in BV

Specifically, no differences were found between genders in good and excellent attacking actions across all types of attacking hits. However, differences were observed in moderate (QL1) and erroneous (QL0) actions. Women performed moderate (QL1) hard-driven ball attacks more frequently than men (z = -2.32, p = 0.02) and made more errors (QL0) in driven ball attacks (z = -2.05, p = 0.04).

On the other hand, men made more errors (QL0) than women when performing poke shot-type attack hits.

The performance of the attacking hit in BV regarding the quality of the setting and the comparison between genders

Overall, as shown in Table 5, 3.093 attacking actions were recorded (M = 1.545 and F = 1.548). The frequency percentage of the quality of the setting (QL), from which the attacking hits were made, was 1.3% for QL1, 11.30% for QL2, and 87.4% for QL3 for men, while for women it was 1.6% for QL1, 21.9% for QL2, and 76.5% for QL3. From the comparison of the ratios and frequencies, it appeared that men performed attacking hits more frequently than women after excellent (QL3) settings (z = 7.87, p = 0.001), while women performed them more frequently after good (QL2) settings (z = -7.92, p = 0.001).

In general, regarding the performance of the attacking hit, the comparison of ratios and frequencies showed significant differences between genders. As shown in Table 5, men were of higher quality (QL3) compared to women (z = 2.79, p = 0.005), while women more frequently executed good (QL2) and average (QL1) attacking hits (z = -4.07, p = 0.001 and z = -2.57, p = 0.01, respectively).

Specifically, significant differences were found between genders, as men performed very good attacking hits more frequently compared to women (z = 3.58, p = 0.001) when they received good settings (QL2). However, when receiving excellent settings, men made more mistakes (z = 3.23, p = 0.001) compared to women, who more frequently performed average and good attacking hits (z = -2.85, p = 0.004 and z = -2.29, p = 0.02, respectively).

Independence tests revealed a significant association between the quality of setting and the quality of attacking for men (χ^2 = 70.702, df = 8 p < 0.001, Cramer's V = 0.151, weak association) and women (χ^2 = 121.483, df = 8, p < 0.001, Cramer's V = 0.198, moderate association). The mosaic plots in Figure 5 (left plot for men, right plot for women) reveal the structure of the relationships between the quality of setting and the quality of attacking per gender. Concerning men, standardized residuals (StRes) showed a discrepancy between observed and expected frequencies. These quality levels, implicated in variable interdependence, were: QL1 setting with QL1and QP4 attack (StRes = 3.2 for QL1 and -2.5 for QL4), QL2 setting with almost all levels of attack except QL2 (StRes = 2.7 for QL0, 2.4 for QL1, 3.5 for QL3 and -4.1 for QL4). Concerning women standardised residuals (StRes) showed a discrepancy between observed and expected frequencies. These quality levels, implicated in variable interdependence, were: QL1 setting and various levels of attacking (StRes = 2.8 for QL0, 5.3 for QL1 and -3.6 for QL4), QL2 setting and various levels of attacking (StRes = 4.9 for QL0, 2.6 for QL1 and -4.1 for QL4), QL3 setting for various levels of attacking (StRes = -3.0 for QL0, -2.1 for QL1 and 2.7 for QL4).

Discussion

The present study aimed to analyze and evaluate the performance of BV players' skill types during Complex I. Additionally the goal was to identify potential gender differences. In every rally, technical skills are performed cyclically, and as has been established in indoor volleyball, each skill significantly influences the subsequent one (Bergeles et al., 2009). Specifically, in Complex I, which involves the organization of the attack, it has been observed

Table 5. The performance of the attacking hit in BV, in relation to the performance of the setting by gender

Setting Performance	Gender	Attacking Performance					Total	χ^2 Value Sig.
		QL0	QL1	QL2	QL3	QL4		
		%(N)	%(N)	%(N)	%(N)	%(N)		
QL1	M	30(6)	30(6)	20(4)	5(1)	15(3)	20	6.851
	F	36(9)	52(13)	12(3)	0.0(0)	0.0(0)	25	0.144
	z	-0.42	-1.48	0.73	-	-		
	p	ns	ns	ns	ns	ns		
QL2	M	25.1(44)	14.3(25)	14.3(25)	12.6(22)	33.7(59)	175	13.530
	F	24.8(84)	18.6(63)	16.5(56)	4.1(14)	36(122)	339	0.009
	z	0.07	-1.22	-0.65	3.58	-0.52		
	p	ns	ns	ns	0.001	ns		
QL3	M	15.6(210)	7.8(105)	10.9(147)	5.3(71)	60.5(817)	1350	22.999
	F	11.2(133)	11.1(132)	13.9(165)	6.2(73)	57.5(681)	1184	0.001
	z	3.23	-2.85	-2.29	-0.97	1.53		
	p	0.001	0.004	0.02	ns	ns		
Total	M	16.8(260)	8.8(136)	11.4(176)	6.1(94)	56.9(879)	1545	26.910
	F	14.6(226)	13.4(208)	14.5(224)	5.6(87)	51.9(803)	1548	0.001
	z	1.68	-4.07	-2.57	0.59	2.79		
	p	ns	0.001	0.01	ns	0.005		

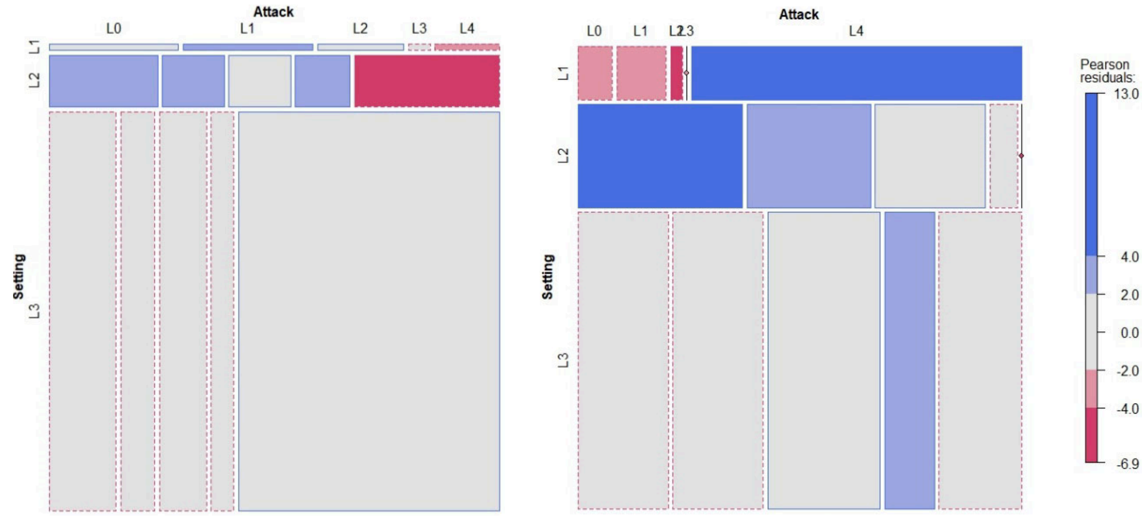

Fig. 5. Mosaic plots of men (left) and women (right)

that the performance of the serve reception affects the performance of the ball setting, while both skills together influence the performance of the subsequent attack hit. Thus, the better the reception and consequently the setting, the higher the offensive performance in both genders (Afonso & Mesquita, 2011; Bergeles et al., 2009; Silva et al., 2013). Moreover, as mentioned above, there were more attacks recorded than settings in the matches. This is widely seen and accepted in BV, because an attack can either occur as a surprising element from a good reception or dig, or it can also be used as a necessary action (Casanova, 2015).

The results of this study confirm the findings of previous research (Koch & Tilp, 2009), as it was found that the types of serve receptions primarily used were the frontal and lateral forearm passes. Simultaneously, it was observed that men were of higher quality than women, who, however, more frequently used other techniques such as dives, one-handed hits, etc. Interestingly, when women utilized these techniques, they exhibited better quality, as they more frequently executed very good and excellent settings compared to men, who made mistakes more often. These differences can be partly attributed to gender-related differences in body dimensions, proportions, and muscular strength (Bishop et al., 1987), as well as to the type and speed of the serves used and the height of the net (Buscá et al., 2012; FIVB, 2021; López-Martínez et al., 2020).

It is well-known that men excel in muscular strength (Bishop et al., 1987), as demonstrated by vertical jumps and the speed of hits, particularly serves, which reach 98.3±4.3 km/h for men and 80.1±2.7 km/h for women (Palao & Valades, 2014). This is also related to BV players' preference for jump serves, especially high-speed spin serves, whose use appears to be decisive at the women's level, as it determines team rankings (Buscá et al., 2012).

Regarding the type of setting, it was found that men compared to women more frequently used overhead settings (63.3% vs. 22.4%), while women did the opposite (77.6% vs. 36.7%). These findings, which align with those of Koch & Tilp (2009), may be due to the higher muscular strength of men, allowing them to move faster and position their bodies under the ball as required by the F.I.V.B. rules and overhead setting techniques (Bishop et al., 1987). Additionally, body proportions play a significant role, as finger size allows men to handle the ball more easily even in more complex situations (Giannopoulos et al., 2017; Malousaris et al., 2008).

In general, it was evident that men were of higher quality than women, as their settings were often excellent, while women's settings were good. Regardless of the technique used during the setting, it has been established that if the previous action, i.e., the reception, is successful, the quality of the setting helps the team fully develop its tactics. Conversely, a poor reception immediately gives an advantage to the opponent, as the quality and options of the setting are reduced (Marcelino et al., 2014).

The results of this study align with previous research (Häyrinen & Tampouratzis, 2012; Koch & Tilp, 2009), as it was observed that as the quality of the reception increased, the percentage of excellent settings also increased. However, when comparing genders, it was evident that men were of higher quality whether they received moderate, good, or excellent receptions, which may partly be due to their higher percentage of excellent receptions. On the other hand, men's better handling of moderate receptions may have contributed to the outcome, as it has been established that they can more frequently convert them into excellent or good settings compared to women (Barzouka et al., 2019; Palao et al., 2005). Furthermore, under the same reception conditions, women were more likely to execute moderate settings or make errors.

Regarding the types of attack hits, it was found that men more frequently used hard driven balls (986 vs. 544), while women favored the driven balls and poke shots (734 and 213 vs. 402 and 84, respectively), as found in previous studies (Koch & Tilp, 2009). Overall, it was evident that men were more effective than women, which can be explained by their preference for powerful hard driven balls and their tendency to take more risks to win the rally as in Volleyball (Bergeles et al., 2009; Drikos et al., 2022).

Although the performance of most attack hit types did not differ between genders, significant differences were observed in the driven ball and the poke shot. In the first case, women made more mistakes, possibly because they more frequently resorted to lower power but technically demanding hits like the driven ball, due to their tendency to take fewer risks compared to men. Moreover, despite their increased frequency and technical demands, driven balls often target the edges of the court at low speed, which in some cases makes the ball's trajectory susceptible to weather conditions. In the second case, men, due to their tendency to take risks in attack, used lower-power hits like the poke shot less frequently and only in exceptional cases. Additionally, the height of the opponent's block combined with men's relatively higher physical abilities makes low-power hits less effective. Therefore, men's sporadic and situational use of the poke shot, combined with less ball control due to the small contact area with the fingers' phalanges, may explain the higher error rate compared to women.

The athletes' offensive choices also affect the defensive tactics of both genders. Beyond the blocking technique, which is common in volleyball and beach volleyball, the latter also employs the "peeling off" movement, where players pretend to block but then retreat to playground defense. This defensive technique appears to be used more by women (28%) compared to men (12.8%), according to FIVB data FIVB data (Beach Volleyball: Picture of the Game, 2015). As mentioned earlier, it has been established that the quality of each action increases as the quality of the previous one improves (Bergeles et al., 2009). However, in this study, it was found that men performed very good attack hits even when they received only good settings more frequently than women. When they received excellent settings, however, they made more mistakes compared to women, who executed moderate (QL1) and good attack hits (QL2), allowing the opposing team to organize their play. This may be due to the higher number of driven ball and poke shot hits (734 vs. 402 and 213 vs. 84, respectively) used by women compared to men, who more frequently chose hard-driven ball hits (986 vs. 554).

The authors acknowledge limitations to the study design. Initially, the sample was limited to the top 32 national beach volleyball teams from a single tournament, potentially restricting generalizability and not reflecting broader performance trends. Secondly, physiological factors were hypothesized but not directly measured, and extraneous variables like weather, court conditions, and team strategies have not been controlled.

Conclusions

In conclusion, men were more effective than women, primarily using the forearm reception, overhead setting and powerful attacking hits, which contribute to higher quality. On the other hand, women used more side and other types of receptions, the forearm pass, driven ball, and poke shot in their attacking hit. It was also evident for both genders that the higher the quality of the service reception, the greater the quality of the setting and the effectiveness of the attack. It is recommended to conduct similar research at different competitive and age levels, as the present study was conducted at a highly competitive level, and its findings may not be generalized.

Conflict of Interest

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

References

Casanova, R. M. (2015). *Beach Volleyball: Picture of the Game.* In FIVB.

Hank, M., Malý, T., Zahálka, F., Dragijský, M., & Bujnovský, D. (2016). Evaluation of the horizontal movement distance of elite female beach volleyball players during an official match. *International Journal of Performance Analysis in Sport, 16*(3), 1087-1101. https://doi.org/10.1080/24748668.2016.11868950

Kumar, P. (2015). Impact of Sand Training for Endurance Development among Athletes. *IJAR, 1*(7), 503–506.

Pinnington, H. C., & Dawson, B. (2001). The energy cost of running on grass compared to soft dry beach sand. *Journal of Science and Medicine in Sport, 4*(4), 416-430. https://doi.org/10.1016/S1440-2440(01)80051-7

Palao, J. M., Gutiérrez, D., & Frideres, J. E. (2008). Height, weight, Body Mass Index, and age in beach volleyball players in relation to level and position. *The Journal of sports medicine and physical fitness, 48*(4), 466-471.

Freire, R., Hausen, M., Pereira, G., & Itaborahy, A. (2023). Body Composition, Aerobic Fitness, Isokinetic Profile, and Vertical Jump Ability in Elite Male and Female Volleyball and Beach Volleyball Players. *Journal of Science in Sport and Exercise, 5*(4), 385-395. https://doi.org/10.1007/s42978-022-00192-y

Tilp, M., Koch, C., Stifter, S., & Ruppert, S. G. (2006). Digital game analysis in beach volleyball. *International Journal of Performance Analysis in Sport, 6*(1), 140-148. https://doi.org/10.1080/24748668.2006.11868362

Medeiros, A. I. A., Marcelino, R., Mesquita, I. M., & Palao, J. M. (2017). Performance differences between winning and losing under-19, under-21 and senior teams in men's beach volleyball. *International Journal of Performance Analysis in Sport, 17*(1-2), 96-108. https://doi.org/10.1080/24748668.2017.1304029

Eom, H. J., & Schutz, N. R. (1992a). Transition playing team performance of volleyball: A log linear analysis. *Research Quarterly for Exercises and Sport, 63*(3), 261-269.

Eom, H. J., & Schutz, R. W. (1992b). Statistical analyses of volleyball team performance. *Research Quarterly for Exercise and Sport, 63*(1), 11-18. https://doi.org/10.1080/02701367.1992.10607551

Tabachnick, B. G., & Fidell, L. S. (2019). *Using Multivariate Statistics* (7th ed.). Pearson.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Altman, D. G. (1991). *Practical statistics for medical research.* Chapman and Hall.

Kortlik, J. W., & Williams, H. A. (2003). The incorporation of effect size in information technology, learning, and performance research. *Information Technology, Learning, and Performance Journal, 21*(1), 1-7.

Meyer, D., Zeileis, A., & Hornik, K. (2020). vcd: Visualizing Categorical Data. *R Package Version 1*, 4-7. https://rdrr.io/cran/vcd/

Zeileis, A., Meyer, D., & Hornik, K. (2007). Residual-based shadings for visualizing (conditional) independence. *Journal of Computational and Graphical Statistics, 16*(3), 507-525. https://doi.org/10.1198/106186007X237856

Bergeles, N., Barzouka, K., & Nikolaidou, M. E. (2009). Performance of male and female setters and attackers on

Olympic-level volleyball teams. *International Journal of Performance Analysis in Sport, 9*(9), 141-148. https://doi.org/10.1080/24748668.2009.11868470

Afonso, J., & Mesquita, I. (2011). Determinants of block cohesiveness and attack efficacy in high-level women's volleyball. *European Journal of Sport Science, 11*(1), 69-75. https://doi.org/10.1080/17461391.2010.487114

Silva, M., Lacerda, D., & João, P. V. (2013). Match analysis of discrimination skills according to the setter attack zone position in high level volleyball. *International Journal of Performance Analysis in Sport, 13*(2), 452-460. https://doi.org/10.1080/24748668.2013.11868661

Koch, C., & Tilp, M. (2009). Beach volleyball techniques and tactics: A comparison of male and female playing characteristics. *Kinesiology, 41*(1), 52-59. https://www.researchgate.net/publication/228659523

Bishop, P., Cureton, K., & Collins, M. (1987). Sex difference in muscular strength in equally-trained men and women. *Ergonomics, 30*(4), 675-687. https://doi.org/10.1080/00140138708969760

Buscá, B., Moras, G., Javier, P., & Rodríguez-Jiménez, S. (2012). The influence of serve characteristics on performance in men's and women's high-standard beach volleyball. *Journal of Sports Sciences, 30*(3), 269-276. https://doi.org/10.1080/02640414.2011.635309

FIVB. (2021). *Official Volleyball Rules 2021-2024.* FIVB. https://www.fivb.com

López-Martínez, A. B., Palao, J. M., Ortega, E., & García-De-Alcaraz, A. (2020). Efficacy and manner of execution of the serve in top-level women's beach volleyball players. *Journal of Physical Education (Maringa), 31*(1). https://doi.org/10.4025/JPHYSEDUC.V31I1.3142

Palao, J. M., & Valadés, D. (2014). Normative profiles for serve speed for the training of the serve and reception in volleyball. *The Sport Journal,* 17, 1-10.

Giannopoulos, N., Vagenas, G., Noutsos, K., Barzouka, K., & Bergeles, N. (2017). Somatotype, Level of Competition, and Performance in Attack in Elite Male Volleyball. *Journal of Human Kinetics, 58*(1), 131-140. https://doi.org/10.1515/hukin-2017-0082

Malousaris, G., Bergeles, N., Barzouka, K., Bayios, I., Nassis, G., & Koskolou, M. (2008). Somatotype, size and body composition of competitive female volleyball players. *Journal of Science and Medicine in Sport, 11*(3), 337-344. https://doi.org/10.1016/j.jsams.2006.11.008

Marcelino, R., Afonso, J., Moraes, J. C., & Mesquita, I. (2014). Determinants of attack players in high-level men's volleyball. *Kinesiology, 46*(2), 234-241.

Häyrinen, M., & Tampouratzis, K. (2012). Technical and tactical game analysis of elite female beach volleyball. *KIHU: Research Institute for Olympic Sports*. https://www.researchgate.net/publication/271209229

Barzouka, K., Sotiropoulos, K., Tsavdaroglou, S., & Kosiva, E. (2019). Comparison of elite male and female volleyball setters regarding the time-zone setting choice and their performance per rotation. *Exercise & Society,* 63, 26-38.

Palao, J. M., Santos, J. A., & Ureña, A. (2005). The effect of the setter's position on the spike in volleyball. *Journal of Human Movement Studies, 48*(1), 25-40.

Drikos, S., Sotiropoulos, K., Gkreka, S., Tsakiri, M., & Barzouka, K. (2022). Variations in Attack Patterns between Female and Male outside hitters in top-level Volleyball. *International Journal of Sports Science & Coaching, 17*(2), 174795412210757. https://doi.org/10.1177/17479541221075723

Порівняльний аналіз виконавської майстерності комплексу I у пляжному волейболі серед спортсменів чоловічої та жіночої статей

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 5 табл., 5 рис., 32 джерела.

Мета дослідження. Метою цього дослідження було проаналізувати та оцінити результативність застосування різних видів навичок серед гравців чоловічої та жіночої статей у Комплексі I.

Матеріали та методи. Дослідження охоплювало 28 чоловічих та 26 жіночих матчів, які представляли 32 національні команди, що брали участь у фіналі Світового туру ФІВБ 2019 року. Загалом було зафіксовано та проаналізовано 3624 послідовності Комплексу I. Навички виконання пасу (прийом та специфічна передача м'яча зв'язуючим гравцем, який направляє м'яч нападаючому для виконання удару) оцінювалися за чотирирівневою шкалою рейтингу якості тактики, а атакуючі удари — за п'ятирівневою шкалою. Тест на визначення обсерваційної надійності продемонстрував високий коефіцієнт кореляції.

Результати. Гравці чоловічої статі в пляжному волейболі загалом продемонстрували вищу якість (рівень якості — QL3) у прийомі подачі та передачі м'яча з позиції зв'язуючого, а також більшу ефективність (QL4) у виконанні нападаючих ударів порівняно з жінками. Чоловіки частіше використовували базову техніку виконання передачі передпліччям при прийомі м’яча (p = 0.001), верхню передачу (p = 0.001) з позиції зв’язуючого та сильний нападаючий удар (p = 0.001) при атакуючих діях, порівнюючи з гравцями жіночої статі. Натомість жінки частіше використовували бічну передачу передпліччям та інші техніки прийому м’яча (p = 0.001 та p = 0.001 відповідно), нижню передачу з позиції зв’язуючого (p = 0.001) та техніки сильного й атакуючого ударів, що виконуються зігнутими пальцями, використовуючи кісточки, щоб завдати швидкого та точного удару по м’ячу при атакуючих діях (p = 0.001 та p = 0.001 відповідно). Крім того, чим вища якість прийому подачі, тим краща якість виконання передачі зв’язуючим гравцем (p < 0.001), а чим вища якість виконання передачі з позиції зв’язуючого, тим ефективніша атака (p < 0.001) для обох статей. Зрештою, результати показали, що чоловіки-спортсмени частіше виконували відмінні передачі з позиції зв’язуючого, ніж жінки-спортсменки (p = 0.02, p =0.001 та p = 0.001 відповідно), незалежно від рівня якості прийнятої подачі.

Висновки. Гравці чоловічої статі виявилися ефективнішими за гравців жіночої статі, оскільки вони насамперед використовували техніку фронтального прийому, верхню передачу з позиції зв’язуючого та потужні атакуючі удари, що підвищило загальну якість їхньої гри. З метою узагальнення отриманих результатів рекомендується провести подальші дослідження різних змагальних рівнів та вікових категорій.

Ключові слова: результативність, технічні навички, комплекс I, пляжний волейбол, гендер.

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Original Scientific Article

The Development and Educational Evaluation of a Smart IoT Relay Baton with Accelerometer Technology

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Abstract

Background. Relay performance depends on both individual speed and the efficiency of baton exchanges. However, conventional batons lack quantitative feedback to guide training.

Objectives. This study aimed to develop and evaluate a Smart IoT Relay Baton equipped with an accelerometer to provide objective, real-time performance data.

Materials and Methods. A modified R&D approach by Borg and Gall was used, involving needs analysis, system design, expert validation, small/large-scale trials, product revision, and finalization. The prototype used an accelerometer + NodeMCU ESP32, MQTT streaming, and a web dashboard. The participants were 241 sprint relay athletes (19–23 years). Baseline runs with conventional batons were followed by identical runs with the IoT baton. The outcomes included the measurement of transition time, entry speed, average acceleration, and team coordination (sync delay). The statistical analysis employed comprised using the Shapiro–Wilk test, paired t-tests, Cohen's d, and Pearson correlations ($\alpha = .05$).

Results. Significant improvements were observed across all variables: transition time −9.97%, entry speed +9.85%, average acceleration +8.98%, and coordination +24.21% (all $p < .05$). Effect sizes were large to very large ($d = 0.70$–1.20). Correlations highlighted strong links between entry speed and acceleration ($r = .74$), as well as between transition time and coordination ($r = .68$).

Conclusions. The IoT baton effectively supported coaches with accurate evaluations and strategic decision-making. These findings underscore the transformative role of IoT-based devices in advancing evidence-based sprint training. Further research should validate the tool in official competitions, integrate biometric and video-tracking technologies.

Keywords: IoT in sports, sprint relay performance, accelerometer evaluation.

Introduction

Individualized training is key to improving athletic performance (Yuwono, Adi S, et al., 2025) and honing talent (Yuwono, Billiandri, et al., 2025), thereby supporting better athletic performance in the future (Kusuma et al., 2023; Yuwono et al., 2024). In line with the need for peak performance, innovations in relay baton design are necessary. Conventional batons may not be suitable for all athletes; modified batons are safer, more comfortable (Hidayatullah et al., 2020), and more precise (Shandal, 2022). In addition, conventional batons do not take into account ergonomic and measurement needs. Conventional batons are unable to provide quantitative data on the speed, acceleration, and rhythm of runners' steps during the exchange. Coaches find it difficult to evaluate athletes due to the scarcity of reliable statistical data (Griffin et al., 2021). Objective data such as race times and movement analysis are crucial for accurate athlete selection and performance evaluation (Johnston & Baker, 2022). Time is critical in extracting insights (Komitova et al., 2022). Optimal baton-passing techniques are crucial in relay races. The lack of objective data makes it difficult for coaches to identify their team's weaknesses. To overcome the difficulties in evaluation caused by scarcity of objective data, the integration of 5G loT technology and accelerometer sensors provides an innovative solution that supplies real-time data.

The lack of quantitative data makes it difficult for coaches to identify weaknesses in baton exchange techniques and determine the most optimal runner order. This is crucial considering that the success of a relay team is greatly influenced by the combination of individual speed and efficient baton exchange techniques. In the national context, although Indonesia won the gold medal in the men's 4x100 m event in 2023, this achievement has not been consistent across all relay events. Until now, there has been no objective evaluation that can determine with certainty which runners are the fastest or slowest in baton exchanges, so team strategies still rely on subjective estimates. This situation underscores the need for technology that can provide real-time, accurate, and practical data to support performance development.

The integration of 5G loT technology facilitates the collection and analysis of multi-index sports data (Wang & Zhao, 2021). Wearable sensors play an important role in improving performance (Sattaburuth & Wannapiroon, 2021), measuring acceleration (Sheerin et al., 2020; Tenforde et al., 2020) and measuring acceleration patterns (Lariviere et al., 2020). In addition, accelerometers can estimate walking speed by analyzing raw data (Davis et al., 2023). By integrating accelerometers into IoT-based relay batons, coaches can obtain detailed information about acceleration, deceleration, and baton exchange effectiveness. This technology not only enables more accurate performance monitoring but also provides a systematic basis for evaluating training strategies and determining team composition.

Previous studies have explored running support technologies, such as the use of drones, smart shoes, and video analysis systems (Balasubramaniam et al., 2023; Cardenas Hernandez et al., 2024; Hébert-Losier & Pamment, 2023). However, these approaches still have limitations, including high costs, complex personalization requirements, limited coverage of straight sprints, and a lack of ability to provide direct quantitative feedback (Mohamed Zaki et al., 2024). This emphasizes the urgency of innovating devices that are more practical, Real-time, and adaptive to the actual conditions of the relay track.

Based on this background, this study aims to develop and evaluate a Smart IoT Relay Baton with an accelerometer sensor as an innovative solution for monitoring the performance of relay runners. The resulting prototype not only functions as a handover tool but also as a data-based evaluation instrument that supports coaches in identifying athletes' strengths and weaknesses, developing team strategies, and comprehensively optimizing sprint performance.

Materials and Methods

Research Design

This study employed a Research and Development (R&D) design based on a modified Borg and Gall model. The process included needs analysis, system design, expert validation, small- and large-scale field testing, product revision, and finalization.

Participants

A total of 241 sprint relay athletes from PASI (Indonesian Athletics Federation) Central Java participated. Purposive sampling was applied with inclusion criteria: age 19–23 years, provincial-level competition experience, and regular training (≥3 sessions per week). Athletes with acute injuries or medical contraindications were excluded. Participant characteristics are summarized in Table 1.

Instruments

The primary instrument was the Smart IoT Relay Baton, integrating an accelerometer with a NodeMCU ESP32 microcontroller. A web-based monitoring application visualized real-time data via MQTT protocol, with PHP backend and MySQL database. Additional tools included observation sheets, expert validation questionnaires, and a digital stopwatch as backup.

Table 1. Participant Characteristics (n = 241)

Variable	Total (n=241) Mean ± SD	Male (n=121) Mean ± SD	Female (n=120) Mean ± SD
Age (years)	19.3 ± 2.4	19.5 ± 2.5	19.1 ± 2.3
Height (cm)	170.6 ± 8.1	174.8 ± 6.9	166.2 ± 6.7
Weight (kg)	62.9 ± 9.8	68.1 ± 8.2	57.7 ± 7.5
Training experience (years)	3.8 ± 1.9	4.0 ± 1.8	3.6 ± 2.0
Event specialization, n (%)			
– 4×100 m	181 (75%)	92 (76%)	89 (74%)
– 4×400 m	60 (25%)	29 (24%)	31 (26%)
Preferred handover hand (R/L), n (%)	197 / 44	104 / 17	93 / 27
Recent injury (last 6 months), n (%)	38 (15.8%)	20 (16.5%)	18 (15.0%)

Fig. 1. Smart IoT Relay Baton Prototype

Procedure

Baseline trials were conducted using conventional batons, followed by trials with the IoT baton under identical conditions. Each athlete performed multiple runs, with performance metrics recorded: (1) transition time, (2) sprint speed entering the exchange zone, (3) average acceleration, and (4) team coordination (sync delay). Expert validation involved sport technology specialists and PASI coaches, ensuring both technical reliability and practical usability.

Ethical Considerations

This study was conducted following ethical standards for research involving human participants. Ethical approval was obtained from the Ethics Committee under Approval No: 0419/KEPK/UNNES/IX/2025. All participants were informed about the study objectives, procedures, potential risks, and benefits, and provided written informed consent prior to participation. To minimize risks, athletes were screened for acute injuries or medical contraindications before data collection, and only those deemed safe to participate continued with the trials. Participation was voluntary, and athletes were allowed to withdraw at any time without penalty.

Data Analysis

Data normality was tested using Shapiro–Wilk. Pre–post comparisons were analyzed with paired sample t-tests, and Cohen's d quantified effect sizes. Pearson's correlation assessed relationships between key variables. Descriptive statistics (mean, SD, percentage improvement) complemented inferential results. Significance was set at $p < 0.05$.

Results

Prior to hypothesis testing, a normality check was conducted using the Shapiro–Wilk test. The results showed that the distribution of all four performance variables met the assumption of normality, with significance values greater than 0.05. This finding indicates that the dataset was suitable for further analysis using parametric statistical tests, specifically paired sample t-tests. The details are presented in Table 2.

Table 2. Normality Test of Performance Variables (Shapiro–Wilk)

Variable	Significance (p)
Relay Transition Time (s)	0.091
Sprint Speed Entering Zone (m/s)	0.087
Average Acceleration (m/s²)	0.094
Team Coordination (Sync Delay) (s)	0.066

Note. All p values exceeded 0.05, confirming that the data were normally distributed

After confirming the assumption of normality, paired sample t-tests were conducted to examine differences in athletes' performance before and after using the IoT-based relay baton. The results demonstrated statistically significant improvements across all four measured variables. Relay transition time decreased by 0.32 seconds (9.97%), sprint speed entering the exchange zone increased by 0.80 m/s (9.85%), average acceleration improved by 0.22 m/s^2 (8.98%), and team coordination, measured by sync delay, improved by 0.23 seconds (24.21%). These findings indicate that the use of the IoT relay baton substantially enhanced both technical and coordinative aspects of sprint relay performance. Figure 1. Pre–post comparison of relay performance variables before and after the implementation of the IoT-based relay baton. Bars represent mean ± standard deviation (SD). Gray bars = pre-test; teal bars = post-test. Percentage values above the post-test bars indicate the relative improvement compared to baseline.

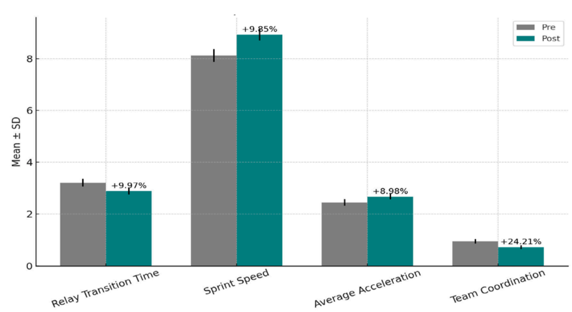


Fig. 2. Pre-Post Comparison of Performance Variables

Table 3. Paired Sample T-Test Results

Variable	Mean (Pre–Post)	t Count	Difference	Sig. (p)	% Improvement
Relay Transition Time (s)	3.21 → 2.89	4.212	−0.32	0.0011	9.97% (Time Decrease)
Sprint Speed Entering Zone (m/s)	8.12 → 8.92	3.654	+0.80	0.002	9.85% (Speed Increase)
Average Acceleration (m/s²)	2.45 → 2.67	2.918	+0.22	0.011	8.98% (Increase)
Team Coordination (Sync Delay) (s)	0.95 → 0.72	3.101	−0.23	0.006	24.21% (Synchronization)

Beyond statistical significance, effect size analysis was conducted to determine the practical magnitude of improvements across the four performance variables. The results confirmed that the intervention had meaningful impacts on relay performance. Transition time (d = 0.90) and sprint speed entering the exchange zone (d = 0.85) demonstrated large effects, while average acceleration (d = 0.70) showed a medium-to-large effect. Notably, team coordination (d = 1.20) exhibited a very large effect, indicating that the IoT-based baton was particularly effective in enhancing synchronization among runners. These findings highlight that the improvements were not only statistically significant but also practically relevant for training and performance optimization.

Table 4. Effect Size (Cohen's d) for Performance Variables

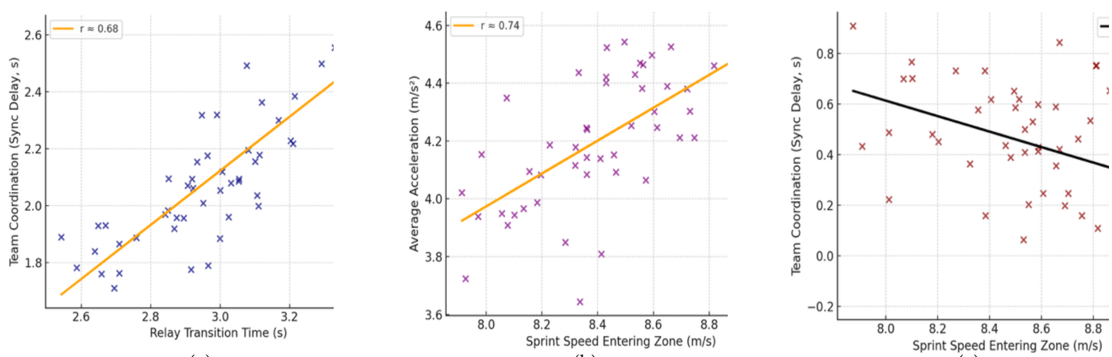
Variable	Cohen's d	Effect Category
Relay Transition Time	0.90	Large
Sprint Speed Entering Zone	0.85	Large
Average Acceleration	0.70	Medium–Large
Team Coordination (Sync Delay)	1.20	Very Large

Note. Interpretation of effect sizes follows cohen's (1998) guidelines, where 0.2 = small, 0.5 = medium, and 0.8 = large

To further explore the relationships between performance indicators, Pearson's correlation analysis was performed. The results revealed several meaningful associations. Transition time was strongly and positively correlated with team coordination (r = 0.68, p = 0.003), suggesting that shorter transition times were achieved when baton exchanges were more synchronized. Sprint speed and average acceleration showed a very strong positive correlation (r = 0.74, p = 0.001), indicating that higher sprinting speed entering the exchange zone was strongly supported by greater initial acceleration. Conversely, sprint speed and team coordination were moderately and negatively correlated (r = –0.58, p = 0.010), implying that increases in speed without sufficient synchronization could disrupt baton exchanges. Figure 2. Correlation analysis of relay performance variables (a) relay transition time and team coordination; (b) Sprint speed entering the exchange zone and average acceleration; (c) Sprint speed and coordination.

Discussion

The use of loT-based baton relay sticks significantly improves team coordination. This is evident from the significant reduction in sync delay (the interval between runners) by 24.21% reflecting improved synergy and harmony in baton exchanges. This improvement in coordination also has the greatest impact compared to other variables. The implementation of IoT-based relay batons significantly improves team coordination during relay transitions by facilitating real-time communication and feedback among team members. This interactive technology enables synchronous interaction, which is crucial in high-tempo environments where quick decision-making is essential (Georganta et al., 2024; Soenyoto et al., 2025). By providing adaptive feedback mechanisms, IoT systems can monitor team dynamics and dynamically adjust coordination strategies, thereby improving overall performance (Irawan et al., 2025; Wiltshire et al., 2024). Furthermore, the use of lean communication tools, such as gestural signals in competitive settings, demonstrates how effective communication can be optimized even under constraints, further supporting team coordination (Nova et al., 2023; Zheng et al., 2023). Overall, the integration of loT technology in relay transitions not only stramlines the process but also fosters a more cohesive team enviroment, ultimately leading to improved performance outcomes (Alfariski et al., 2022; Narvios et al., 2022).



(a) (b) (c)

Fig. 3. Correlation analysis of relay performance variables

Table 5. Correlations Between Performance Variables

Variable Correlation	r Value	Sig. (p)	Interpretation
Transition Time vs. Team Coordination	0.68	0.003	Strong positive correlation
Sprint Speed vs. Average Acceleration	0.74	0.001	Very strong correlation
Sprint Speed vs. Team Coordination	–0.58	0.010	Moderate negative correlation

Note. Positive correlations indicate that improvements in one variable are associated with improvements in another, while negative correlations suggest a trade-off relationship

The relay transition time decreased from 3.21 seconds to 2.89 seconds, demonstrating improved technicl efficiency due to the real-time information provided by the tool. This quantitative data helps coaches evaluate athletes' timing and responses objectively, which was previously based solely on manual observation. The transition time variable shows a significant improvement in performance after technological intervention due to increased efficiency in detecting and managing transitions in various contexts. For example, in healthcare, technology facilitates better integrated care coordination, addressing gaps in information exchange and communication among providers, which is particularly important for patients with chronic conditions such as CKD (Feldner & Davey, 2023). Similarly, advances in assistive devices, such as exoskeletons, leverage machine learning to optimize real-time transition detection, significantly improving processing time and user experience (Orhan et al., 2023). In product development, the use of virtual reality (VR) during transition activities has been shown to improve team performance by encouraging more effective discussion and decision-making processes (Horvat et al., 2023). Furthermore, in an organizational context, acquiring alliance partners can streamline knowledge absorption, thereby increasing inventive output and improving technological performance (McCarthy & Aalbers, 2022). Finally, innovations in adaptive optics have drastically reduced response times, demonstrating the impact of technological advances on performance metrics (Boudjema et al., 2025). Collectively, these interventions show that technology not only streamlines, processes but also improves overall performance in various fields.

There is a very strong correlation (r = 0.74) between sprint speed and average acceleration. This indicates that the increase in a runner's speed when entering entering the transition zone is greatly influenced by their initial acceleration ability. Thus, training that combines sprinting and acceleration techniques will be more effective. The relationship between sprint speed entering the zone and the runner's average acceleration is significant, as evidenced by various studies. Research shows that the ability to generate a high force ratio during initial acceleration is crucial for sprint performance, with kinematic characteristics such as foot placement and ankle dorsiflexion playing an important role in improving acceleration ability (Bhakti et al., 2024). Additionally, hip torque has been identified as a mechanistic link between acceleration and maximum speed, suggesting that increased thigh angle acceleration can benefit both phases of sprinting (Adi et al., 2023). Research shows that the ability to generate a high force ratio during initial acceleration is crucial for sprint performance, with kinematic characteristics such as foot placement and ankle dorsiflexion playing an important role in improving acceleration ability (King et al., 2022; Rumini et al., 2024b). Additionally, hip torque has been identified as a mechanistic link between acceleration and maximum speed, suggesting that increased thigh angle acceleration can benefit both phases of sprinting (Clark & Ryan, 2022; Rumini et al., 2024a). Finally, innovations in adaptive optics have drastically reduced response times, demonstrating the impact of technological advances on performance metrics (Annas et al., 2024; Boudjema et al., 2025). Collectively, these interventions show that technology not only streamlines processes but also improves overall performance in various fields.

.Futhermore, metrics such as sprint distance and acceleration at varying speeds have been shown to correlate with player workload, indicating that these factors are important for understanding the dynamics of sprinting in a competitive context (Aliriad et al., 2024; Prudholme et al., 2022). Overall, these findings underscore the interplay between acceleration and sprint speed, highlighting the importance of targeted training to optimize performance (Irawan et al., 2023; Silva et al., 2024).

Real-time data from the tool enables coaches to identify the most efficient runners and those who need improvement, as well as to sequence runners based on quantitative data such as reaction time, zone entry speed, and transition time. This provides a strategic advantage previously unavailable through subjective methods. The effectiveness of real-time data in helping coaches strategize and sequence relay runners is significantly enhanced through the use of objective measurement protocols and advanced analytics.

Wearable devices, such as inertial measurement units (IMUs), provide coaches with measurable performance metrics, enabling accurate evaluation of athletes' coordination abilities and fatigue levels, which are crucial for optimizing relay strategies (Carissimo et al., 2023; Hamidi Rad et al., 2022; Permana et al., 2024). Additionally, the integration of real-time data into training dashboards facilities informed decision-making by providing comprehensive performance reports that track progress over time.

The integration of IoT relay batons in sports education and athlete training curriculum development holds significant implications, as evidenced by the advancements in IoT technologies across various sports contexts. The broader application of IoT in physical education, as highlighted by the use of wearable devices, underscores the potential for these technologies to facilitate more effective teaching and learning processes in sports education, thereby supporting sustainable higher education in physical education and sports (PES) (Cojocaru et al., 2022). Furthermore, the integration of advanced technologies like virtual reality, augmented reality, and wearable tech in professional sports training has been shown to enhance performance metrics, reduce injury risks, and improve cognitive skills, which could be mirrored in the use of IoT relay batons to optimize training outcomes (Huang & Tang, 2024). The acceptance of wearable IoT devices, such as smart bracelets, has been shown to significantly enhance physical performance metrics among college students, suggesting that similar acceptance and integration of IoT relay batons could lead to improved training results and curriculum development in sports education (Xu et al., 2024). Additionally, the use of IoT devices in sports, such as the rowing propulsion monitoring system, demonstrates the potential for real-time data analysis and performance optimization, which could be adapted for relay baton use to provide athletes and coaches with valuable insights for performance improvement (Castro et al., 2022). The continuous advancements in wearable technology and ubiquitous computing further support the development of personalized training programs and data-driven decision-making, which are crucial for modernizing sports education curricula and enhancing athlete training programs (Setyawati et al., 2024). Overall, the integration of IoT relay batons in sports education and training curricula can lead to more personalized, data-driven, and effective training methodologies, ultimately enhancing athletic performance and educational outcomes.

This study has several limitations that should be considered when interpreting the results. First, there is a potential for a sequence effect because all participants performed a baseline trial with a conventional cane followed by a trial using an IoT-based cane. Although the same warm-up and rest intervals were applied, fatigue or adaptation effects may have influenced the performance differences. Future studies should consider a randomized or balanced crossover design to minimize this effect. Second, the performance metrics (transition time, sprint speed, acceleration, and synchronization delay) were primarily obtained from accelerometers and a web-based dashboard developed for this study. Although these devices have been validated by experts, some level of measurement error (e.g., sensor calibration drift, data transmission latency) may have affected the accuracy of the collected data. The integration of high-speed video analysis or force plates could further strengthen the accuracy of performance measurements. Finally, participants were limited to provincial-level athletes aged 19–23 years. Therefore, generalizing the results to elite or younger athletes should be done with caution.

Conclusion

The development and evaluation of the Smart IoT Relay Baton with an integrated accelerometer proved to be effective in enhancing sprint relay performance by providing objective and real-time data. Significant improvements were observed across all measured variables, including reduced transition time (–9.97%), increased entry speed (+9.85%), enhanced average acceleration (+8.98%), and notably improved team coordination (+24.21%). Effect sizes ranging from large to very large confirm that the intervention was not only statistically significant but also practically relevant. These findings highlight the potential of IoT-based devices to replace subjective observational methods, allowing coaches to make more accurate evaluations and strategic decisions in athlete training and team composition. Future research is recommended to validate the system in official competition settings, integrate biometric and video-tracking technologies to broaden analytical capabilities, and develop predictive models for optimizing relay runner order, as well as to extend the application to other relay events and youth athletes to strengthen data-driven athletic development.

Conflict of Interest and Funding

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Author Contributions

All authors contributed substantially to the conception and design of the study, data acquisition, analysis, and interpretation, as well as drafting and revising the manuscript. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

References

Yuwono, C., Adi S, Appukutty, M., Setyowati, E., Riyalda, B. F., Aliriad, H., & Utama, M. B. R. (2025). High-Flying Research Trends and Innovations in Young Athletes' Jump Training: A Bibliographic Analysis of Research Over Ten Years. *Physical Education Theory and Methodology, 25*(1), 202-208. https://doi.org/10.17309/tmfv.2025.1.24

Yuwono, C., Billiandri, B., Putri, D. T., & Adi, S. (2025). A Machine Learning - Based Framework for Optimizing Sports Talent Identification and Development. *Cuestiones de Fisioterapia, 54*(2), 3934-3952. https://doi.org/https://doi.org/10.48047/8sxdfm81

Kusuma, D. W. Y., Yuwono, C., Qoriah, A., Supriyono, S., & Wiyanto, A. (2023). Psychological and nutritional analysis of athletes for Semarang sports week championship 2023. Jurnal SPORTIF : Jurnal Penelitian Pembelajaran, 10(2 SE-Article), 288–304. https://doi.org/10.29407/js_unpgri.v10i2.23338

Yuwono, C., Adi, S., Annas, M., Darmawan, A., Billiandri, B., Putri, D. T., & Pratama, A. B. (2024). Determinants of Performance of 12-Year-Old Soccer School Players in Central Java. *ACTIVE: Journal of Physical Education, Sport, Health and Recreation, 13*(2). https://doi.org/10.15294/peshr.v13i2.1383

Hidayatullah, F., Anwar, K., & Ruski. (2020). Care Stick dan Core Paddle: Media Pembelajaran Pendidikan Jasmani Adaptif Untuk Siswa Disabilitas. *Journal Sport Area, 5*(2), 199-214. https://doi.org/10.25299/sportarea.2020.vol5(2).5185

Shandal, B. A. H. (2022). The effect of an educational training curriculum on receiving and delivering the stick in the modern way and the achievement of (4 x 100) runners. *International Journal of Health Sciences, 6*(S9), 3992–3997. https://doi.org/10.53730/ijhs.v6nS9.13543

Griffin, A., Kenny, I. C., Comyns, T. M., Purtill, H., Tiernan, C., O'Shaughnessy, E., & Lyons, M. (2021). Training load monitoring in team sports: a practical approach to addressing missing data. *Journal of Sports Sciences, 39*(19), 2161-2171. https://doi.org/10.1080/02640414.2021.1923205

Johnston, K., & Baker, J. (2022). Sources of information used by elite distance running coaches for selection decisions. *PloS One, 17*(8), e0268554. https://doi.org/10.1371/journal.pone.0268554

Komitova, R., Raabe, D., Rein, R., & Memmert, D. (2022). Time Series Data Mining for Sport Data: a Review. *International Journal of Computer Science in Sport, 21*(2), 17-31. https://doi.org/10.2478/ijcss-2022-0008

Wang, H., & Zhao, B. (2021). Constructing Sports Multi-Index Data Analysis Based on 5G IoT Technology. *Mathematical Problems in Engineering, 2021*(1), 6982366. https://doi.org/10.1155/2021/6982366

Sattaburuth, C., & Wannapiroon, P. (2021). Sensorization of Things Intelligent Technology for Sport Science to Develop an Athlete's Physical Potential. *Higher Education Studies,* 11, 201. https://doi.org/10.5539/hes.v11n2p201

Sheerin, K. R., Besier, T. F., & Reid, D. (2020). The influence of running velocity on resultant tibial acceleration in runners. *Sports Biomechanics, 19*(6), 750-760. https://doi.org/10.1080/14763141.2018.1546890

Tenforde, A. S., Hayano, T., Jamison, S. T., Outerleys, J., & Davis, I. S. (2020). Tibial Acceleration Measured from Wearable Sensors Is Associated with Loading Rates in Injured Runners. *PM & R : The Journal of Injury, Function, and Rehabilitation, 12*(7), 679-684. https://doi.org/10.1002/pmrj.12275

Lariviere, O., Provot, T., Valdes-Tamayo, L., Bourgain, M., & Chadefaux, D. (2020). Force Pattern and Acceleration Waveform Repeatability of Amateur Runners. *In Proceedings, 49*(1). https://doi.org/10.3390/proceedings2020049136

Davis, J. J., Oeding, B. E., & Gruber, A. H. (2023). Estimating Running Speed From Wrist- or Waist-Worn Wearable Accelerometer Data: A Machine Learning Approach. *Journal for the Measurement of Physical Behaviour, 6*(1), 24-36. https://doi.org/10.1123/jmpb.2022-0011

Balasubramaniam, A., Reidsma, D., & Heylen, D. (2023). Drone-Driven Running: Exploring the Opportunities for Drones to Support Running Well-being through a Review of Running and Drone Interaction Technologies. *Proceedings of the 11th International Conference on Human-Agent Interaction,* 209-220. https://doi.org/10.1145/3623809.3623831

Cardenas Hernandez, F. P., Schneider, J., Di Mitri, D., Jivet, I., & Drachsler, H. (2024). Beyond hard workout: A multimodal framework for personalised running training with immersive technologies. *British Journal of Educational Technology, 55*(4), 1528-1559. https://doi.org/10.1111/bjet.13445

Hébert-Losier, K., & Pamment, M. (2023). Advancements in running shoe technology and their effects on running economy and performance – a current concepts overview. *Sports Biomechanics, 22*(3), 335-350. https://doi.org/10.1080/14763141.2022.2110512

Mohamed Zaki, M. T. A., Sakr, M. A. K., Khafagy, A. A. E.-W., & Sallam, B. M. (2024). New Trend for Evaluating the Technical Performance of 4×100m Relay through Predicting the Team Targeted Record. *Journal of Theories and Applications of Physical Education Sport Sciences, 11*(1), 1-10. https://doi.org/10.21608/jat.2024.293853.1019

Georganta, E., Claudia, P., & and Niess, J. (2024). Interactive technologies through the lens of team effectiveness: an interdisciplinary systematic literature review. *European Journal of Work and Organizational Psychology, 33*(2), 172-187. https://doi.org/10.1080/1359432X.2023.2178904

Soenyoto, T., Adi, S., Darmawan, A., Aliriad, H., & Utama, M. B. R. (2025). Smart physical education: Integrating flipped classroom with IoT and android for enhanced learning. *Journal of Human Sport and Exercise, 20*(4), 1122-1132. https://doi.org/10.55860/ydz9ex90

Irawan, R., Priyono, B., Soedjatmiko, S., Santoso, I. C. W., Wahyudi, A., & Adi S. (2025). Biomechanical Kinetic Chain Analysis of Service Motion for Speed Ball Prediction Through SBM-03 App Development. *Physical Education Theory and Methodology, 25*(3), 601-608. https://doi.org/10.17309/tmfv.2025.3.16

Wiltshire, T. J., van Eijndhoven, K., Halgas, E., & Gevers, J. M. P. (2024). Prospects for Augmenting Team Interactions with Real-Time Coordination-Based Measures in Human-Autonomy Teams. *Topics in Cognitive Science, 16*(3), 391-429. https://doi.org/10.1111/tops.12606

Nova, A., Sinulingga, A. R., Syahputra, M., Helmi, B., Aditya, R., Adi, S., Nofrizal, D., & Firmansyah, G. (2023). Analysis of Factors Affecting Policy Development of Achievement Sports in Aceh Province. *International Journal of Human Movement and Sports Sciences, 11*(5), 1121-1131. https://doi.org/10.13189/saj.2023.110521

Zheng, K., Stein, B., & Farzan, R. (2023). Use Ping Wisely: A Study of Team Communication and Performance under Lean Affordance. *Trans. Soc. Comput., 5*(1-4). https://doi.org/10.1145/3557022

Alfariski, M. R., Dhandi, M., & Kiswantono, A. (2022). Automatic Transfer Switch (ATS) Using Arduino Uno, IoT-Based Relay and Monitoring. *JTECS : Jurnal Sistem Telekomunikasi Elektronika Sistem Kontrol Power Sistem Dan Komputer, 2*(1), 1. https://doi.org/10.32503/jtecs.v2i1.2238

Narvios, W. M. O., Unabia, S. M., Batayola, F. F., Remo, K. J., Villarin, E. M., & Nguyen, Y. Q. (2022). IoT based automatic transfer switch with monitoring and control system. *AIP Conference Proceedings, 2502*(1), 20003. https://doi.org/10.1063/5.0108724

Feldner, K., & Davey, C. (2023). Exploring the Evidence: Using Technology to Improve Integrated Care Coordination. *Nephrology Nursing Journal : Journal of the American Nephrology Nurses' Association, 50*(1), 59-64. https://doi.org/10.37526/1526-744X.2023.50.1.59

Orhan, Z. O., Prete, A. D., Bolotnikova, A., Gandolla, M., Ijspeert, A. J., & Bouri, M. (2023). Maximizing Performance with Minimal Resources for Real-Time Transition Detection. In CoRR: Vol. abs/2310.0. https://doi.org/10.48550/ARXIV.2310.04117

Horvat, N., Martinec, T., Brnčić, M., & Škec, S. (2023). Is It Better? Exploring The Effect Of Transition Goal And Virtual Reality On Team Performance. *Proceedings of the Design Society,* 3, 2385-2394. https://doi.org/10.1017/pds.2023.239

McCarthy, K. J., & Aalbers, H. L. (2022). Alliance-to-acquisition transitions: The technological performance implications of acquiring one's alliance partners. *Research Policy, 51*(6), 104512. https://doi.org/10.1016/j.respol.2022.104512

Boudjema, I., Sinquin, B., Schimpf, A., Forrière, H., Martin, B., & Charton, J. (2025). Advanced control of ALPAO DMs leads to significant AO performance improvements. *In H. Hemmati & B. S. Robinson (Eds), Free-Space Laser Communications XXXVII* (p. 64). SPIE. https://doi.org/10.1117/12.3041793

Bhakti, Y. H., Rahayu, T., Kristiyanto, A., Azam, M., S, A., & Aliriad, H. (2024). Analyzing Handball Techniques Using A Biomechanical Approach: A Systematic Literature Review. *Physical Education Theory and Methodology, 24*(2), 338–343. https://doi.org/10.17309/tmfv.2024.2.20

Adi, S., Rohidi, T. R., & Rustiadi, T. (2023). Digital literacy of physical education teachers in the 5.0 era. *Sport TK,* 12. https://doi.org/10.6018/SPORTK.562941

King, D., Burnie, L., Nagahara, R., & Bezodis, N. (2022). Relationships between kinematic characteristics and ratio of forces during initial sprint acceleration. *Journal of Sports Sciences,* 40, 2524–2532. https://doi.org/10.1080/02640414.2023.2172797

Rumini, Adi S, & Kusuma, D. W. Y. (2024b). The Mechanics of Speed: A Systematic Literature Review on Athletic Sprint Techniques. *Physical Education Theory and Methodology, 24*(6), 990-996. https://doi.org/10.17309/tmfv.2024.6.17

Clark, K. P., & Ryan, L. J. (2022). Hip Torque Is a Mechanistic Link Between Sprint Acceleration and Maximum Velocity

Performance: A Theoretical Perspective. *Frontiers in Sports and Active Living,* 4. https://doi.org/10.3389/fspor.2022.945688

Rumini, Adi S, & Kusuma, D. W. Y. (2024a). Beyond the Finish Line: Muscle Injuries in Athletic Competition. *Physical Education Theory and Methodology, 24*(5), 744-748. https://doi.org/10.17309/tmfv.2024.5.09

Annas, M., Soegiyanto, S., Hidayah, T., Hartono, M., Setyawati, H., Setyawati, H., & S, A. (2024). Anthropometry and Biomotor of Various position Young Football Athletes: does it affect performance? *Jurnal Kesehatan Masyarakat, 20*(1). https://doi.org/10.15294/kemas.v20i1.44488

Aliriad, H., Adi, S., Manullang, J. G., Endrawan, I. B., & Satria, M. H. (2024). Improvement of Motor Skills and Motivation to Learn Physical Education Through the Use of Traditional Games. *Physical Education Theory and Methodology, 24*(1), 32-40. https://doi.org/10.17309/tmfv.2024.1.04

Prudholme, D. C., Coburn, J. W., Lynn, S. K., & Lockie, R. G. (2022). Relationships Between Sprint, Acceleration, and Deceleration Metrics with Training Load in Division I Collegiate Women's Soccer Players. *Journal of Human Kinetics,* 85, 53-62. https://doi.org/10.2478/hukin-2022-0109

Irawan, R., Azam, M., Rahayu, S., Setyawati, H., Soedjatmiko, Adi, S., Priyono, B., & Nugroho, A. (2023). Biomechanical Motion of the Tennis Forehand Stroke: Analyzing the Impact on the Ball Speed Using Biofor Analysis Software. *Physical Education Theory and Methodology, 23*(6), 918-924. https://doi.org/10.17309/tmfv.2023.6.14

Silva, H., Fábio Yuzo, N., Gibson, P., João, R., & and Marcelino, R. (2024). The Relationship Between Individually Assessed High-Intensity Accelerations, High-Intensity Decelerations, Sprints, and Technical Performances During Soccer Matches: A Full Season Analysis. *Research Quarterly for Exercise and Sport, 95*(4), 930-937. https://doi.org/10.1080/02701367.2024.2353713

Carissimo, C., Cerro, G., Libero, T. D., Ferrigno, L., Marino, A., & Rodio, A. (2023). Objective Evaluation of Coordinative Abilities and Training Effectiveness in Sports Scenarios: An Automated Measurement Protocol. *IEEE Access,* 11, 76996-77008. https://doi.org/10.1109/ACCESS.2023.3290471

Hamidi Rad, M., Gremeaux, V., Massé, F., Dadashi, F., & Aminian, K. (2022). SmartSwim, a Novel IMU-Based Coaching Assistance. *In Sensors, 22*(9). https://doi.org/10.3390/s22093356

Permana, R., Isti'adah, F. N., Dewi, R. S., Nurkamilah, M., Fitri, S., Nofrizal, D., Purba, P. H., Pranata, D. Y., & Sari, L. P. (2024). Instrument for Assessing Physical Literacy Skills Competence in Primary School Tasikmalaya, Indonesia. *Retos: Nuevas Perspectivas de Educación Física, Deporte y Recreación,* 58. https://doi.org/10.47197/retos.v58.107671

Cojocaru, A. M., Bucea-Manea-Ţoniş, R., Jianu, A., Dumangiu, M., Alexandrescu, L., & Cojocaru, M. (2022). The Role of Physical Education and Sports in Modern Society Supported by IoT—A Student Perspective. *Sustainability, 14*(9), 5624. https://doi.org/10.3390/su14095624

Huang, M., & Tang, Y. (2024). Tech-driven excellence: A quantitative analysis of cutting-edge technology impact on professional sports training. *Journal of Computer Assisted Learning, 41*(1). https://doi.org/10.1111/jcal.13082

Xu, Y., Peng, J., Jing, F., & Ren, H. (2024). From wearables to performance: how acceptance of IoT devices influences physical education results in college students. *Dental Science Reports, 14*(1). https://doi.org/10.1038/s41598-024-75071-3

Castro, R., Mujica, G., & Portilla, J. (2022). Internet of Things in Sport Training: Application of a Rowing Propulsion Monitoring System. *IEEE Internet of Things Journal,* 9, 18880-18897. https://doi.org/10.1109/JIOT.2022.3163181

Setyawati, H., Kusuma, D. W. Y., Appukutty, M., & Adi, S. (2024). Analysis of Spoºrt Tourism Potential, Occupational Safety and Health in Tandem Paragliding. *Kemas, 20*(2), 295–302. https://doi.org/10.15294/kemas.v20i2.50323

Розроблення та оцінка освітньої ефективності використання смарт-естафетної палички на основі Інтернету речей (IoT) з технологією акселерометра

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Реферат. Стаття: 9 с., 5 табл., 3 рис., 52 джерела.

Історія питання. Результативність естафети залежить як від індивідуальної швидкості, так і від ефективності передачі естафетної палички. Однак традиційні естафетні палички не дають кількісної інформації, необхідної для планування тренувань.

Мета дослідження. Мета цього дослідження полягала у розробленні та оцінці смарт-естафетної палички з інтеграцією Інтернету речей (IoT), оснащеної акселерометром, для надання об'єктивних даних щодо продуктивності в режимі реального часу.

Матеріали та методи. Застосовано метод науково-дослідних та дослідно-конструкторських робіт за моделлю Борга і Галла, що включав аналіз потреб, дизайн системи, експертну валідацію, невеликі/великомасштабні випробування, доопрацювання продукту та фіналізацію. У прототипі використовувалися акселерометр + NodeMCU ESP32, MQTT-стрімінг та веб-дашборд. У дослідженні взяли участь 241 спортсмен зі спринтерської естафети віком 19–23 роки. Після базових забігів із звичайними естафетними паличками були проведені ідентичні забіги з паличками IoT. Результити включали вимірювання показників часу переходу, швидкості на старті, середнього прискорення та координації команди (затримка синхронізації). Статистичний аналіз охоплював використання критерію Шапіро-Вілка, t-критерії для парних вибірок, коефіцієнт d Коена та кореляції Пірсона ($\alpha = .05$).

Результати. За всіма показниками спостерігалися значні поліпшення: час переходу −9.97%, швидкість на старті +9.85%, середнє прискорення +8.98% і координація +24.21% (всі $p < .05$). Розміри ефекту становили від великих до дуже великих показників ($d = 0.70–1.20$). Кореляції підкреслили міцні зв'язки між стартовою швидкістю та прискоренням ($r = .74$), а також між часом переходу та координацією ($r = .68$).

Висновки. Використання естафетної палички з інтеграцією Інтернету речей (IoT) сприяло ефективній підтримці тренерів у проведенні точних оцінок та ухваленні стратегічних рішень. Отримані результати підкреслюють трансформаційну роль пристроїв на основі Інтернету речей (IoT) у розвитку науково обґрунтованого тренування спринту. Подальші дослідження мають валідувати зазначений інструмент в офіційних змаганнях, а також інтегрувати біометричні та відеотрекінгові технології.

Ключові слова: Інтернет речей (IoT) у спорті, результативність спринтерської естафети, оцінювання даних за допомогою акселерометра.

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Enhancing Handball Shooting Skills: The Effectiveness of a Website-Based Training Model for Youth Athletes

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Abstract

Objectives. This study aimed to explore the development and supportive role of a website-based training model designed to complement coach-led instruction and improve handball shooting skills in athletes aged 15–17. Traditional training methods have limitations in engagement and consistency, which the web-based model seeks to mitigate by enhancing athlete–coach interaction and accessibility.

Materials and Methods. The study employed a Research and Development (R&D) design, following the Borg and Gall model, with a pre-test and post-test design. The experimental group (n = 20) used the website-based model under coach supervision, while the control group (n = 20) followed conventional training methods. Data was collected through shooting accuracy tests, surveys, interviews, and observations.

Results. The results revealed that the experimental group demonstrated a significantly greater improvement in shooting accuracy, with an N-Gain of 63.90% (95% CI [58.7, 69.1]; $p < .001$), compared to the control group's N-Gain of 24.62% (95% CI [20.3, 29.0]). The website-based model was found to be supportive and effective in standardizing improvements and providing flexible, coach-assisted interactive training. However, challenges such as athlete resistance to new methods and technology access issues were identified.

Conclusions. The study highlights the potential of digital tools in sports training, emphasizing the need for blended implementation with traditional coaching and continued development to address technical and accessibility challenges. Further research should be conducted to investigate the long-term integration, scalability, and coach-mediated implementation of this training model across various sports and age groups.

Keywords: website-based training, handball shooting skills, youth sports training, digital learning tools, athletic performance improvement.

Introduction

Handball is a dynamic and physically demanding sport that requires athletes to master various technical skills to perform effectively. Among these, shooting is one of the most critical skills as it directly impacts an athlete's ability to score (Nopianto et al., 2021; Onell et al., 2023). At the junior level, athletes aged 15-17 are often still developing the necessary technical foundations to excel in shooting. While there are established methods of training in place, particularly for shooting, many of these techniques have not kept pace with advances in technology (Uylas et al., 2024). Traditional training methods, such as repetitive drills, tend to focus on isolated skills but often lack engagement and fail to simulate match conditions. These limitations hinder the development of the all-rounded, dynamic shooting abilities needed for competitive play (Muttib et al., 2024; Uylas et al., 2024). Furthermore, traditional approaches often underutilize digital tools that could assist coaches in providing personalized, data-driven feedback. In response, the integration of technology in sports training, especially web-based platforms, presents an innovative solution that promises to support and enhance the coach-led process, increasing engagement and standardizing athlete progress. This study examines the development of a website-based handball shooting training model for athletes aged 15–17 years, aiming to overcome the limitations of conventional methods by offering a more interactive and personalized coach-assisted approach.

Research on skill acquisition in sports has highlighted the importance of not only physical but also cognitive and psychological factors in developing proficiency (Akyüz et al., 2019; Saavedra & Saavedra, 2020). Specifically, shooting techniques in handball require complex coordination of upper and lower body movements, as well as acute perceptual-cognitive abilities, including the ability to anticipate the goalkeeper's movements and make split-second decisions. Several studies have explored the biomechanics and kinematics of handball shooting, emphasizing the importance of technique, strength, and power in executing accurate shots (Belčić et al., 2023; Dahl & Tillaar, 2021). Furthermore, it has been shown that strength training and power development in the lower limbs and core significantly enhance shot velocity and accuracy (Gómez-Ferolla et al., 2024). While traditional training methods such as blocked drills and strength training have shown some success, they often fail to account for the dynamic nature of actual match situations, where athletes must make decisions under pressure and with varied defensive challenges (Apidogo et al., 2023). The increasing adoption of digital tools, particularly web-based platforms, offers a promising avenue to address these shortcomings by supplementing existing coach-directed sessions rather than replacing them.

Web-based training systems have the potential to provide athletes with real-time feedback, personalized drills, and the flexibility to practice at their convenience. Technologies like wearable sensors, depth cameras, and automated video analysis systems have been successfully applied in various sports to monitor technique and improve performance (Gençoğlu & Gümüş, 2020; Zhao & Lu, 2024). These systems offer the advantage of providing objective, repeatable measures of key performance variables, such as shooting velocity, and can track progress over time without the need for constant in-person coaching. By integrating such technologies into training models, athletes can receive immediate feedback on their performance, allowing for more effective skill refinement and improved match preparation. Moreover, these platforms can be used to simulate game-like conditions, providing athletes with a more realistic and engaging training experience (Bhakti et al., 2024; Schrapf et al., 2017). However, the question remains whether these technological solutions can outperform traditional methods in improving shooting performance in handball, particularly for adolescent athletes.

This study posits that the implementation of a website-based training model can support and enhance the handball shooting skills of athletes aged 15–17 years when integrated with coach guidance. The hypothesis centers on the idea that a web-based system, which offers individualized training programs, real-time feedback, and contextualized practice scenarios, will serve as a supportive mechanism to enhance coach-led instruction, improving athlete engagement and shooting accuracy. The focus of the study is to develop, validate, and test this model in a real-world setting, using both a control group (traditional training) and an experimental group (coach-supervised, web-based training). By addressing the existing gap in the literature regarding the integration of technology into handball training, this research aims to contribute valuable insights into how digital tools can be used to improve skill acquisition in young athletes.

The importance of this study lies in its potential to address several limitations inherent in traditional training approaches. First, traditional methods often fail to individualize training programs to account for variations in athlete maturity, playing position, and physical characteristics (Akinci & Ateş, 2023; Havolli et al., 2020). In contrast, web-based systems can provide personalized feedback based on objective data, which can be adjusted for factors such as the athlete's age, size, and strength (Gençoğlu & Gümüş, 2020; Zhang et al., 2025), hereby assisting coaches in tailoring training intensity and focus. Additionally, while repetitive drills are effective in the short term, they tend to lack the variability and decision-making challenges present in actual match play (Apidogo et al., 2023). Web-based platforms can simulate such match conditions, allowing athletes, under coach direction, to practice under more realistic constraints, such as shooting under pressure or making quick decisions based on opponent movements (Sahli et al., 2024; Schrapf et al., 2017). Finally, the integration of strength and power training with shooting practice is often neglected in conventional methods, but web-based platforms can incorporate strength assessments and drills that complement shooting practice, thereby promoting more holistic development of the athlete's skills in coordination with the coach's program (Abod & AlHaddad, 2022; Dahl & Tillaar, 2021).

While web-based training systems have shown promise in other sports, there is limited research on their specific application to handball. Therefore, the research aims to fill this gap by developing and testing a website-based shooting model tailored to adolescent handball players that operates as an adjunct to conventional training. This study will focus on the practical application of web-based tools, investigating their feasibility and supportive contribution in a real-world training context. Through a carefully designed research methodology, including pre-tests and post-tests, expert validation, and iterative testing phases, the study will provide comprehensive insights into the potential benefits of digital training tools for handball shooting. It is expected that the findings will contribute to the growing body of knowledge on digital sports training, highlighting the advantages of integrating web-based tools with traditional, coach-guided programs.

The primary goal of this study is to explore whether a web-based training model can offer a supportive and engaging complement to traditional handball shooting training for adolescent athletes. The novelty of this research lies in the use of a web-based platform to deliver personalized training, monitor progress, and provide contextualized practice opportunities, working alongside coaches to enhance learning outcomes. The study also aims to assess the broader applicability of such digital training models, with the potential for their implementation in other sports or training settings. By providing evidence on the supportive function of web-based systems in improving shooting skills, this research could inform future practices in sports training, particularly for young athletes. Ultimately, the goal is to enhance the quality of training, improve performance, and make training more accessible and engaging for athletes at all levels through collaboration between technology and coaching.

Materials and Methods

This research employs a Research and Development (R&D) design, specifically using the Borg & Gall model, which is well-suited for creating and validating applied training interventions in sports. The R&D design follows a structured, iterative process that includes several stages, such as problem identification, design and prototyping, validation, testing, and final implementation. This methodology is particularly relevant for developing and testing a coach-assisted, website-based training model for handball shooting skills targeted at athletes aged 15–17. In this section, we describe the steps involved in the design, development, and testing of the model, as well as the methods used for data collection, fidelity assessment, and analysis.

Research Design

The first phase of the research focused on identifying the need for an engaging and supportive training model to improve shooting skills in young handball athletes. Existing training methods were found to be inadequate in addressing the needs of athletes aged 15–17, especially regarding engagement and skill variability. This gap informed the creation of a website-based platform designed to complement, not replace, coach-led instruction. The research team gathered insights from athletes, coaches, and stakeholders through surveys, interviews, and observations to identify training challenges and expectations (Kozieł et al., 2024). In the design phase, the team incorporated domain knowledge, including biomechanics, strength, power, and perceptual skills, into the training model, guided by pedagogical frameworks such as the tactical-game approach and representative learning design (Juliantine & Setiawan, 2022). The prototype was validated by nine experts, ensuring its technical and pedagogical soundness (Zhao & Lu, 2024). After revisions, the model was tested with 40 participants (20 in the coach-supervised web-based group and 20 in the control group), focusing on how digital support enhanced the existing coaching process.

Research Site and Duration

The research was conducted in DKI Jakarta province, targeting handball athletes aged 15–17 who were actively participating in school teams and handball clubs. This geographic focus ensured diversity in training environments and coaching styles. The study lasted for 12 weeks, with the intervention phase running for eight consecutive weeks. Initially, a pilot trial was conducted to refine the web interface, followed by a full implementation phase. Each training session was delivered under the supervision of certified handball coaches (minimum 5 years' experience, Level II coaching license). This multi-phase approach ensured comprehensive data collection and consistency of implementation.

Participants and Sampling Methodology

The participants were 40 handball athletes aged 15–17 years, selected using purposive sampling to ensure uniformity in skill and age criteria. The experimental group (n = 20) participated in the coach-mediated, website-based training, while the control group (n = 20) continued with conventional sessions. Coaches maintained weekly digital logs and session checklists to ensure fidelity to the training protocol. Participants were drawn from multiple schools and clubs within DKI Jakarta, ensuring variation in playing experience and minimizing sampling bias.

Data Collection Methods

Various data collection methods were utilized to evaluate the supportive impact of the coach-mediated, web-based model. A standardized shooting accuracy test was administered, where each participant took five shots, and accuracy scores were compared between pre-test and post-test results (Dahl & Tillaar, 2021). Surveys and semi-structured interviews were conducted with both athletes and coaches to capture perceptions of usability, engagement, and coach–athlete interaction. Observations focused on the fidelity of training delivery, including how consistently coaches followed the online modules and how athletes responded to feedback. All training sessions were documented through a digital logbook integrated into the platform. This mixed-methods design provided both quantitative outcomes and qualitative insights (Apidogo et al., 2023). Table 1 presents the intervention description based on the TIDieR framework.

Data Analysis

Data from the accuracy tests, surveys, interviews, and observations were analyzed using both qualitative and quantitative approaches. Open-ended responses were thematically analyzed to capture athlete and coach experiences. Quantitatively, N-Gain analysis measured improvement in shooting accuracy between pre- and post-tests. Independent sample t-tests ($p < .001$) and Cohen's d effect sizes (with 95% confidence intervals) were computed to assess magnitude and precision of differences (Gençoğlu & Gümüş, 2020; Iacono et al., 2021) The analysis emphasized the supportive contribution of the web-based training in enhancing coaching effectiveness and athlete engagement.

Results

The study compared the outcomes of a coach-supervised, web-based training model and traditional methods in improving handball shooting skills among athletes aged 15–17. The experimental group showed improvement (M_{pre} = 8.90, SD = 2.22; M_{post} = 15.90, SD = 1.82; 95% CI [6.2, 8.4], $p < .001$, Cohen's d = 1.55). In contrast, the control group showed smaller gains (M_{pre} = 7.05, SD = 3.07; M_{post} = 10.15, SD = 3.07; 95% CI [2.4, 3.5], $p < .001$, Cohen's d = 0.62). These findings highlight that the web-based model effectively supported the coaching process and provided more consistent improvement across athletes.

The pre-test and post-test results for both groups are summarized in Table 2.

Table 1. Intervention Description (TIDieR Framework)

TIDieR Item	Description of the Intervention
1. Brief Name	Website-Based Handball Shooting Skills Training Model
2. Why (Rationale)	Designed to enhance engagement, feedback, and flexibility in handball shooting practice through digital support, complementing coach-led instruction.
3. What (Materials)	The website-based platform included instructional videos, interactive quizzes, real-time feedback modules, and a coach dashboard for monitoring athlete progress.
4. Who Provided	Certified handball coaches (Level II certification, ≥5 years of experience) supervised both in-person and online components of the program.
5. How (Mode of Delivery)	Delivered via an interactive website accessible on both desktop and mobile devices. Sessions integrated video-based demonstrations, digital assignments, and immediate performance feedback.
6. Where (Setting)	Conducted across selected handball clubs and school training facilities in DKI Jakarta Province, Indonesia. Athletes performed digital modules at home or in computer labs, and on-site sessions on the training field.
7. When and How Much	The intervention ran for 8 consecutive weeks with 3 sessions per week. Each session lasted 60 minutes (30 minutes field practice + 30 minutes digital module).
8. Tailoring (Personalization)	Individual training load, drill difficulty, and feedback content were adjusted based on baseline shooting test results and weekly progress analytics.
9. Fidelity (Adherence and Monitoring)	Fidelity was tracked using digital session logs, attendance records, and weekly supervision checklists completed by coaches. System-generated data were reviewed to ensure consistency in delivery.
10. Modifications (Adaptations)	After the pilot phase, interface navigation and visual clarity were refined based on user feedback. Content sequencing and feedback prompts were adjusted to improve usability.
11. Planned Assessment of Adherence	System analytics automatically recorded athlete engagement and completion rates. Coaches conducted regular check-ins and qualitative feedback sessions to ensure adherence.
12. Actual Implementation	The model was fully implemented with 40 athletes divided into experimental and control groups. Coaches followed structured lesson plans and logged session outcomes through the platform.

Table 2. Summarizes the pre-test and post-test results

Group	Pre-test Minimum	Pre-test Maximum	Pre-test Average	Pre-test Standard Deviation	Post-test Minimum	Post-test Maximum	Post-test Average	Post-test Standard Deviation
Experimental	5	13	8.90	2.2219	13	19	15.90	1.8160
Control	2	4	7.05	3.0689	12	16	10.15	3.0655

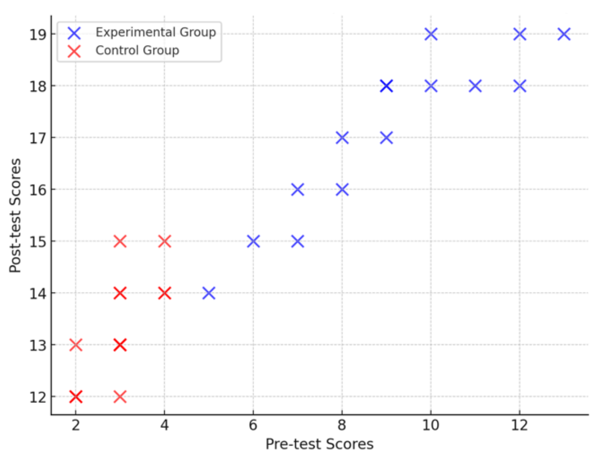

Fig. 1. Pre-Test vs Post-Test Score: Experimental vs Control Group

N-Gain analysis was used to assess improvement. For the experimental group, the N-Gain was 63.90% (95% CI [58.7, 69.1]), categorized as "sufficiently effective," showing

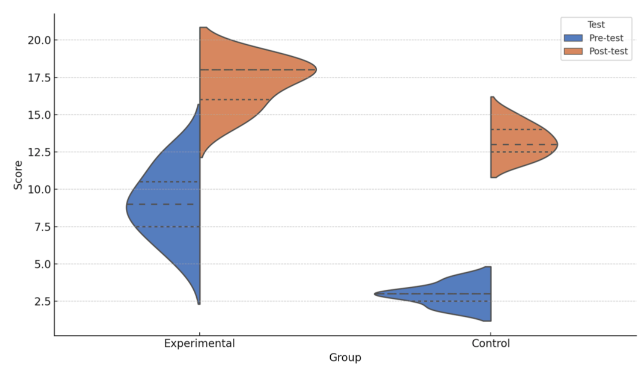

Fig. 2. Distribution of Pre-Test and Post-Test Score

consistent progress under coach supervision. In contrast, the control group had an N-Gain of 24.62% (95% CI [20.3, 29.0]). Effect size analysis confirmed large improvement (Cohen's d = 1.55) for the experimental group, compared with a medium effect (d = 0.62) for the control group. This suggests that the web-based model acted as a valuable adjunct to conventional training.

Table 3 presents the N-Gain results for both groups.

Table 3. Presents the N-Gain results

Group	Mean N-Gain (%)	SE	SD
Experimental	63.90	3.28873	14.70765
Control	24.62	2.92635	13.08703

Normality and homogeneity tests were performed to ensure the data met the assumptions for parametric analysis. The normality test using Kolmogorov-Smirnov and Shapiro-Wilk tests showed that both the experimental and control groups' data were normally distributed, as the significance values were greater than 0.05, allowing for the use of parametric tests like the t-test. The homogeneity test indicated that the variances between the two groups were equal, with a significance value of 0.672 (greater than 0.05), confirming that an independent sample t-test could be used. The independent sample t-test revealed a significant difference between the experimental and control groups ($t(38) = 6.42$, $p < .001$), confirming that the coach-assisted, web-based model supported significantly greater improvement in shooting skills. The experimental group demonstrated higher improvement with less score variation and a higher N-Gain, confirming the model's supportive role in promoting consistent skill acquisition.

Discussion

The results indicated that the experimental group, which used the website-based model, experienced a significantly higher improvement in shooting skills than the control group that employed conventional methods. Consistent with this, the coach-supervised platform showed large improvements (e.g., $p < .001$; large effect sizes reported in Results), indicating a supportive contribution of the website to coach-led practice rather than a replacement. The findings reflect the growing potential of integrating technology into sports training, especially for youth athletes who are in the critical stages of skill development. Nevertheless, we interpret these gains within a blended-learning frame in which coaching remains central. However, while the digital model provided notable advantages, several challenges must be addressed for broader adoption and effectiveness.

Effectiveness of the Website-Based Model

The significant improvement observed in the experimental group, with a mean N-Gain of 63.90%, together with large standardized effects (e.g., Cohen's d reported in Results) and $p < .001$, aligns with findings that technology-enhanced training can benefit performance when integrated with coaching (Gençoğlu & Gümüş, 2020; Zhao & Lu, 2024). The N-Gain value of 63.90% in the experimental group is a strong indicator of enhanced training consistency under coach mediation, as it shows that athletes improved at a higher rate than those in the control group (24.62%). Accordingly, we interpret the website as a complementary tool that supports coach-led instruction rather than a superior stand-alone alternative.

A possible explanation for the observed improvement is the platform's flexible, on-demand modules that extend coach-led practice, enabling athletes to train outside scheduled sessions (Iannaccone et al., 2020; Zhao & Lu, 2024). The ability to review instructional media repeatedly supports skill retention (Juliantine & Setiawan, 2022; Sha'lan, 2022). This flexibility enhances the learning experience, particularly for young athletes with fixed schedules. Importantly, the website structured homework and feedback loops, which may have increased adherence and practice volume under coach oversight (Gençoğlu & Gümüş, 2020). Furthermore, the website-based model's design, which includes interactive elements and real-time feedback, likely contributed to the higher engagement observed. Traditional drills can be monotonous and reduce adherence (Apidogo et al., 2023; Foretić et al., 2022). In contrast, the platform's interactive tasks—paired with coach feedback—appeared to sustain motivation and reinforce correct technique execution.

Challenges in Implementation and Athlete Resistance

While the model was effective, some athletes were reluctant to shift parts of training to a technology-mediated format, being accustomed to the hands-on nature of coach-led practice (Zhao & Lu, 2024). This reluctance is reported elsewhere, where athletes prefer familiar, social in-person contexts (Apanasenko & Tyshchenko, 2024; Madruga-Parera et al., 2025). In this study, hesitancy reduced as coaches actively mediated platform use and clarified expectations, highlighting the importance of change management. However, this resistance does not undermine the observed gains. Instead, it suggests that the best approach is blended delivery, where digital modules extend and structure coach-led sessions (Juliantine & Setiawan, 2022) Prior work indicates that combining digital tools with face-to-face coaching yields a more holistic experience (Gençoğlu & Gümüş, 2020). Our fidelity procedures (coach supervision and session logs) likely supported smoother adoption. Moreover, resistance can be reduced by emphasizing personalization, progressive loading, and clear coach feedback loops. Virtual check-ins and coach dashboards can further increase engagement and accountability, consistent with guidance to keep tools accessible and aligned with athlete needs (Akbar et al., 2024; Schrapf et al., 2017).

Technical Barriers and Accessibility Issues

Another significant challenge was the need for stable connectivity and adequate devices. In settings with limited resources, these requirements may hinder use, creating inequities in access to structured practice (Zhao & Lu, 2024). This is particularly relevant for athletes in developing regions or lower-SES contexts. To address this challenge, offline-capable modules, low-data video, and downloadable practice packs can improve reach (Benešová & Drozdová, 2024; Nadhem et al., 2020). Partnerships for loaner devices and club-based access points may help bridge gaps (Gençoğlu & Gümüş, 2020). Expert validation supported feasibility; subsequent UI and interactivity refinements during R&D iterations improved usability (Zhao & Lu, 2024).

The model's successful validation supports its potential for broader application. However, further development is needed to improve scalability, contextual adaptation, and integration with club workflows. Expanding to additional handball skills (e.g., passing, defending) and embedding load-management/injury-risk features would align performance gains with athlete safety (Gkagkanas et al., 2023). While the findings are promising, future work should include longitudinal follow-up on match-level outcomes, testing in other sports and age bands, and experiments that vary the intensity of coach mediation to identify optimal blends of digital and in-person delivery. Process evaluations (e.g., fidelity/adherence) and cost-effectiveness analyses would further inform scale-up.

Conclusions

This study evaluated a coach-assisted, website-based training model for handball shooting in athletes aged 15–17. The experimental group showed greater improvements (e.g., N-Gain = 63.90%; Results report $p < .001$ and large effect sizes) when the platform was integrated with coach supervision, compared to the control group (24.62%). The model's flexibility supported structured at-home practice and feedback loops, which may enhance learning. Interpreting these findings within a blended-learning framework, we position the website as a supportive adjunct to coach-led training, not a replacement. Remaining challenges include athlete adoption and equitable technology access. Future work should refine offline capability, examine long-term and match-level outcomes, and test scalability across contexts and sports. This study contributes to evidence on digital tools that augment coaching in youth sport.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

Nopianto, W., Setiakarnawijaya, Y., Widiastuti, W., Daryono, D., & Lanos, M. E. C. (2021). Shooting Skills Training Needs Analysis in Handball Game for Young Athlete. *International Journal of Human Movement and Sports Sciences, 9*(3), 554-559. https://doi.org/10.13189/saj.2021.090322

Onell, C., Skillgate, E., Melin, A., Källberg, H., Waldén, M., Edlund, K., Hägglund, M., Côté, P., & Asker, M. (2023). Dietary habits in adolescent male and female handball players: the Swedish Handball Cohort. *BMJ Open Sport & Exercise Medicine, 9*(4), e001679. https://doi.org/10.1136/bmjsem-2023-001679

Uylas, E., Mancı, E., Rodríguez-Sánchez, N., Bediz, C. Ş., & Günay, E. (2024). The Effect of Fluid Restriction and Intake Conditions on the Shooting Performance of Competitive Adolescent Handball Players. *Nutrients, 16*(23), 4246. https://doi.org/10.3390/nu16234246

Muttib, F., Hamzah, M. A. M., & Fadhel, M. (2024). Psychological Toughness and Its Relationship to Some Coordination, Physical Abilities and Accuracy of Some Basic Skills Performance Among the Iraqi Junior National Handball Team Players. *International Journal of Disabilities Sports & Health Sciences,* 330-336. https://doi.org/10.33438/ijdshs.1436061

Akyüz, B., Arpinar-Avsar, P., Bilge, M., Deliceoğlu, G., & Korkusuz, F. (2019). Skeletal Muscle Fatigue Does Not Affect Shooting Accuracy of Handball Players. *Isokinetics and Exercise Science, 27*(4), 253-259. https://doi.org/10.3233/ies-193178

Saavedra, Y., & Saavedra, J. M. (2020). The Association Between Relative Age Effect, Goals Scored, Shooting Effectiveness and the Player's Position, and Her Team's Final Classification in International Level Women's Youth Handball. *Montenegrin Journal of Sports Science and Medicine, 9*(1), 19-25. https://doi.org/10.26773/mjssm.200303

Belčić, I., Očić, M., Dukarić, V., Knjaz, D., & Zoretić, D. (2023). Effects of One-Step and Three-Step Run-Up on Kinematic Parameters and the Efficiency of Jump Shot in Handball. *Applied Sciences, 13*(6), 3811. https://doi.org/10.3390/app13063811

Dahl, K. S., & Tillaar, R. (2021). The Effect of Eight Weeks of Sling-Based Training With Rotational Core Exercises on Ball Velocity in Female Team Handball Players. *Journal of Human Kinetics,* 77, 261-272. https://doi.org/10.2478/hukin-2021-0024

Gómez-Ferolla, M., Feye, A. S. P., & Magallanes, C. (2024). Comparative Analysis of Two Strength Training Protocols on Throwing Speed in Women's Handball. *Retos,* 56, 439-448. https://doi.org/10.47197/retos.v56.104191

Apidogo, J. B., Ammar, A., Salem, A., Burdack, J., & Schöllhorn, W. I. (2023). Resonance Effects in Variable Practice for Handball, Basketball, and Volleyball Skills: A Study on Contextual Interference and Differential Learning. *Sports, 12*(1), 5. https://doi.org/10.3390/sports12010005

Gençoğlu, C., & Gümüş, H. (2020). Standing Handball Throwing Velocity Estimation With a Single Wrist-Mounted Inertial Sensor. *Annals of Applied Sport Science, 8*(3), 0–0. https://doi.org/10.29252/aassjournal.893

Zhao, X., & Lu, M. (2024). Design and Application of a Handball Training Level Evaluation System for College Students. *Intelligent Decision Technologies, 19*(2), 766-780. https://doi.org/10.1177/18724981241303222

Bhakti, Y. H., Rahayu, T., Kristiyanto, A., Azam, M., Adi S, & Aliriad, H. (2024). Analyzing Handball Techniques Using A Biomechanical Approach: A Systematic Literature Review. *Physical Education Theory and Methodology, 24*(2), 338-343. https://doi.org/10.17309/tmfv.2024.2.20

Schrapf, N., Alsaied, S., & Tilp, M. (2017). Tactical Interaction of Offensive and Defensive Teams in Team Handball Analysed by Artificial Neural Networks. *Mathematical and Computer Modelling of Dynamical Systems, 23*(4), 363-371. https://doi.org/10.1080/13873954.2017.1336733

Akinci, Y., & Ateş, B. (2023). The Effects of School-Based Handball Intervention on 12–14-Year-Old Children's Physical Fitness and Performance. *Physical Education Theory and Methodology, 23*(5), 754-761. https://doi.org/10.17309/tmfv.2023.5.14

Havolli, J., Bahtiri, A., Kambič, T., Idrizović, K., Bjelica, D., & Pori, P. (2020). Anthropometric Characteristics, Maximal Isokinetic Strength and Selected Handball Power Indicators Are Specific to Playing Positions in Elite

Kosovan Handball Players. *Applied Sciences, 10*(19), 6774. https://doi.org/10.3390/app10196774

Zhang, P., Luo, J., & Liang, X. (2025). Symmetric Model for Predicting Homography Matrix Between Courts in Co-Directional Multi-Frame Sequence. *Symmetry, 17*(6), 832. https://doi.org/10.3390/sym17060832

Sahli, F., Bouzouraa, M. M., Rebhi, M., Romdhani, A., Sahli, H., Salem, A., Trabelsi, K., Ammar, A., & Zghibi, M. (2024). Enhancing Skills, Mood, and Performance in Overweight Handball Players: Exploring Individual vs. Collective Verbal Encouragement Strategies. *Children, 11*(4), 432. https://doi.org/10.3390/children11040432

Abod, Z. F., & AlHaddad, N. H. (2022). Achievement Motivation and Its Relationship to Jump Pass and Jump Shot in Handball. *Sport Tk-Revista Euroamericana De Ciencias Del Deporte,* 11. https://doi.org/10.6018/sportk.537131

Kozieł, S., Suder, A., Chrzanowska, M., Králík, M., & Malina, R. M. (2024). Growth Status and Age at Peak Height Velocity Among Youth Participants in Several Sports: The Cracow Longitudinal Study. *BMC Sports Science Medicine and Rehabilitation, 16*(1). https://doi.org/10.1186/s13102-024-00905-6

Juliantine, T., & Setiawan, E. (2022). Effect of Tactical Game Models on Formation of Basic Techniques in Handball Players: Mixed Method. *Physical Education Theory and Methodology, 22*(3), 373-378. https://doi.org/10.17309/tmfv.2022.3.11

Iacono, A. D., Vigotsky, A. D., Laver, L., & Halperin, I. (2021). Beneficial Effects of Small-Sided Games as a Conclusive Part of Warm-Up Routines in Young Elite Handball Players. *The Journal of Strength and Conditioning Research, 35*(6), 1724-1731. https://doi.org/10.1519/jsc.0000000000002983

Iannaccone, A., Fusco, A., Conte, D., & Cortis, C. (2020). Notational Analysis of Beach Handball. *Human Movement, 23*(1), 69-79. https://doi.org/10.5114/hm.2021.101757

Sha'lan, M. A. M. (2022). The Impact of Using Small-Sided Games on Teaching Basic Handball Skills to Students of the College of Sports Sciences at Mu'tah University. *Sport Tk-Revista Euroamericana De Ciencias Del Deporte,* 23. https://doi.org/10.6018/sportk.539091

Foretić, N., Pavlinović, V., & Veršić, Š. (2022). Shooting Speed Differences Between Playing Positions in Top Level Handball. *Sport Mont, 20*(1), 21-24. https://doi.org/10.26773/smj.220204

Apanasenko, A., & Tyshchenko, V. (2024). Innovative methodological approaches to the assessment of psychophysical abilities of handball players at the stage of preliminary basic training. *Sports Games, 4*(34), 15-22. https://doi.org/10.15391/si.2024-4.02

Madruga-Parera, M., Esteves, P. T., Fernandes, J. F. T., Beltrán-Garrido, V., Bird, S., Leite, N., Romero-Rodriguez, D., & Arede, J. (2025). Inclusion of Game-Based Stimulus During Flywheel Resistance Training Positively Influences Physical Performance in Handball Players. *Research Quarterly for Exercise and Sport, 96*(1), 1-10. https://doi.org/10.1080/02701367.2024.2359603

Akbar, S., Soh, K. G., Bashir, M., Mohd, N. N. J. Bin, Luo, S., & Sun, H. (2024). Effects of Different Exercise Training on Physical Fitness and Technical Skills in Handball Players. A Systematic Review. *The Journal of Strength and Conditioning Research.* https://doi.org/10.1519/jsc.0000000000004908

Benešová, D., & Drozdová, P. (2024). The Effect of Controlled Movement Imaginary on Performance in a Modified 7-Metre Shot Test of Elite Female Handball Players. *Studia Sportiva, 18*(2). https://doi.org/10.5817/sts2024-2-3

Nadhem, Z., Algabry, K., Tariq, R., & Faisal, B. D. (2020). The Impact of Over-Learning Exercises in Developing Some of the Optical Vision Capabilities and Shooting Skill From Jumping in Handball Game for Young Players. *Indian Journal of Forensic Medicine & Toxicology.* https://doi.org/10.37506/ijfmt.v14i4.11967

Gkagkanas, K., Hatzimanouil, D., Totlis, T., & Stavropoulou, G. (2023). The Effect of an Exercise Program on the Biomechanics of the Shoulder Girdle in Overhead Shooting in High-Level Handball Players. *Montenegrin Journal of Sports Science and Medicine, 12*(2), 17-24. https://doi.org/10.26773/mjssm.230903

Покращення навичок виконання кидків у гандболі: Ефективність використання моделі тренування на основі веб-технологій для юних спортсменів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 табл., 2 рис., 31 джерело.

Мета дослідження. Мета цього дослідження полягала у вивченні розвитку та допоміжної ролі моделі тренування на основі веб-технологій, розробленої для доповнення тренерських вказівок та поліпшення навичок виконання кидків у гандболі серед спортсменів віком 15–17 років. Традиційні методи тренувань мають обмеження щодо залученості та послідовності занять, які використання моделі на основі веб-технологій спрямовано мінімізувати шляхом підвищення взаємодії між спортсменами та тренерами й забезпечення доступності.

Матеріали та методи. У дослідженні застосовано метод науково-дослідних та дослідно-конструкторських робіт за моделлю Борга і Галла із претестовим та посттестовим дизайном. Експериментальна група (n = 20) під керівництвом тренера використовувала модель на основі веб-технологій, тоді як контрольна група (n = 20) дотримувалася традиційних методів тренування. Збір даних здійснювався за допомогою тестів на точність виконання кидків, опитувань, інтерв'ю та спостережень.

Результати. Результати показали, що експериментальна група продемонструвала суттєвіше поліпшення показників у точності виконання кидків, з нормалізованим приростом (N-Gain) 63.90% (95% ДІ [58.7, 69.1]; $p < .001$), порівнюючи з N-Gain 24.62% (95% ДІ [20.3, 29.0]) у контрольній групі. Встановлено, що модель на основі веб-технологій підтримує та ефективно сприяє стандартизації поліпшень, забезпечуючи гнучке інтерактивне навчання за допомогою тренера. Однак визначено проблемні питання, як-от опір спортсменів застосуванню нових методів та труднощі із доступом до технологій.

Висновки. Дослідження підкреслює потенціал цифрових інструментів у спортивному тренуванні, наголошуючи на необхідності комбінованого впровадження з традиційним тренерським підходом та постійного розвитку для розв'язання проблем технічного характеру та доступності. Необхідно провести подальші дослідження з метою вивчення довгострокової інтеграції, масштабованості та тренерсько-опосередкованого впровадження цієї моделі тренувань у різних видах спорту та вікових групах.

Ключові слова: тренування на основі веб-технологій, навички виконання кидків у гандболі, тренування молоді у спорті, цифрові навчальні інструменти, поліпшення спортивної результативності.

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Original Scientific Article

Implementing Big Ball Games to Enhance Coordination in 11–12-Year-Old Students: A Gender-Based Analysis

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Abstract

Background. The development of coordination during childhood, particularly between the ages of 11 and 12, plays a critical role in overall well-being and long-term physical development. Big ball games have been recognized as an effective medium to improve coordination. However, these games often emphasize basic technical skills, with limited scientific evidence exploring whether gender moderates the effect of big ball games on coordination outcomes.

Objectives. This study's primary objective was to evaluate the impact of big ball games on coordination development in 11–12-year-old students, with consideration of gender differences.

Materials and Methods. A quasi-experimental research design with a pretest–posttest approach was employed. Participants included 40 students: 20 male students (age: 11.5 ± 0.3 years; height: 148.9 ± 3.0 cm; weight: 44.6 ± 2.5 kg), and 20 female students (age: 11.4 ± 0.2 years; height: 145.7 ± 1.3 cm; weight: 40.0 ± 1.1 kg). Samples with known initial pretest scores were divided using ordinal pairing with the A-B-B-A formula and then grouped into the experimental group (EG) and the control group (CG). The intervention consisted of five big ball game models delivered over six weeks (18 sessions), with three sessions per week held from 7:00 to 9:00 AM. Intensity monitoring for this game was 65% - 75% or rating of perceived exertion (RPE) at level 12 - 14 (moderate). Coordination was assessed using the Alternate Hand Wall Toss Test (AHWT), a validated tool for evaluating hand-eye coordination. Data were analyzed using MANOVA via SPSS version 26.

Results. MANOVA analysis showed a significant effect between gender ($p < 0.05$) and EG ($p < 0.05$) on coordination. Meanwhile, interaction between the two did not determine a substantial effect multivariately ($p > 0.05$). The results of the Univariate Test revealed that gender had a significant influence on the improvement of coordination ($F = 85.652$, $p < 0.001$, $\eta^2_p = 0.704$), which shows that 70.4% of the variation in coordination enhancement is explained by gender differences. Subsequently, based on the treatment (EG and CG) on student coordination ($F = 147.366$, $p < 0.001$, $\eta^2_p = 0.804$), it was demonstrated that 80.4% of the variation in coordination is explained by differences in treatment. Between-Subjects Effect Test indicated that in pretest stage there was no difference in coordination between EG and CG ($p = 0.600$), while in posttest stage there was a significant difference ($p = 0.000$). In addition, a marked interaction was found between gender and group in posttest stage ($p = 0.048$).

Conclusions. The structured, engaging, and consistent application of big ball games significantly enhances coordination in children aged 11–12 years, with pronounced effects in the experimental groups. These findings underscore the influence of physiological and psychological factors on coordination development, highlighting gender-based differences in responsiveness to physical activity interventions. Therefore, physical education programs should adopt inclusive game-based approaches that consider gender-specific needs to maximize coordination development in all students.

Keywords: children's games, children's motor coordination, big ball games, 11–12-year-old children.

Introduction

Coordination is a physical component that needs to be developed for children aged 11-12 years. In this age range, children's motor coordination undergoes essential developments that will affect their physical and cognitive abilities in the future (Çakit et al., 2022). Good coordination is vital for a variety of daily activities and is critical in academic, social, and sports activities (Tanineh & Halaweh, 2023). Understanding the factors that can improve coordination at this age is key to helping them reach their full potential in various aspects of life.

Factors that affect coordination in children aged 11-12 years, based on the results of previous research studies, include physical growth, specifically anthropometry, which is often unbalanced, the development of gross and fine motor skills, and genetic factors, all of which affect children's motor skills (Sabău et al., 2023; Putro et al., 2025). Prior physical experience and environmental support, including regular opportunities to participate in physical activities such as sports clubs or extracurricular sports at school, also play an essential role (Sobko et al., 2021; Yin et al., 2023). Good coordination at this age provides broad benefits, ranging from increasing efficiency and safety in physical activities to developing academic skills such as writing, enhancing social interaction, and improving children's self-confidence (Aguayo et al., 2022). Therefore, understanding and supporting the development of coordination at an early age can significantly impact a child's overall well-being and future growth.

Some methods to improve coordination in one child include playing games that involve a ball (Ramli et al., 2023; Hikmawati et al., 2023). To date, no study has examined the coordination in children during big ball games, particularly at the age of 11–12 years. Big ball games can utilize various sports, such as football, basketball, and volleyball (Dewi, 2023). Based on the results of previous studies, basketball games can affect physical ability and fitness, particularly in terms of coordination among elementary school children (Mitova et al., 2022; Glišović, 2022). Then, basic technique training methods in soccer and basic techniques in volleyball can affect coordination movements at the ages of 10–15 years (Marchenko & Dykhanova, 2019; Mikail & Suharjana, 2019). However, the study's results indicate that the method employed utilizes only one type of game, featuring a big ball, and is tailored specifically to the basic techniques of the sport.

However, a problem that has not been extensively studied is the extent to which gender influences the impact of big ball games on motor coordination in children aged 11-12 years. Previous studies have often overlooked this gender dimension, even though physical and psychological differences between male and female at this age can significantly impact the results obtained from certain types of physical training. Thus, this study will build upon the results of previous studies to analyze and discuss details related to gender. According to the results of previous studies, traditional games and circuit games are effective in reducing manipulative movements in children aged 9–12 years, regardless of gender (Santoso et al., 2024; Kuspratiwi et al., 2025). Therefore, it is important to examine more deeply how gender can moderate the effectiveness of big ball games in developing coordination.

The purpose of this study is to investigate the impact of big ball games on the coordination of students aged 11-12 years, taking into account gender variables. This study aims to provide scientific evidence that physical educators can use in designing more efficient and effective exercise programs tailored to specific gender needs. Thus, the results of this study are expected to contribute to the physical education literature and enhance the quality of teaching coordination and physical activity in children, thereby benefiting them not only in physical activity but also in other aspects of learning and social interaction.

Materials and Methods

Study Participants

The population of this study consisted of elementary schools in the city of Yogyakarta, Indonesia. The elementary schools involved were Sorobayan Elementary School and Bantul Timur Elementary School, all of which had 5th and 6th-grade students aged 11-12 years. Selection of samples was offered voluntarily to students, provided that they were physically and mentally healthy, not experiencing any illness or injury and were willing to attend at least 80% of the intervention sessions. The ethical aspects of the study were fully adhered to. This research was approved by the institutional ethics committee (B/1468/UN34.16/PT.01.02/2025), and written informed consent was obtained from the school principals, physical education teachers, and the parents/guardians of all participants. Before giving consent, all participants and their parents/guardians were provided with complete information regarding the study's objectives, procedures, potential risks, and participant rights, including the right to withdraw at any time.

So that the number of students willing to be a sample is 40 students (20 male and 20 female students), with 20 students per school. The characteristics of the students in the male group (mean±SD) are as follows: age, 11.5±0.3 years; height, 148.9±3.0 cm; and body weight, 44.6±2.5 kg, and in 20 female students, aged 11.4±0.2 years, with a height of 145.7±1.3 centimeters and a body weight of 40±1.1 kilograms. Then, the 40 students were divided into four groups: 1) 10 male students in the experimental group, 2) 10 female students in the experimental group, 3) 10 male students in the control group, and 4) 10 female students in the control group.

Study Organization

This study employed a quasi-experimental design with a pretest–posttest approach. The research flow, designed for clarity and ease of understanding, is illustrated in detail in Figure 1.

The study was conducted in seven stages. The first stage involved a document analysis based on previous research findings, using keywords such as big ball games, coordination, and children aged 11–12 years, to identify the research problem and establish novelty in this field. The second stage consisted of observing elementary school students during physical education classes, with the approval of the school principal. This observation was followed by tracking the learning process, particularly among 5th-

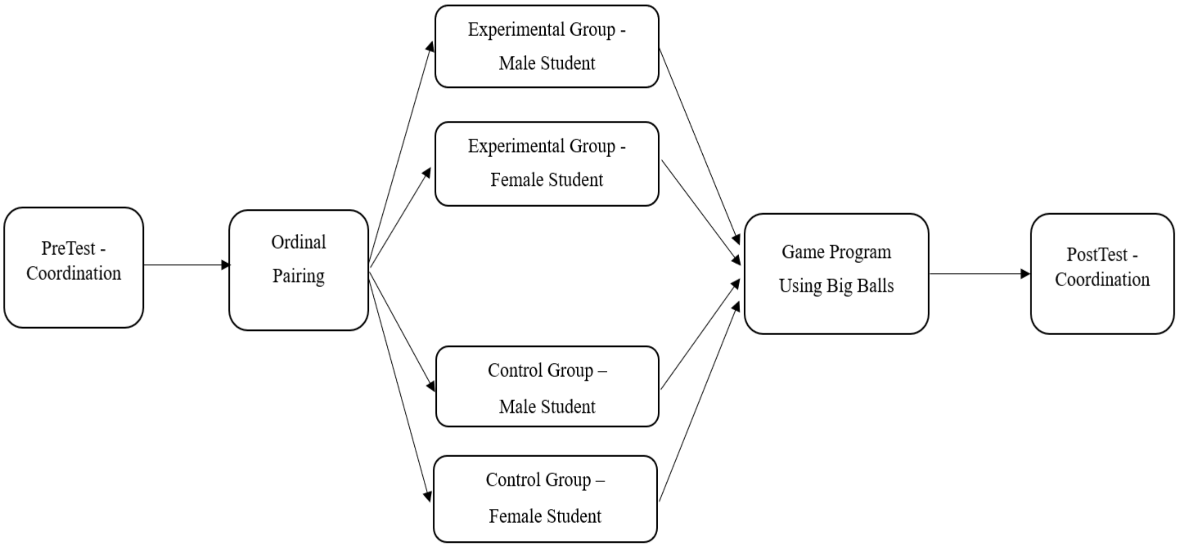

Fig. 1. Research framework referring to stage four - stage six

and 6th-grade students aged 11–12 years. The third stage included the preparation of a big ball game program and its validation to ensure the program's feasibility for training students.

The fourth stage involved the collection of baseline data through a pretest using the Alternative Hand Wall Toss Test (AHWT) with the 40 student participants. Once the pretest results were obtained, the experimental group (EG) and control group (CG) were determined using the ordinal pairing technique A-B-B-A, as shown in Figure 1 (Rusli et al., 2024). This counterbalancing method aimed to ensure balanced distribution of students' initial characteristics across experimental and control groups, as well as across genders. The process was carried out by ranking students' pretest scores from highest to lowest, then sequentially assigning them to groups as follows: the first-ranked student entered Group A (experimental), the second-ranked student entered Group B (control), the third-ranked student entered Group B (control), and the fourth-ranked student entered Group A (experimental), and so on until all students were distributed. This method ensured that both groups (experimental and control) included students with both high and low levels of coordination, for both male and female students.

The fifth stage consisted of the intervention, delivered over six weeks with three sessions per week, totaling 18 sessions. During this period, the experimental group received interventions using five validated big ball game models designed to enhance coordination, while the control group engaged in free play activities that did not specifically target coordination. The sixth stage involved the collection of post-intervention data through a posttest using the AHWT, administered after the students had completed the intervention. The seventh stage encompassed data analysis, reporting of findings, and revision of the article until it was ready for publication.

The research instrument adapted a coordination test, namely the Alternative Hand Wall Toss Test (AHWT), which has been proven reliable and valid for evaluating the coordination skills of students aged 11–12 years (Cho et al., 2020; Çakit et al., 2022). AHWT is performed by throwing the ball towards a wall that is 2-meter away, with a minimum height of 2-meter using 1 hand and catching it using 2 hands for 30 seconds. The equipment consists of tennis balls, duct tape, wall with a flat surface, whistle, stopwatch, forms and stationery. The implementation procedure is as follows: 1) students with the ball in their hands stand on the throwing boundary line at a distance of 2-meter from the wall, 2) students throw (over head pass) the ball to the wall using 1 hand when the whistle sounds, the target of the throw is as high as the boundary that has been made, 3) students then catch it using 2 hands, 4) students do the test for 30 seconds, and the end is marked by the sound of the whistle. AHWT examiners during pretest and posttest were assessed directly by research team, not by the physical education teacher from the student's school, this aim was to maintain the transparency of test results.

Big Ball Games Program

This game program was developed based on the results of previous research studies (Hikmawati et al., 2023; Mikalonytė et al., 2022). Then the researchers developed it again with the aim of producing an original game model. For this game program to run effectively, specific equipment was required. The equipment consisted of: 1) a ball, 2) a cone, 3) a jump square, 4) a mini-goal, 5) a basket or basketball hoop, 6) a marking line, 7) a whistle, 8) a mini-goal. In addition to some supporting equipment, such as health box components for first aid in case of accidents, stationery, chalk, and a stopwatch. After the equipment was prepared, the following game models were available, each representing one of the five models.

The first game started by dividing students into three groups. Each group marched against the other. The first student from Group 1 performed an overhead pass to the first student from Group 2. After throwing the ball, the student ran and moved to Group 2. Next, the first student from Group 2 performed a bounce pass with one hand to the first student from Group 3, then ran and moved to the Group 3 area. Next, the first student from Group 3 performed a two-handed bounce pass to the leading student in Group 1, then moved to join Group 1. This exercise pattern was carried out alternately and continuously until the teacher felt that training was enough.

The second game involved students running while carrying the ball, then jumping over the jump plots that the teacher had prepared. After successfully passing the jump plot, students continued to run and jump over the safe goal, then stopped at the designated place. Next, the student attempted to put the ball into the provided basket. If it failed, the experiment was repeated until the ball successfully entered the basket. After that, the students ran back to the line and continued with the next student in line. To make the game more interesting and challenging, it could be played in the form of competitions between groups.

The third game began by dividing the students into two large groups that faced each other at a distance of approximately two meters. Each member of one of the groups held a ball. The teacher then gave two codes: the correct code and the wrong code. If the teacher provided the wrong code, the student must follow the opposite instruction. Students were asked to follow the teacher's instructions, such as jumping forward or throwing a ball, as indicated by the provided code. This game trains concentration, reaction speed, and coordination between body movements, as well as understanding instructions.

The fourth game began by dividing students into three large groups. Each student in the group ran a zig-zag through the obstacles that the teacher had compiled while carrying the ball. After completing the zig-zag trajectory, students quickly ran to the provided cone, circled it, and then ran back to the predetermined line, which was approximately two meters from the colleague lined up behind them. After arriving at the line, the student threw the ball to his partner in the line, who then performed the same sequence of activities. This game was played until all students had a turn, and it could be made into a competition to increase students' enthusiasm.

The Fifth Game was conducted by dividing the students into three large groups. The first person from each group ran towards the cone, then circled the cone, and continued running until the limit set by the teacher. After that, the student must put the ball into the goal by kicking it; if it fails, the experiment is repeated until it succeeds. After succeeding, the student retrieved the ball that had been kicked and returned it to its original place, then ran to clap the next friend's hand as a turn signal. This game was played in turns, allowing all group members to participate.

This game program was held over six weeks, consisting of 18 meetings, with three sessions every week on Mondays, Wednesdays, and Fridays. Student attendance is monitored directly at the beginning and end of each meeting. The implementation time was from 7:00 am to 9:00 am, with 1 hour allocated for play and 1 hour used for warm-up, cooling, and evaluation at the end of the meeting. The implementation of the game in one meeting involved two models that will alternate in each subsequent meeting. The time allocated for each game model is 25 minutes, with a 10-minute rest between games.

The intensity of each session was set between 65% - 75% to ensure students enjoyed their time and fitness, while avoiding stress and fatigue. Heart rate intensity monitoring, based on the rating of perceived exertion (RPE) with a moderate target (12–14) (Chowdhury et al., 2019). This monitoring was recorded every 10–15 minutes during the main training session during a major ball game and summarized per session. Progression rules for each model of the big ball game included adding targets, widening the distance, or increasing the number of participants. However, these progression rules adhered to maximum and minimum intensity limits. Close supervision by the research team and each physical education teacher was also implemented to avoid accidents and minimize conflicts during play.

Validity of the Big Ball Games Program and Coordination Test

The Big Ball Games program and the coordination test using the Alternative Hand Wall Toss Test (AHWT) required validation to ensure their feasibility, credibility, and ability to produce reliable and significant research findings. The validation of both the program and the test instrument was calculated using Aiken's V formula (Aiken, 1985):

$$\text{V Aiken's: } \frac{\sum S}{n\,(c-1)}$$

S : r – lo
Lo : lowest rating score
C : highest rating score
r : the score given by the assessor

The validation process involved six physical education teachers from the participating elementary schools. A 4-point rating scale was applied, and five assessment statements were evaluated based on a literature review and the research context. The validation results are presented in Table 1.

Table 1. Validation results of training programs and coordination instrument

	Assessment aspects	ΣS	n(c-1)	Aiken V
	Big Ball Games Program			
1	Game models using big balls	15	18	0.833
2	Fun and varied game models	17		0.944
3	Safe game models	15		0.833
4	Easy-to-understand game procedures	16		0.889
5	Systematic and measurable game programs (training dosages)	15		0.833
	Alternative Hand Wall Toss Tes (AHWT)			
1	Capable of measuring coordination skills	17	18	0.944
2	Suitability of coordination tests for children aged 11-12 years	15		0.833
3	Produces objective test scores	16		0.889
4	Adequate test security	15		0.833
5	Easy-to-understand test procedures	15		0.833

Based on Table 1, the validation results of the Big Ball Games program across all aspects, use of big balls, fun and varied models, safety, ease of understanding, and systematic structure with measurable dosage, showed Aiken's V values greater than 0.8. Similarly, the AHWT validation also showed Aiken's V > 0.8 for all assessed aspects, including measurement of coordination skills, suitability for children aged 11–12 years, objectivity of test scores, safety, and procedural clarity. Therefore, with all Aiken's V values exceeding 0.8, the program and test instrument can be considered to have a high level of validity and are deemed appropriate for use in children aged 11–12 years (Wedi et al., 2024; Putro et al., 2025).

Statistical Analysis

Analysis of this research, the first stage carried out was to display descriptive statistics to analyze the pretest-posttest values in each group. The second stage involved a normality test to analyze whether the data had a normal distribution, with a significance value of $p > 0.05$. Then, the third stage involved hypothesis testing using MANOVA (Multivariate Analysis of Variance). MANOVA results can analyze gender differences, group differences, and gender-group interactions based on pre-test and post-test scores. MANOVA can examine model variation in coordination tests. Then, further testing through effect size using partial eta squared and the results of pairwise comparisons to analyze how gender and group differences affect the results of the coordination test. Analysis of the research data was conducted using SPSS version 26 software (George & Mallery, 2019).

Results

The first research report is a descriptive analysis based on the scores from the coordination pretest and posttest by student gender. These scores represent the number of repetitions of the coordination test, indicating the minimum and maximum scores. The following is a descriptive table of the results of this study.

Based on the descriptive results in table 2, mean EG-pretest for male was 13.30 and mean EG-posttest for male was 20.80 with a difference of 7 repetitions. Then, mean CG-pretest for male was 13.20 and mean EG-posttest for male was 14.90 with a difference of 1 repetition. Meanwhile, mean EG-pretest for female was 10.70 and mean EG-posttest for female was 16.10 with a difference of 6 repetitions. Then, mean CG-pretest for female was 11.20 and mean CG-posttest for female was 11.90.

After the research results were reported based on pretest and posttest values, followed by the second analysis, which included a normality test and homogeneity test. However, to keep the tables in this study concise and easy to understand, the researchers combined the normality test results with the descriptive results in Table 2. In this study, the normality test used was the Shapiro-Wilk test because the sample size was 10 students in each group. Based on the results in Table 2, the significance value from the Shapiro-Wilk test is sig. >0.05, so the research data is usually distributed (Bernadett & Csaba, 2024).

After the normality test, a homogeneity test was performed to assess whether two or more data groups had equal variance. The results of the homogeneity test are shown in Table 3 below.

Table 3. The results of the homogeneity test in this study

		Levene Statistic	df1	df2	Sig.
Pretest on Coordination	Based on Mean	1.168	3	36	0.335
	Based on Median	1.064	3	36	0.376
Posttest on Coordination	Based on Mean	0.189	3	36	0.903
	Based on Median	0.134	3	36	0.939

Based on the results of Table 3, the homogeneity value refers to the average value of each pretest and posttest. The pretest on coordination shows a sig. 0.335 > 0.05, and the posttest on coordination shows a sig. 0.903 > 0.05, indicating that all samples involved in this study come from the same population.

After the data were assumed to be normally distributed and homogeneous, MANOVA was used to analyze the results from the students in the big ball game group and the control group. The following are the results of the MANOVA test.

Based on the results of table 4 referring to Wilks' Lambda, the effect shown on gender is sig. 0.000 < 0.05 (F = 56.646) so there is a difference in coordination ability based on gender. The effect shown on the group is 0.000 < 0.05 (F = 72.383) so the big ball game significantly improves student coordination compared to the control group. The effect shown on Gender*Group is sig. 0.120 < 0.05 (F = 2.252) so there is no significant interaction between gender and group.

Table 2. Descriptive results and normality of coordination test

	Descriptive Statistics					Shapiro-Wilk		
	N	Minimum	Maximum	Mean	Std. Deviation	Statistics	df	Sig.
EG-pretest pria	10	12	15	13,30	0,949	0.911	10	0.287
EG-posttest pria	10	19	23	20,80	1,317	0.942	10	0.575
CG-pretest pria	10	11	16	13,20	1,476	0.918	10	0.337
CG-posstest pria	10	13	17	14,90	1,197	0.952	10	0.691
EG-pretest wanita	10	9	12	10,70	0,949	0.911	10	0.287
EG-posttest wanita	10	14	19	16,10	1,524	0.929	10	0.441
CG-pretest wanita	10	9	13	11,20	1,317	0.942	10	0.575
CG-posstest wanita	10	10	14	11,90	1,197	0.952	10	0.691

Table 4. Multivariate Test Results on the Big Ball Game Program

Effect		Value	F	Sig.
Intercept	Pillai's Trace	0.996	4580.984[b]	0.000
	Wilks' Lambda	0.004	4580.984[b]	
	Hotelling's Trace	261.771	4580.984[b]	
	Roy's Largest Root	261.771	4580.984[b]	
Gender	Pillai's Trace	0.764	56.646[b]	0.000
	Wilks' Lambda	0.236	56.646[b]	
	Hotelling's Trace	3.237	56.646[b]	
	Roy's Largest Root	3.237	56.646[b]	
Group	Pillai's Trace	0.805	72.383[b]	0.000
	Wilks' Lambda	0.195	72.383[b]	
	Hotelling's Trace	4.136	72.383[b]	
	Roy's Largest Root	4.136	72.383[b]	
Gender*Group	Pillai's Trace	0.114	2.252[b]	0.120
	Wilks' Lambda	0.886	2.252[b]	
	Hotelling's Trace	0.129	2.252[b]	
	Roy's Largest Root	0.129	2.252[b]	

The third analysis was an tests of between-subjects effects to examine the differences between experimental groups and those by gender in students aged 11-12 years. The following are the results of the tests of between-subjects effects.

Based on the results of table 4, Tests of Between-Subjects Effects shows that at the pretest stage there was no difference in coordination between EG and CG sig. 0.600 < 0.05, indicating equivalent initial conditions. However, after being given the big ball game treatment, there was a significant increase in coordination in EG compared to CG (F = 147.366; 0.000 < 0.05). In addition, a significant interaction between gender and group was also found in the posttest coordination (F = 4.175; 0.048 < 0.05), indicating that the effect of the big ball game on coordination differs between male and female students. Overall, the analysis model explains 86.8% of the variation in changes in student coordination, confirming that the big ball game is effective in improving coordination abilities in students aged 11–12 years.

The final analysis involved testing the effect size using partial eta squared and the results of pairwise comparisons based on gender and group. The results of the effect size and pairwise comparisons are presented in Table 6 below.

Based on the results of table 6, it shows that gender has a significant influence on student coordination ($F = 85.652$, $p < 0.001$, $\eta^2_p = 0.704$). The partial η^2 value of 0.704 indicates a very large effect, so approximately 70.4% of the variation in coordination improvement can be explained by gender differences. Then, there is a very significant influence between treatments (EG vs CG) on improving student coordination ($F = 147.366$, $p < 0.001$, $\eta^2_p = 0.804$). The partial η^2 value of 0.804 indicates a very large effect, which means approximately 80.4% of the variation in coordination improvement is explained by differences in treatment types.

Discussion

Based on the results of this study, it was found that big ball games have a positive effect on coordination skills, especially in male and female students who are members of the experimental group. Meanwhile, the control group of

Table 5. Result of Tests of Between-Subjects Effects

Source		Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	Pretest Coordination	54.200a	18.067	12.654	0.000
	Posttest Coordination	410.475b	136.825	79.064	0.000
Intercept	Pretest Coordination	5856.400	5856.400	4101.759	0.000
	Posttest Coordination	10144.225	10144.225	5861.831	0.000
Gender	Pretest Coordination	52.900	52.900	37.051	0.000
	Posttest Coordination	148.225	148.225	85.652	0.000
Group	Pretest Coordination	0.400	0.400	0.280	0.600
	Posttest Coordination	255.025	255.025	147.366	0.000
Gender*Group	Pretest Coordination	0.900	0.900	0.630	0.432
	Posttest Coordination	7.225	7.225	4.175	0.048

a.R Squared = .513 (Adjusted R Squared = .473)

b.R Squared = .868 (Adjusted R Squared = .857)

Table 6. Results of Estimated Marginal Means, Pairwise Comparisons, and Univariate Tests

Factor	Category	Estimates				Pairwise Comparisons		Univariate Tests		
		Mean	Std. Error	95% CI Lower	95% CI Upper	Mean Difference	Sig.	F	Sig	Partial Eta Squared
Gender	Male	17.85	0.29	17.25	18.45	3.85*	0.000	85.652	0.000	0.704
	Female	14.00	0.29	13.40	14.60					
Group	Experiment	18.45	0.29	17.85	19.05	5.05*	0.000	147.366	0.000	0.804
	Control	13.40	0.29	12.80	14.00					

female students did not show any significant effect, indicating that their coordination did not increase significantly in the absence of the big ball game treatment.

These findings suggest that big ball games are effective as a practice method for improving coordination, particularly when administered in a structured and consistent manner. This finding has also been supported by the results of previous studies, which have shown that training programs using structured big balls, such as those with clear procedures and fun game models, can improve physical skills in students aged 11-12 years (Mikail & Suharjana, 2019; Nikšić et al., 2020). In big ball games, such as soccer, basketball, or volleyball, cooperation between the various systems of the body is required (Dewi, 2023). These body systems include fine and gross motor, as well as sensory systems such as vision and balance (Cenizo-Benjumea et al., 2022; Wedi et al., 2024). In this training method, students are also required to be physically active, such as running by moving, jumping and leaping, and playing reactions. Therefore, training methods with various games are able to stimulate an increase in overall coordination (Giuriato et al., 2022), in the new findings of this study through big ball games.

In male students, both the experimental group and the control group showed significant differences in coordination, with the experimental group that received the big ball game treatment showing a higher increase. This can be explained based on previous scientific studies, that male students aged 11-12 years tend to be more physically active (Sari et al., 2024; Syahriadi et al., 2024). So it has higher courage in playing competitively, and is more familiar with big ball games. Then, the basis of the big ball game in this study is fun, but the factor of the difficulty level of the game model also has an impact on self-confidence and motivation to complete challenges (Arifin et al., 2021; Kurniawan et al., 2024). These factors can increase the effectiveness of the exercises they undergo.

Meanwhile, in female students, increased coordination also occurred in the experimental group. This suggests that big ball games are also effective for female students, although they may exhibit different physiological and psychological responses compared to male students. Physiologically, based on the results of the study, it was found that male students tend to have more developed muscle strength, reaction speed, and motor capacity than female students at that age (Sánchez-Díaz et al., 2021; Sugimoto et al., 2023). This ability supports their involvement in dynamic physical activities, such as big ball games, which require movement coordination, balance, and quick responses to visual and tactical stimuli (Dewi, 2023). Psychologically, male students generally show a higher interest in competitive and physical games, so their involvement in big ball game activities becomes more intense (Aguayo et al., 2022). In contrast, female students tend to be more cautious, tend to participate in collaborative activities, and may feel less confident in competitive games (Amenya et al., 2021), which may limit the optimization of coordination development through such exercises.

Then, other findings showed that there was no significant effect in the control group of female students, indicating that without stimulation of exercises such as big ball games, coordination skills tended to stagnate. It can be influenced by a lack of spontaneous physical activity or involvement in games that require complex coordination, outside of treatment (Sugimoto et al., 2023). Therefore, the coordination development program should consider a game-based approach tailored to gender characteristics so that the benefits are even and optimal. As the results of previous studies indicate, female students can improve their physical skills through traditional games for female students aged 9–12, such as scholarship games (Santoso et al., 2024) and circuit games, including the Fabric Volleyball Game, Football Circuit Game, and Suki Basketball Circuit Game, as well as Quickie (Who's Fast?)—a game for female students (Kuspratiwi et al., 2025). Then, a more specific training program was developed specifically for female students, without groups for male students, such as using the small-sided game method (Mikalonytė et al., 2022). To enable female students to be more confident from a young age, without a comparison group, such as male students.

This study has several limitations worth noting, including the involvement of students in the experimental and control groups, which cannot be fully controlled in terms of motivation, interest, and active participation, especially among female students, which affects the results obtained. In addition, the duration and intensity of treatment for big ball games are still limited, so it does not fully describe the long-term impact, and the approach has not been fully adapted to psychological characteristics based on gender. External factors, such as physical activity outside of school, also cannot be controlled thoroughly. Nevertheless, the results of this study have important implications for the development of physical education learning in elementary schools, where big ball games are effective in improving students' motor coordination, for both boys and girls aged 11–12 years. Therefore, educators and coaches are advised to integrate varied and adaptive game approaches to enhance students' character development and maximize participation and overall motor development.

Conclusion

The results of this study indicate that playing with a large ball significantly improves the coordination skills of 11–12-year-old students, particularly in the experimental group compared to the control group ($F = 147.366$, $p < 0.001$, $\eta^2_p = 0.804$). This effect is very large, indicating that approximately 80.4% of the variation in coordination improvement is explained by treatment differences. In addition, gender also significantly influences coordination ($F = 85.652$, $p < 0.001$, $\eta^2_p = 0.704$), with male students tending to show better coordination than female students. Big ball games, presented in a structured, fun, and consistent manner, have been proven to stimulate the motor and sensory systems while also encouraging students' overall active physical involvement. Differences in responses between male and female students showed that physiological and psychological factors also influenced the coordination results obtained. Meanwhile, although female students in the experimental group also showed increased coordination, the control group of female students did not exhibit significant changes, which highlighted the importance of physical stimulation through game activities in their coordination development process. Thus, physical education learning programs should incorporate game approaches that consider differences in gender characteristics, allowing all students to benefit optimally from them.

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Conflict of Interest

The author declares no conflict of interest with any other authors or related research findings.

References

ÇAKIT, İ., ÇAMLIGÜNEY, F., & ERDİL, G. (2022). The Impact of Differential Learning Model on Motor Skills and Handball-Specific Coordination Performance in 11–13-Year-Old Beginners in Handball. *International Journal of Sport, Exercise & Training Sciences*. https://doi.org/10.18826/useeabd.1152610

Tanineh, W., & Halaweh, H. (2023). Cardiorespiratory Fitness, Motor Coordination, and Academic Achievement in School Students (11-13 years). *Global Pediatric Health,* 10. https://doi.org/10.1177/2333794X231207311

Sabău, A. M., Săvescu, B., Bulz, C., Damian, M., & Săvescu, D. (2023). Development study determining motor qualities in rhythmic gymnastics. Mobility and coordination in gymnasts 10-12 years old. *GeoSport for Society, 19*(2), 65-75. https://doi.org/10.30892/gss.1903-097

Putro, K. H., Suharjana, S., Marhaendro, A. S. D., Hariono, A., Siswantoyo, S., Fauzi, F., & Prabowo, T. A. (2025). Evaluating Validity and Test-retest Reliability on Indonesian Basketball Talent Scouting Model for Athletes Aged 10 to 14. *Physical Education Theory and Methodology, 25*(3), 540-547. https://doi.org/10.17309/tmfv.2025.3.09

Sobko, S. H., Sobko, N. H., Maleniuk, T. V., Babalich, V. A., & Panchenko, H. I. (2021). Improving coordination of young footballers aged 9-10 years. *International Journal of Human Movement and Sports Sciences, 9*(5), 940-947. https://doi.org/10.13189/saj.2021.090515

Yin, X., Zhu, R., Shi, X., Cai, G., Jing, C., Pan, Q., & Yang, T. (2023). The effect of rhythm training on the motor coordination abilities of 8–12-year-old freestyle swimmers. *PeerJ,* 11. https://doi.org/10.7717/peerj.15667

Aguayo, B. B., Román, P. Á. L., Sánchez, J. S., & Vallejo, A. P. (2022). Effect of physical activity and fitness on executive functions and academic performance in children of elementary school. A systematic review. *Cultura, Ciencia y Deporte, 17*(51), 85-103. https://doi.org/10.12800/ccd.v17i51.1699

Ramli, R., Aji, T., Suwardi, S., Yanti, N., & Hanafi, M. (2023). Eye-foot coordination and balance with serving ability: A correlation study in sepak takraw game. *Jurnal SPORTIF : Jurnal Penelitian Pembelajaran, 9*(3), 483-495. https://doi.org/10.29407/js_unpgri.v9i3.21217

Hikmawati, H., Hartati, H., & Usra, M. (2023). The Impact of Hanging Ball Training Method on Volleyball Under Passing and Hands Eye Coordination. *AL-ISHLAH: Jurnal Pendidikan, 15*(4), 4527-4536. https://doi.org/10.35445/alishlah.v15i4.3862

Dewi, R. (2023). The Effect Of Big Ball Game Modification On Gross Motor Development Of Elementary School Students. *COMPETITOR: Jurnal Pendidikan Kepelatihan Olahraga, 15*(1), 48. https://doi.org/10.26858/cjpko.v15i1.43810

Mitova, O., Griban, G., Oleniev, D., Yakovenko, A., Onyshchenko, V., Mozolev, O., & Hres, M. (2022). The Impact of Mini-Basketball Training Sessions on the 6-7-Year-Old Boys' Physical Fitness and Physical Development. *International Journal of Human Movement and Sports Sciences, 10*(4), 754-767. https://doi.org/10.13189/saj.2022.100416

Glišović, G. (2022). Influence of basketball training on morphological characteristics and motor abilities of younger grades of primary school. *Metodicka Praksa, 25*(1), 69-82. https://doi.org/10.5937/metpra2201069g

Marchenko, S. I., & Dykhanova, A. I. (2019). Motor abilities: Peculiarities of effects of volleyball training on coordination preparedness of girls aged 15. *Physical Education Theory and Methodology, 19*(1), 23-28. https://doi.org/10.17309/tmfv.2019.1.03

Mikail, K., & Suharjana, S. (2019). Pengembangan model latihan teknik dasar sepakbola bagi anak usia 10-12 tahun di sekolah sepakbola. *Jorpres (Jurnal Olahraga Prestasi), 15*(1), 14–27. https://doi.org/10.21831/jorpres.v15i1.26023

Santoso, N. P., Subagyo, S., Santoso, N., Prabowo, T. A., & Yulianto, W. D. (2024). Assessing the Effect of Traditional Games on Manipulative Movements in Elementary School Students Based on Gender. *Physical Education Theory and Methodology, 24*(3), 441-448. https://doi.org/10.17309/tmfv.2024.3.13

Kuspratiwi, F. W., Suherman, W. S., & Komari, A. (2025). The effect of circuit games on manipulative movement for elementary school students aged 9-10 years. *Retos,* 65, 13-21. https://doi.org/10.47197/retos.v65.111144

Rusli, M., Marsuna, M., & Jud, J. (2024). Increase the speed of running 100 meters using the bench and skipping training methods. *Pedagogy of Physical Culture and Sports, 28*(5), 336-343. https://doi.org/10.15561/26649837.2024.0501

Cho, E. H., Yun, H. J., & So, W. Y. (2020). THE validity of alternative hand wall toss tests in Korean children. *Journal of Men's Health, 16*(1), e10-e18. https://doi.org/10.15586/jomh.v16i1.166

Mikalonytė, R., Paulauskas, R., Abade, E., & Figueira, B. (2022). Effects of small-sided games vs. simulated match training on physical performance of youth female handball players. *PLoS ONE, 17*(9 September). https://doi.org/10.1371/journal.pone.0273574

Chowdhury, A. K., Tjondronegoro, D., Chandran, V., Zhang, J., & Trost, S. G. (2019). Prediction of relative physical activity intensity using multimodal sensing of physiological data. *Sensors (Switzerland), 19*(20). https://doi.org/10.3390/s19204509

Aiken, L. R. (1985). Three Coefficients For Analyzing The Reliability And Validity Of Ratings. *Educational and Psychological Measurement,* 45, 131-141. https://doi.org/10.1177/0013164485451012

Wedi, S., Tomoliyus, T., Fauzi, F., Gemaini, A., & Prabowo, T. A. (2024). Innovation, Validity, and Reliability of Modified Dynamic Balance Test for Karate Kata Category. *Sport Mont, 22*(3), 3-8. https://doi.org/10.26773/smj.241004

George, D., & Mallery, P. (2019). *IBM SPSS Statistics 26 Step by Step.* Routledge. https://doi.org/10.4324/9780429056765

Bernadett, S. P., & Csaba, B. M. (2024). Examining normal distribution: which test to use? *Statisztikai Szemle, 102*(1), 5-37. https://doi.org/10.20311/stat2024.01.hu0005

Nikšić, E., Beganović, E., & Joksimović, M. (2020). The impact of the program of basketball, volleyball and handball on the situation-motorized capability of the first classes of the elementary school. *Pedagogy of Physical Culture and Sports, 24*(2), 85-92. https://doi.org/10.15561/26649837.2020.0206

Cenizo-Benjumea, J. M., Vázquez-Ramos, F. J., Ferreras-Mencía, S., & Gálvez-González, J. (2022). Effect of a gamified program on physical fitness and motor coordination. *Cultura, Ciencia y Deporte, 17*(52), 155-177. https://doi.org/10.12800/ccd.v17i52.1786

Giuriato, M., Lovecchio, N., Pellino, V. C., Mieszkowski, J., Kawczynski, A., Nevill, A., & Biino, V. (2022). Gross motor coordination and their relationship with body mass and physical activity level during growth in Children aged 8-11 years old: a longitudinal and allometric approach. *PeerJ,* 10. https://doi.org/10.7717/peerj.13483

Sari, I. P. T. P., Doewes, M., Hidayatullah, M. F., & Hariono, A. (2024). Physical activity questionnaire for older children (PAQ-C) versi Indonesia: confirmatory factor analysis. *Retos,* 61, 100-107. https://doi.org/10.47197/retos.v61.109522

Syahriadi, S., Sugiyanto, F. X., Lumintuarso, R., Juita, A., & Prabowo, T. A. (2024). The effect of groundstroke forehand exercise on enhancing cardiorespiratory endurance (VO2 MAX) in 12- to 14-year-old tennis athletes. *SPORT TK-Revista EuroAmericana de Ciencias Del Deporte, 13*(13), 1-17. https://doi.org/10.6018/sportk.564831

Arifin, R., Erliana, M., & Faisal, A. (2021). Improving Learning Outcomes Of Big Ball Games Using Coopertive Methods In Primary Schools. *Kinestetik: Jurnal Ilmiah Pendidikan Jasmani, 5*(1), 179-185. https://doi.org/10.33369/jk.v5i1.14616

Kurniawan, F., Hidayatullah, M. F., Kristiyanto, A., Riyadi, S., Ekawati, F. F., Ningrum, N. R., & Prabowo, T. A. (2024). Physical literacy needs in esports: literature review. *Retos,* 58, 495-505. https://doi.org/10.47197/retos.v58.107885

Sánchez-Díaz, S., Yanci, J., Raya-González, J., Scanlan, A. T., & Castillo, D. (2021). A Comparison in Physical Fitness Attributes, Physical Activity Behaviors, Nutritional Habits, and Nutritional Knowledge Between Elite Male and Female Youth Basketball Players. *Frontiers in Psychology,* 12. https://doi.org/10.3389/fpsyg.2021.685203

Sugimoto, D., Stracciolini, A., Berbert, L., Nohelty, E., Kobelski, G. P., Parmeter, B., & Myer, G. D. (2023). Assessment of Physical Tests in 6–11 Years Old Children: Findings from the Play Lifestyle and Activity in Youth (PLAY) Study. *International Journal of Environmental Research and Public Health, 20*(3). https://doi.org/10.3390/ijerph20032552

Akpene Amenya, P. C., Annan, R. A., Apprey, C., & Agbley, E. N. (2021). The relationship between nutrition and physical activity knowledge and body mass index-for-age of school-aged children in selected schools in Ghana. *Heliyon, 7*(11). https://doi.org/10.1016/j.heliyon.2021.e08298

Впровадження ігор з великим м’ячем для покращення координації учнів 11–12 років: Аналіз з урахуванням гендерних аспектів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 6 табл., 1 рис., 34 джерела.

Історія питання. Розвиток координації в дитинстві, зокрема у віці від 11 до 12 років, відіграє важливу роль у загальному самопочутті та довгостроковому фізичному розвитку. Ігри з великим м’ячем визнані ефективним засобом покращення координації. Однак у зазначених іграх часто акцентується увага на базових технічних навичках, причому наукові дані щодо впливу статі на показники координації у іграх з великим м’ячем представлені в обмеженій кількості.

Мета дослідження. Основною метою цього дослідження було оцінити вплив ігор з великим м’ячем на розвиток координації учнів 11–12 років з урахуванням гендерних відмінностей.

Матеріали та методи. Застосовано квазіекспериментальний дизайн дослідження з використанням претестового та посттестового методів. У дослідженні взяли участь 40 учнів: 20 хлопців (вік: 11.5 ± 0.3 роки; зріст: 148.9 ± 3.0 см; вага: 44.6 ± 2.5 кг) та 20 дівчат (вік: 11.4 ± 0.2 роки; зріст: 145.7 ± 1.3 см; вага: 40.0 ± 1.1 кг). Вибірки з визначеними початковими показниками претесту було розподілено за методом порядкового сполучення за формулою A-B-B-A, а потім об'єднано в експериментальну групу (ЕГ) та контрольну групу (КГ). Інтервенція складалася з п'яти моделей ігор з великим м'ячем, що проводилися протягом шести тижнів (18 сесій), з трьома сесіями на тиждень у період з 7:00 до 9:00 ранку. Моніторинг інтенсивності для цієї гри становив 65% – 75% або рейтинг сприйнятого навантаження (Rating of Perceived Exertion, RPE) на рівні 12 – 14 (помірний). Координація оцінювалася з використанням тесту почергового підкидання м'яча до стіни (Alternative Hand Wall Toss Test, AHWT), валідованого інструменту для оцінки зорово-моторної координації. Аналіз даних проводився з використанням багатовимірного дисперсійного аналізу (MANOVA) за допомогою програмного забезпечення SPSS версії 26.

Результати. Багатовимірний аналіз показав значний вплив на координацію між статтю ($p < 0.05$) та ЕГ ($p < 0.05$). Водночас взаємодія між зазначеними факторами не визначила істотного впливу на багатовимірному рівні ($p > 0.05$). Результати одновимірного тесту виявили, що стать мала суттєвий вплив на поліпшення координації ($F = 85.652$, $p < 0.001$, $\eta^2_p = 0.704$), вказуючи на наявність 70.4% варіації в покращенні показників координації, що пояснюється гендерними відмінностями. Згодом на основі інтервенційного підходу (ЕГ та КГ) щодо координації учнів ($F = 147.366$, $p < 0.001$, $\eta^2_p = 0.804$) було продемонстровано, що 80.4% варіації координації пояснюється відмінностями методики. Тест міжсуб'єктного ефекту показав, що на претестовому етапі не спостерігалося відмінностей у координації між ЕГ і КГ ($p = 0.600$), тоді як на посттестевому етапі дослідження було виявлено значущу відмінність ($p = 0.000$). Крім того, на посттестевому етапі встановлено помітну взаємодію між статтю та групою ($p = 0.048$).

Висновки. Структуроване, цікаве та послідовне застосування ігор з великим м'ячем сприяє значному покращенню координації у дітей віком 11–12 років та має виражений ефект в експериментальних групах. Отримані результати підкреслюють вплив фізіологічних та психологічних чинників на розвиток координації, висвітлюючи гендерні відмінності у реагуванні на інтервенції з фізичної активності. Отже, програми фізичного виховання повинні застосовувати інклюзивні ігрові підходи, що враховують гендерно-специфічні потреби з метою забезпечення максимізації розвитку координації у всіх учнів.

Ключові слова: ігри для дітей, моторна координація дітей, ігри з великим м'ячем, діти віком 11–12 років.

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Original Scientific Article

Identifying Biomechanical Risk Factors for Lower Limb Injuries in High Jump Athletes Using Penalised Logistic Regression

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Abstract

Background. High jump athletes are exposed to considerably lower limb injury risk due to repetitive high-impact loading and asymmetrical force application during the approach and take-off phases. Despite the biomechanical demands of the event, limited research has examined the predictive value of combined kinematic and neuromuscular factors in identifying athletes at elevated risk of musculoskeletal injury.

Objectives. This study aimed to identify biomechanical predictors of lower limb injury risk in competitive male high jump athletes using penalised logistic regression.

Materials and Methods. Twenty-one male national-level high jump athletes (age 21.14 ± 2.22 years; height 187.04 ± 5.36 cm; body mass 74.09 ± 5.04 kg) underwent 3D motion capture, ground reaction force analysis, and surface electromyography. Key predictors included cadence (steps/min), pelvic obliquity (°), pelvic rotation (°), and muscle activation asymmetry (% difference in EMG amplitude between limbs). Injury classification followed the International Olympic Committee's consensus criteria, with injury history verified by medical records. Correlation analyses were followed by LASSO logistic regression with leave-one-out cross-validation. Model performance was assessed using AUC, sensitivity, specificity, predictive values, F1 score, calibration slope, intercept, and Brier score.

Results. Four variables were retained in the final model: cadence (OR = 1.60, p = 0.021), pelvic obliquity (OR = 1.48, p = 0.033), pelvic rotation (OR = 1.36, p = 0.072), and muscle activation asymmetry (OR = 1.66, p = 0.018). The model demonstrated moderate discriminative ability (AUC = 0.78, 95% CI: 0.64–0.92), sensitivity of 0.75, and specificity of 0.71. However, calibration was suboptimal (slope = 0.24, intercept = 0.47, Brier score = 0.21), suggesting risk underestimation and potential overfitting.

Conclusions. Muscle activation asymmetry, cadence, and pelvic kinematic deviations were associated with an increased risk of lower limb injury in high jump athletes. These findings highlight the importance of neuromuscular balance and lumbopelvic stability in injury screening. While the results demonstrate preliminary utility, small sample size and calibration limitations necessitate validation in larger, prospective cohorts before clinical application.

Keywords: high jump, biomechanics, injury prediction, muscle activation asymmetry, logistic regression.

Introduction

Participation in sports and physical activity is not only vital for developing athletic performance but also plays a transformative role in enhancing both physical resilience and psychological well-being, which underscores the importance of identifying biomechanical factors that influence injury risk (Choudhary & Dubey, 2024; P. K. Choudhary et al., 2024). High jump is a technically demanding track and field discipline characterised by unique biomechanical requirements during approach, penultimate step, take off, flight, and landing phases (Burns et al., 2019). Athletes participating in track and field jumping events are exposed to ground-reaction forces on the take-off leg that are several times their body weight, creating substantial stress on lower limb structures and predisposing athletes to specific injury patterns. Lower limb musculoskeletal injuries represent a significant burden in high jump, with ankle sprains, patellar tendinopathy, quadriceps/hamstring strains, and hip joint overload being the most frequently reported conditions (Enoki et al., 2021). The biomechanical demands of high jump create a complex interplay of forces that must be precisely coordinated to achieve optimal performance while minimizing injury risk. During the approach phase, athletes must generate horizontal velocity while maintaining optimal cadence and stride mechanics (Heiderscheit et al., 2011). The penultimate step serves as a critical transition phase, lowering the center of mass and preparing the body for explosive take-off, while the final step transmits ground reaction forces exceeding several times body weight through the lower limb kinetic chain (Wilson et al., 2007). Compromised force transmission due to poor alignment or muscular imbalances significantly escalates injury risk (Croisier et al., 2008). Pelvic stability emerges as a fundamental component in high jump biomechanics, serving as the cornerstone for optimal force transfer and lower limb alignment (Leetun et al., 2004). Excessive pelvic obliquity or rotation disrupts normal loading patterns across the kinetic chain, predisposing athletes to overuse injuries (Zazulak et al., 2007). These kinematic deviations may be magnified in high jumpers due to the inherent rotational and asymmetrical forces present during the approach and take-off phases. Furthermore, bilateral quadriceps strength asymmetries and deficits in eccentric strength have been identified as modifiable risk factors in jumping sports (Hewett et al., 2005).

A stiffer jump-landing technique is a risk factor in the development of overuse injuries and acute injuries, caused by less active motion in the lower extremity joints and increased valgus position of the knee. Gait parameters, particularly cadence and stance phase characteristics, influence joint loading patterns and have been linked to injury incidence in running and jumping sports (Bramah et al., 2018). Higher cadence is associated with reduced joint loading, offering potential protective effects against overuse injuries (Ceyssens et al., 2019). Contemporary injury prediction approaches recognize that sports injuries emerge from complex interactions among biomechanical, physiological, and contextual variables rather than single causative factors (Bittencourt et al., 2016). This understanding has promoted the adoption of multifactorial injury models utilizing statistical approaches capable of handling variable interdependence (Meeuwisse et al., 2007). Penalized regression methods such as Least Absolute Shrinkage and Selection Operator (LASSO) logistic regression enable simultaneous variable selection and coefficient shrinkage, enhancing model interpretability and prediction accuracy (Tibshirani, 1996). The 79% of studies using drop jump observed an association with future injury, while only 8% of countermovement jump studies observed an association with injury risk, highlighting the importance of sport-specific assessment protocols. Despite the recognized importance of biomechanical factors in high jump injury risk, limited research has specifically examined the predictive value of combined gait, pelvic kinematic, and strength variables in this population. A comprehensive understanding of these relationships is crucial for developing targeted injury prevention strategies in high jump athletes.

This study aimed to identify biomechanical predictors of lower limb musculoskeletal injury risk in high jump athletes using penalized logistic regression modeling. The specific objectives were to: (1) quantify key gait and pelvic kinematic variables alongside quadriceps strength measures in elite high jumpers; (2) examine relationships between these variables and injury risk; and (3) develop and validate a predictive model using LASSO logistic regression with Leave One Out Cross Validation (LOOCV). It was hypothesized that greater pelvic rotation and obliquity angles, reflecting compromised lumbopelvic stability, would be positively associated with increased lower limb injury risk, while lower step cadence during approach would be associated with higher injury risk due to increased joint loading. Additionally, interlimb quadriceps strength asymmetry (≥10% difference between dominant and non-dominant limbs) was expected to be predictive of elevated injury risk in high jump athletes.

Materials and Methods

Study Design

This study adopted a retrospective observational design to examine biomechanical factors associated with lower limb musculoskeletal injury risk in competitive high jump athletes. The design allowed evaluation of associations between biomechanical variables and retrospectively verified injury history, without inferring causality or intervention effects.

Study Participants

A total of twenty-one male high jump athletes, aged between 18 and 25 years, were recruited using purposive sampling. To ensure homogeneity, only athletes with a minimum of five consecutive years of structured training under certified coaches and active participation at the national competitive level were included. Athletes were excluded if they had undergone lower limb surgery within the previous year, presented with diagnosed neurological conditions affecting gait or motor control, or had incomplete biomechanical or neuromuscular data. All participants provided written informed consent was obtained. The Institutional Ethics Committee granted ethical approval, and the study was conducted in compliance with the Declaration of Helsinki (World Medical Association, 2013).

Table 1. Baseline Characteristics of Participants

Variable	Mean ± SD	Units	Notes
Age	21.14 ± 2.22	years	Chronological age at testing
Body mass	74.09 ± 5.04	kg	Measured using a calibrated digital scale
Height	187.04 ± 5.36	cm	Stadiometer measurement
BMI	21.20 ± 1.6	kg/m^2	Calculated as mass (kg)/height^2 (m^2)
Training experience	5.09 ± 0.53	years	Continuous structured training

Data are presented as Mean ± Standard Deviation (SD). Anthropometric measurements were obtained with participants barefoot and in light athletic clothing. Body mass was measured using a calibrated digital scale with ±0.1 kg accuracy, and height was measured using a wall-mounted stadiometer with ±0.1 cm accuracy. Body mass index (BMI) was calculated as body mass (kg) divided by squared height (m^2). Training experience reflects the number of consecutive years of structured, coach-supervised high jump training.

Injury Classification

Injury classification was carried out according to the International Olympic Committee consensus statement (Fuller et al., 2006). An injury was defined as any musculoskeletal condition sustained during training or competition that caused at least 24 hours of restricted participation. Severity was categorized as mild (1-7 days), moderate (8-28 days), or severe (>28 days). Injury history was obtained through athlete interviews and verified against medical records, with confirmation provided by a certified sports physiotherapist who was blinded to all kinematic and EMG data. Athletes who had sustained one or more documented lower limb musculoskeletal injuries in the past 12 months were classified as "at risk" (coded as 1), whereas those without any such history were classified as "no risk" (coded as 0).

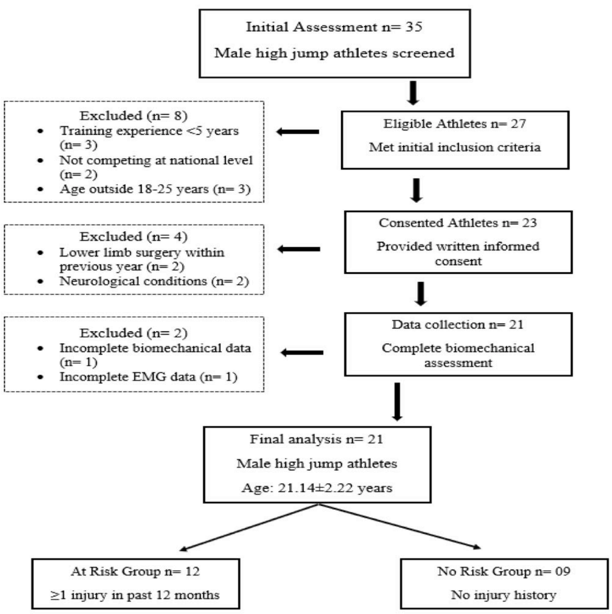

Fig 1. Participants Recruitment and Selection Process

Instrumentation

Biomechanical and neuromuscular measurements were obtained using an integrated motion analysis system. A Vicon® 3D motion capture system (200 Hz) with reflective markers (modified Plug-in Gait model) was used to record kinematic data (Kadaba et al., 1990), while ground reaction forces were measured using AMTI® force plates (1000 Hz) (Winter, 2009). Neuromuscular activity was captured with a Delsys Trigno™ wireless surface electromyography (sEMG) system (band-pass 20-450 Hz), with electrodes placed bilaterally on selected lower limb muscles following SENIAM guidelines (Hermens et al., 2000). All systems were synchronised to ensure precise temporal alignment of kinematic, kinetic, and EMG data (Robertson et al., 2004).

Measured Parameters

Key biomechanical and neuromuscular parameters were extracted from the motion capture and EMG systems. Cadence was defined as the number of steps per minute during the approach phase, while pelvic obliquity and pelvic rotation were measured as tilt in the frontal plane and rotation in the transverse plane, respectively. Standard joint kinematic variables, including hip flexion/extension, hip abduction/adduction, knee flexion/extension, and ankle plantarflexion/dorsiflexion were calculated according to established biomechanical conventions.

Neuromuscular measures included muscle activation asymmetry, defined as the percentage difference in EMG activity between dominant and non-dominant limbs, calculated as:

$$\text{Asymmetry (\%)} = \frac{|EMG_{dom} - EMG_{non-dom}|}{\max(EMG_{dom}, EMG_{non-dom})} \times 100$$

Higher values indicate greater inter-limb imbalance. Additional neuromuscular variables included peak EMG amplitude (μV) and time to peak activation (ms). Injury risk was coded as a binary outcome, with athletes reporting at least one lower limb injury in the past 12 months classified as "1 = at risk" and those without such history classified as "0 = no risk," consistent with epidemiological criteria (Fuller et al., 2006).

Testing Protocol

The test protocol began with a standardized warm-up consisting of 10 minutes of dynamic stretching and five minutes of submaximal running. Reflective markers and EMG electrodes were then applied, and each athlete performed three maximal-intensity approach and take-off trials replicating their habitual competitive technique. Trials were repeated if there was marker occlusion, motion capture drop-out, or excessive EMG signal noise. Only technically valid trials were included, and the mean of three valid trials was used in the analysis to improve stability. Intra-trial reliability was assessed using intraclass correlation coefficients, which demonstrated excellent agreement (ICC = 0.90–0.94).

Experimental Protocol

The assessments were conducted indoors on a uniform synthetic track surface to ensure consistency. Athletes performed the high jump using their habitual competitive technique. The approach phase was divided into early, mid, and final strides, with kinematic data captured at each stage. Neuromuscular activity was continuously recorded, with particular emphasis on the penultimate and take-off steps where loading demands are highest.

Statistical Analysis

Statistical analyses were conducted in Python (v3.11) using scikit-learn and statsmodels libraries. Descriptive statistics were calculated for all continuous variables, and the

Shapiro–Wilk test was applied to assess normality, guiding the use of Pearson or Spearman correlations as appropriate. Multicollinearity was assessed using variance inflation factors (VIF) to ensure model stability. The core modelling technique was L1-penalized logistic regression (LASSO), with the penalty parameter (λ) selected through leave-one-out cross-validation (LOOCV). Model performance was evaluated using multiple indices: area under the ROC curve (AUC) with 95% confidence intervals, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), balanced accuracy, F1 score, calibration intercept and slope, and the Brier score. ROC and calibration plots were used to visualize discriminative and calibration performance. All analyses were conducted using a complete-case approach, as no missing values were identified in the biomechanical or neuromuscular datasets. All reporting adhered to the STROBE guidelines for observational studies and the TRIPOD checklist for prediction modelling.

Result

The present study examined associations between selected biomechanical variables and lower limb injury risk in competitive high jump athletes. Descriptive statistics for anthropometric and training characteristics are presented in Table 1. Correlation analyses were performed to identify significant biomechanical predictors of injury risk, followed by penalised logistic regression modelling to develop a multivariable prediction model. The retained predictors, model coefficients, and corresponding odds ratios are summarised to highlight their contribution to injury risk. Predictive performance metrics were then evaluated to determine the discriminative ability, calibration, and overall accuracy of the model. Graphical representations, including the ROC curve and calibration plot, provide additional insight into model behaviour and diagnostic validity.

In the multicollinearity diagnostics, all predictor variables demonstrated acceptable tolerance values. Variance inflation factors (VIFs) were below 2.5 for all retained predictors, indicating no concerning multicollinearity.

In Table 2 Correlation analysis examined associations between biomechanical predictors and lower limb injury risk in high jump athletes. Cadence was expressed in steps per minute during the approach run, pelvic obliquity as frontal plane pelvic tilt in degrees, and pelvic rotation as transverse plane pelvic rotation in degrees.

Muscle activation symmetry was defined as the percentage difference in EMG amplitude between dominant and non-dominant limbs. Correlation coefficients are presented as Pearson's r or Spearman's ρ, depending on data distribution, with p-values <0.05 considered statistically significant.

In Table 3, the final penalised logistic regression model (LASSO) retained four predictors of lower limb injury risk. Cadence, pelvic obliquity, pelvic rotation, and muscle activation symmetry were expressed in standardised units to allow direct comparison of effect sizes.

Odds ratios (OR) are presented with 95% confidence intervals (CI), and p-values <0.05 were considered statistically significant. Muscle activation symmetry was calculated as the percentage difference in EMG amplitude between limbs. Variables excluded during penalisation are not shown in the table.

In Table 4, Model performance metrics for the final LASSO logistic regression model predicting lower limb injury risk in high jump athletes are presented in Table 4. Discrimination was assessed using the area under the receiver operating characteristic curve (AUC) with 95% confidence intervals, while calibration was evaluated using the calibration intercept, slope, and Brier score.

The optimal classification threshold was identified using the Youden index, with a cut-off probability of 0.43 applied to balance sensitivity and specificity. At this threshold, the model achieved a sensitivity of 0.75 and a specificity of 0.71. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), balanced accuracy, and F1 score were derived accordingly. AUC values closer to 1 indicate excellent discrimination, whereas calibration slope values closer to 1 reflect stronger agreement between predicted and observed risks.

Table 2. Correlation of Predictors with Injury Risk

Predictor	Correlation coefficient (r/ρ)	p-value	Units/Definition
Cadence (steps/min)	0.58	0.012	Steps per minute during approach phase
Pelvic obliquity (°)	0.46	0.033	Frontal plane pelvic tilt (degrees)
Pelvic rotation (°)	0.39	0.072	Transverse plane pelvic rotation (degrees)
Muscle activation symmetry (%)	0.55	0.018	% difference in EMG amplitude between limbs
Other joint kinematics	<0.30	>0.05	Standard lower-limb joint angles

Table 3. Final LASSO Logistic Regression Model Predictors of Injury Risk

Predictor	Standardized β	OR (95% CI)	p-value	Units/Definition
Cadence (steps/min)	0.47	1.60 (1.10–2.40)	0.021	Steps per minute during approach phase
Pelvic obliquity (°)	0.39	1.48 (1.05–2.10)	0.033	Frontal plane pelvic tilt (degrees)
Pelvic rotation (°)	0.32	1.36 (0.95–1.95)	0.072	Transverse plane pelvic rotation (degrees)
Muscle activation symmetry (%)	0.51	1.66 (1.12–2.46)	0.018	% difference in EMG amplitude between limbs

Table 4. Predictive Performance of the Final LASSO Model

Metric	Value (95% CI)	Units/Definition
AUC (ROC)	0.78 (0.64–0.92)	Area under the receiver operating characteristic curve
Sensitivity	0.75 (0.51–0.91)	Proportion of injured athletes correctly identified
Specificity	0.71 (0.46–0.89)	Proportion of non-injured athletes correctly identified
Positive predictive value (PPV)	0.69	Probability that predicted "at risk" athletes were truly injured
Negative predictive value (NPV)	0.77	Probability that predicted "no risk" athletes were truly uninjured
Balanced accuracy	0.73	Mean of sensitivity and specificity
F1 score	0.72	Harmonic mean of sensitivity and PPV
Calibration intercept	0.47	Ideal value = 0; reflects systematic under/overestimation
Calibration slope	0.24	Ideal value = 1; <1 indicates overfitting
Brier score	0.21	Mean squared error of predicted probabilities; lower = better calibration

The final LASSO model achieved moderate discriminative performance with an AUC of 0.78 (95% CI: 0.64–0.92), sensitivity of 0.75, and specificity of 0.71. See Fig. 2. Receiver Operating Characteristic (ROC) curve showing the discriminative performance of the final LASSO logistic regression model in predicting lower limb injury risk in high jump athletes.

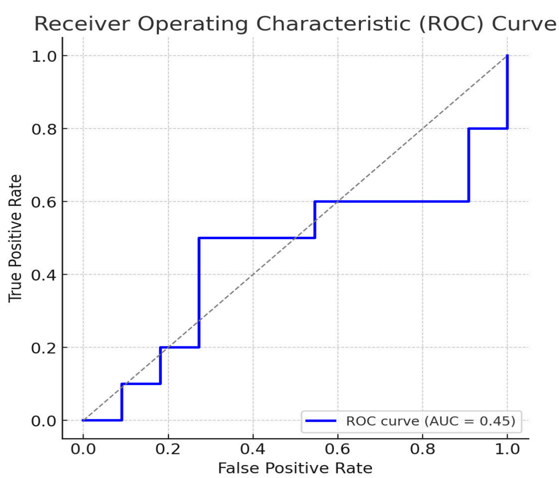

Fig. 2. Receiver Operating Characteristic (ROC) curve for the final LASSO model

The area under the curve (AUC) was 0.78 (95% CI: 0.64–0.92), indicating moderate discrimination. The dashed diagonal represents chance-level classification (AUC = 0.50). Calibration plot of predicted versus observed probabilities for the final LASSO model. The solid blue line shows actual calibration, while the dashed line represents perfect calibration (slope = 1, intercept = 0). The calibration intercept was 0.47 and the slope 0.24, indicating systematic underestimation of true injury probabilities and some degree of overfitting. The Brier score was 0.21, reflecting moderate but suboptimal calibration accuracy. Calibration analysis indicated an intercept of 0.47 and a slope of 0.24, suggesting systematic underestimation of true probabilities. The calibration plot is shown in Figure 2, with a Brier score of 0.21 reflecting fair but suboptimal calibration accuracy.

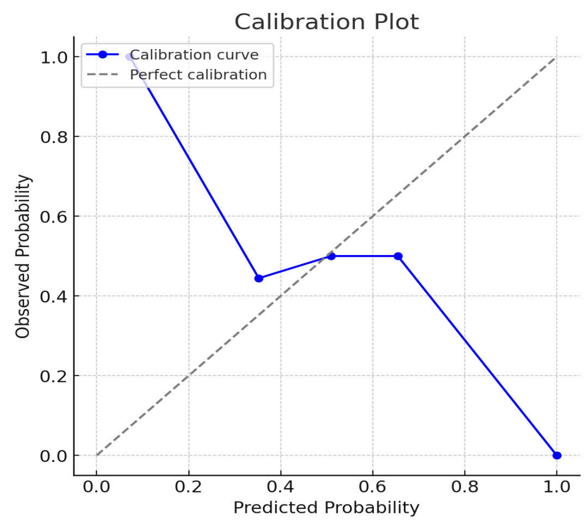

Fig. 3. Calibration plot for the final LASSO model

Discussion

This retrospective observational study identified four biomechanical variables associated with lower limb injury risk in competitive high jump athletes using penalized logistic regression. The final LASSO model retained cadence, pelvic obliquity, pelvic rotation, and muscle activation asymmetry as predictors, achieving moderate discriminative performance (AUC = 0.78). These findings provide empirical evidence supporting the multifactorial nature of injury risk in high jump and highlight sport-specific biomechanical factors that may serve as screening markers and intervention targets.

The strongest predictor in our model was muscle activation asymmetry (OR = 1.66, 95% CI: 1.12–2.46), indicating that greater inter-limb neuromuscular imbalances substantially increase injury risk. Higher asymmetry values reflect greater imbalance between dominant and non-dominant limbs, which has been consistently linked to elevated lower limb injury risk in jumping sports (Hewett et al., 2005; Croisier et al., 2008). Previous systematic reviews reported that nearly 79% of drop jump assessments revealed predictive associations with future injury (Paterno et al., 2010). More recent evidence reinforces these findings, showing that lower-limb asymmetry is consistently associated with increased injury risk, albeit with some variability depending on the measure (Helme et al., 2021; Guan et al., 2022; Fox et al., 2023). Prospective studies confirm that pre-season asymmetry predicts non-contact injuries in elite athletes (Wang et al., 2025). Moreover, asymmetry has also been linked to impaired performance and efficiency, suggesting broader implications for both injury prevention and sport optimization (D'Hondt et al., 2024; Heil, 2022). The asymmetric loading demands of high jump may exacerbate such imbalances, contributing to preferential strain on tissues and long-term overuse risk.

Cadence emerged as the second strongest predictor (OR = 1.60, 95% CI: 1.10–2.40). Interestingly, while running studies report protective effects of higher cadence on joint loading and oxygen cost (Ceyssens et al., 2019; Anderson et al., 2022; Figueiredo et al., 2025), our findings suggest the opposite in high jump. Excessive cadence may indicate compromised approach mechanics, insufficient stride optimization, or poor horizontal-to-vertical momentum transfer (Heiderscheit et al., 2011; Wilson et al., 2007). This highlights the sport-specific biomechanics of high jump, where cadence interacts with stride length and velocity to determine take-off efficiency.

Pelvic obliquity also demonstrated a moderate association with injury risk (OR = 1.48, 95% CI: 1.05–2.10), supporting the hypothesis that compromised lumbopelvic stability predisposes athletes to overloading (Zazulak et al., 2007; Burns et al., 2019). Prior work has shown sex-related differences in pelvic kinematics (Leetun et al., 2004), and more recent evidence confirms the role of pelvic orientation and tilt in determining biomechanical load distribution (Glakousakis et al., 2024; Hegyi et al., 2025). While pelvic rotation showed weaker but clinically relevant associations (OR = 1.36, p = 0.072), excessive transverse plane pelvic motion may reflect neuromuscular deficits or insufficient core stability during the crucial approach-to-take-off transition (Bramah et al., 2018; Bittencourt et al., 2016). The prospective cohort study by Gogoi et al. (2021) similarly identified pelvic kinematic variables (range of obliquity, tilt, and rotation) and limb symmetry as predictors of lower limb injury, reinforcing the present study's findings that pelvic control and neuromuscular asymmetry are critical determinants of injury risk. This external evidence strengthens the validity of our model's retained predictors.

Although the LASSO model showed acceptable discrimination (AUC = 0.78) with balanced sensitivity (0.75) and specificity (0.71), calibration analysis revealed substantial shortcomings. The calibration slope (0.24) and intercept (0.47) indicated systematic underestimation of injury probabilities, reflecting one of the common pitfalls of predictive models in sports medicine (Van Calster et al., 2019). Calibration has been recognized as the "Achilles heel" of prediction modeling (Collins et al., 2024), and our findings align with critiques of overfitting and poor generalizability in small-sample models (Tibshirani, 1996; Bullock et al., 2024). These limitations emphasize the necessity of larger, prospective cohorts and external validation before translation into applied practice.

The practical implications of these findings are significant. Neuromuscular training programs designed to reduce bilateral asymmetry have consistently demonstrated efficacy in lowering injury risk (Meeuwisse et al., 2007; Guan et al., 2022). Similarly, interventions focused on core strengthening and lumbopelvic stabilization may reduce abnormal pelvic kinematics (Leetun et al., 2004; Glakousakis et al., 2024; Hegyi et al., 2025). Screening protocols in high jump could also incorporate cadence analysis to identify maladaptive approach mechanics that elevate loading demands.

At a methodological level, our findings align with emerging literature advocating for integration of advanced statistical and machine learning approaches in sports injury prediction. Musculoskeletal stiffness (MSS) has been highlighted as a strong prospective predictor of overuse injury (Moresi et al., 2012). Similarly, abnormal joint mechanics such as limited ankle dorsiflexion, joint laxity, or foot arch abnormalities contribute to injury susceptibility (Neely, 1998). Jump landing biomechanics remain critical, as video-based analyses of landing control have shown strong predictive validity for injury risk (Sharma et al., 2023). Recent work applying machine learning, including logistic regression, random forests, and AdaBoost, demonstrates how multivariable models can quantify the relative contributions of predictors, thereby refining understanding of injury mechanisms (Dandrieux et al., 2023). Dynamic task analysis, such as drop jumps and sidesteps, further highlights consistent markers like knee abduction angle, suggesting potential for developing risk "passports" for ACL and related injuries (Sharir et al., 2017). These approaches, when combined with penalized logistic regression, may substantially improve the precision and real-world applicability of predictive models in sport.

Several methodological limitations warrant consideration. The retrospective design prevents establishing temporal causality (Claudino et al., 2019). Compensatory movement adaptations following previous injuries may confound observed associations (Paterno et al., 2010). The small sample (n = 21) yields an unfavourable events-per-variable ratio, heightening risk of overfitting and instability (Van Calster et al., 2019). Injury classification was binary, not accounting for severity gradations or recurrent episodes, which may oversimplify complex patterns (Fuller et al., 2006; World Medical Association, 2013). Finally, LOOCV, though suitable for small samples, may inflate predictive performance compared with independent validation (Tibshirani, 1996).

In summary, this study highlights the combined influence of neuromuscular asymmetry, cadence, and pelvic kinematics on injury susceptibility in high jump athletes. Our integrated discussion, supported by both classical and contemporary evidence (2005-2025), suggests that these are modifiable factors with potential value in targeted prevention strategies. However, calibration limitations, retrospective design, and small sample size underscore the urgent need for larger, prospective, and externally validated studies. Integrating biomechanical measures with advanced predictive modeling represents a promising frontier for enhancing injury prevention in technical jumping sports.

Conclusion

This preliminary investigation highlights critical avenues for future research and practical application in injury prevention among high jump athletes. To establish stronger causal links between biomechanical variables and injury occurrence, prospective cohort studies with substantially larger sample sizes are required. External validation across independent datasets is equally important to ensure the robustness and generalizability of predictive models. Future research should expand the biomechanical scope by incorporating three-dimensional joint kinematics during take-off, ground reaction force characteristics, and approach velocity profiles. Examining sex-specific differences, developmental stages, and competitive levels will further enhance model applicability across diverse athletic populations. Additionally, integrating training load, previous injury history, and psychosocial determinants into multifactorial frameworks may improve the accuracy of injury prediction. Advances in wearable technology and real-time biomechanical monitoring hold promise for dynamic risk assessment, offering immediate feedback and facilitating timely intervention strategies. However, widespread implementation will require substantial improvements in model calibration and external validation across varied sporting contexts.

Despite methodological limitations, the present findings provide preliminary guidance for evidence-based prevention strategies in high jump. Regular monitoring of bilateral neuromuscular symmetry through standardized strength assessments or functional movement screens may assist in identifying athletes at heightened risk. Interventions targeting asymmetry such as unilateral strengthening and neuromuscular training offer practical means of mitigating injury susceptibility. Furthermore, pelvic stability and core control should be prioritized as fundamental components of both technical optimization and injury prevention programs. Structured interventions focusing on lumbopelvic control, core strengthening, and movement quality may address the kinematic deviations identified in this study. Nevertheless, validation of these approaches through well-designed randomized controlled trials remains essential before their broad application in athletic populations.

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Conflict of Interest

There is no potential conflict of interest declared by the authors. The authors did not use generative AI tools in data analysis or manuscript writing. All content was produced and verified manually by the research team.

References

Choudhary, P. K., Dubey, S., Rawat, B., Kumar, S., Pratap, B., Bangari, D., Kumar, S., Prasad, S., & Kaunteya, D. S. (2024). Assessing Strength Effort in Pre-Adolescent Girls: Insights into Effort Accuracy at Different Strength Thresholds. *Physical Education Theory and Methodology, 24*(6), 873-880. https://doi.org/10.17309/tmfv.2024.6.03

Choudhary, P. K., & Dubey, S. (2024). Physiological effects of Zumba exercise on male college students: an intervention study. *Physical Education Theory and Methodology, 24*(3), 404-410. https://doi.org/10.17309/tmfv.2024.3.08

Burns, G., Kozloff, K., & Zernicke, R. (2019). Biomechanics of elite performers: Economy and efficiency of movement. *Kinesiology Review, 9*(1), 1-10. https://doi.org/10.1123/kr.2019-0058

Enoki, S., Nagao, M., Ishimatsu, S., Shimizu, T., & Kuramochi, R. (2021). Injuries in collegiate track and field jumping: A 2-year prospective surveillance study. *Orthopaedic Journal of Sports Medicine, 9*(1), 2325967120973397. https://doi.org/10.1177/2325967120973397

Heiderscheit, B. C., Chumanov, E. S., Michalski, M. P., Wille, C. M., & Ryan, M. B. (2011). Effects of step rate manipulation on joint mechanics during running. *Medicine and Science in Sports and Exercise, 43*(2), 296-302. https://doi.org/10.1249/MSS.0b013e3181ebedf4

Wilson, C., Yeadon, M. R., & King, M. A. (2007). Considerations that affect optimised simulation in a running jump for height. *Journal of Biomechanics, 40*(14), 3155-3161. https://doi.org/10.1016/j.jbiomech.2007.03.030

Croisier, J.-L., Ganteaume, S., Binet, J., Genty, M., & Ferret, J.-M. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: A prospective study. *The American Journal of Sports Medicine, 36*(8), 1469-1475. https://doi.org/10.1177/0363546508316764

Leetun, D. T., Ireland, M. L., Willson, J. D., Ballantyne, B. T., & Davis, I. M. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine and Science in Sports and Exercise, 36*(6), 926-934. https://doi.org/10.1249/01.mss.0000128145.75199.c3

Zazulak, B. T., Hewett, T. E., Reeves, N. P., Goldberg, B., & Cholewicki, J. (2007). Deficits in neuromuscular control of the trunk predict knee injury risk: A prospective biomechanical-epidemiologic study. *The American Journal of Sports Medicine, 35*(7), 1123-1130. https://doi.org/10.1177/0363546507301585

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Colosimo, A. J., McLean, S. G., van den Bogert, A. J., Paterno, M. V., & Succop, T. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: A prospective study. *The American Journal of Sports Medicine, 33*(4), 492-501. https://doi.org/10.1177/0363546504269591

Bramah, C., Preece, S. J., Gill, N., & Herrington, L. (2018). Is there a pathological gait associated with common soft tissue running injuries? *The American Journal of Sports Medicine, 46*(12), 3023-3031. https://doi.org/10.1177/0363546518793657

Ceyssens, L., Vanelderen, R., Barton, C., Malliaras, P., & Dingenen, B. (2019). Biomechanical risk factors associated with running-related injuries: A systematic review. *Sports Medicine, 49*(7), 1095-1115. https://doi.org/10.1007/s40279-019-01110-z

Bittencourt, N. F. N., Meeuwisse, W. H., Mendonça, L. D., Nettel-Aguirre, A., Ocarino, J. M., & Fonseca, S. T. (2016). Complex systems approach for sports injuries: Moving from risk factor identification to injury pattern recognition Narrative review and new concept. *British Journal of Sports Medicine, 50*(21), 1309-1314. https://doi.org/10.1136/bjsports-2015-095850

Meeuwisse, W. H., Tyreman, H., Hagel, B., & Emery, C. (2007). A dynamic model of etiology in sport injury: The recursive nature of risk and causation. *Clinical Journal of Sport Medicine, 17*(3), 215-219. https://doi.org/10.1097/JSM.0b013e3180592a48

Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society: Series B (Methodological), 58*(1), 267-288. https://doi.org/10.1111/j.2517-6161.1996.tb02080.x

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA, 310*(20), 2191-2194. https://doi.org/10.1001/jama.2013.281053

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P., & Meeuwisse, W. H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *British Journal of Sports Medicine, 40*(3), 193-201. https://doi.org/10.1136/bjsm.2005.025270

Kadaba, M. P., Ramakrishnan, H. K., & Wootten, M. E. (1990). Measurement of lower extremity kinematics during level walking. *Journal of Orthopaedic Research, 8*(3), 383-392. https://doi.org/10.1002/jor.1100080310

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). John Wiley & Sons.

Robertson, D., Caldwell, G., Hamill, J., Kamen, G., & Whittlesey, S. (2004). Research methods in biomechanics. *Human Kinetics.* https://doi.org/10.5040/9781492595809

Paterno, M. V., Schmitt, L. C., Ford, K. R., Rauh, M. J., Myer, G. D., Huang, B., & Hewett, T. E. (2010). Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. *The American Journal of Sports Medicine, 38*(10), 1968-1978. https://doi.org/10.1177/0363546510376053

Helme, M., Tee, J., Emmonds, S., & Low, C. (2021). Does lower-limb asymmetry increase injury risk in sport? A systematic review. *Physical therapy in sport: official journal of the Association of Chartered Physiotherapists in Sports Medicine,* 49, 204-213. https://doi.org/10.1016/j.ptsp.2021.03.001

Guan, Y., Bredin, S. S. D., Taunton, J., Jiang, Q., Wu, N., & Warburton, D. E. R. (2022). Association between Inter-Limb Asymmetries in Lower-Limb Functional Performance and Sport Injury: A Systematic Review of Prospective Cohort Studies. *Journal of clinical medicine, 11*(2), 360. https://doi.org/10.3390/jcm11020360

Fox, K. T., Pearson, L. T., & Hicks, K. M. (2023). The effect of lower inter-limb asymmetries on athletic performance: A systematic review and meta-analysis. *PloS one, 18*(6), e0286942. https://doi.org/10.1371/journal.pone.0286942

Wang, P., Qin, Z., & Zhang, M. (2025). Association between pre-season lower limb interlimb asymmetry and non-contact lower limb injuries in elite male volleyball players. *Scientific reports, 15*(1), 14481. https://doi.org/10.1038/s41598-025-98158-x

D'Hondt, J., Chapelle, L., Bishop, C. et al. (2024). Association Between Inter-Limb Asymmetry and Determinants of Middle- and Long-distance Running Performance in Healthy Populations: A Systematic Review. *Sports Med - Open,* 10, 127. https://doi.org/10.1186/s40798-024-00790-w

Heil, J. (2022). Load-Induced Changes of Inter-Limb Asymmetries in Dynamic Postural Control in Healthy Subjects. *Frontiers in Human Neuroscience,* 16, 824730. https://doi.org/10.3389/fnhum.2022.824730

Anderson, L. M., Martin, J. F., Barton, C. J., & Bonanno, D. R. (2022). What is the Effect of Changing Running Step Rate on Injury, Performance and Biomechanics? A Systematic Review and Meta-analysis. *Sports medicine - open, 8*(1), 112. https://doi.org/10.1186/s40798-022-00504-0

Figueiredo, I., Reis E Silva, M., & Sousa, J. E. (2025). The Influence of Running Cadence on Biomechanics and Injury Prevention: A Systematic Review. *Cureus, 17*(8), e90322. https://doi.org/10.7759/cureus.90322

Glakousakis, G., Kalatzis, P., & Mandalidis, D. (2024). Exploring 3D Pelvis Orientation: A Cross-Sectional Study in Athletes Engaged in Activities with and without Impact Loading and Non-Athletes. *Journal of functional morphology and kinesiology, 9*(1), 19. https://doi.org/10.3390/jfmk9010019

Hegyi, A., Sarcher, A., Varenne, F., Mornet, A., Cadu, J. P., Carcreff, L., & Lacourpaille, L. (2025). Validating Field Methods to Estimate the Pelvic Tilt in Sprinting and the Relationship between Prior Hamstring Injury and the Pelvic Tilt in Elite Female Soccer Players. *Journal of human kinetics,* 98, 17-28. https://doi.org/10.5114/jhk/194851

Gogoi, H., Rajpoot, Y. S., & Borah, P. (2021). A Prospective Cohort Study to Predict Running-Related Lower Limb Sports Injuries Using Gait Kinematic Parameters. *Physical Education Theory and Methodology, 21*(1), 69-76. https://doi.org/10.17309/tmfv.2021.1.09

Van Calster, B., McLernon, D. J., van Smeden, M., Wynants, L., Steyerberg, E. W., & STRATOS Initiative. (2019). Calibration: The Achilles heel of predictive analytics. *BMC Medicine, 17*(1), 230. https://doi.org/10.1186/s12916-019-1466-7

Collins, G. S., Dhiman, P., Ma, J., Schlussel, M. M., Archer, L., Van Calster, B., Harrell, F. E., Martin, G. P., Moons, K. G. M., Van Smeden, M., Sperrin, M., Bullock, G. S., & Riley, R. D. (2024). Evaluation of clinical prediction models (part 1): from development to external validation. *BMJ,* e074819. https://doi.org/10.1136/bmj-2023-074819

Bullock, G.S., Ward, P., Collins, G.S. et al. (2024). Comment on: Machine Learning for Understanding and Predicting Injuries in Football. *Sports Med - Open,* 10, 84. https://doi.org/10.1186/s40798-024-00745-1

Moresi, M. P., Bradshaw, E. J., Greene, D., & Naughton, G. (2012). Lower limb musculoskeletal stiffness can predict overuse injuries in high level adolecsent female athletes. 1(1), 175. https://ojs.ub.uni-konstanz.de/cpa/article/download/5258/4832

Neely, F. G. (1998). Biomechanical risk factors for exercise-related lower limb injuries. Sports Medicine, 26(6), 395–413. https://doi.org/10.2165/00007256-199826060-00003

Sharma, S., Divakaran, S., Kaya, T., Taber, C., & Raval, M. S. (2023). A Framework for Biomechanical Analysis of Jump Landings for Injury Risk Assessment. *2023 IEEE 28th Pacific Rim International Symposium on Dependable Computing (PRDC),* 327-331. https://doi.org/10.1109/PRDC59308.2023.00052

Dandrieux, P.-E., Tondut, J.-L., Mendiguchia, J., Morin, J.-B., Lahti, J., Ley, C., Edouard, P., & Navarro, L. (2023).

Prédiction des blessures des ischiojambiers en football à l'aide d'apprentissage automatique: étude préliminaire sur 284footballeurs. *Journal De Traumatologie Du Sport, 40*(2), 69-73. https://doi.org/10.1016/j.jts.2023.04.003

Sharir, R., Vanrenterghem, J., Robinson, M. A., & George, K. (2017). What separates an individual at risk of acl injury? a first step towards an acl-risk movement passport. *British Journal of Sports Medicine, 51*(4), 388. https://doi.org/10.1136/BJSPORTS-2016-097372.264

Claudino, J. G., Capanema, D. de O., de Souza, T. V., Serrão, J. C., Machado Pereira, A. C., & Nassis, G. P. (2019). Current approaches to the use of artificial intelligence for injury risk assessment and performance prediction in team sports: A systematic review. *Sports Medicine – Open, 5*(1), 28. https://doi.org/10.1186/s40798-019-0202-3

Визначення біомеханічних факторів ризику травмування нижніх кінцівок у спортсменів зі стрибків у висоту із використанням методу штрафної логістичної регресії

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 4 табл., 3 рис., 41 джерело.

Історія питання. Спортсмени зі стрибків у висоту схильні до значно вищого ризику травмування нижніх кінцівок через повторювані ударні навантаження високої інтенсивності та асиметричне прикладання сили під час етапів розбігу та відштовхування. Незважаючи на біомеханічні вимоги цього виду спорту, лише в обмеженій кількості досліджень вивчалася прогностична цінність комбінованих кінематичних та нервово-м'язових факторів у визначенні спортсменів із підвищеним ризиком травмування опорно-рухового апарату.

Мета дослідження. Мета цього дослідження полягала у визначенні біомеханічних предикторів ризику травмування нижніх кінцівок у конкурентоспроможних спортсменів-чоловіків зі стрибків у висоту із використанням методу штрафної логістичної регресії.

Матеріали та методи. Двадцять один спортсмен чоловічої статі національного рівня зі стрибків у висоту (вік 21.14 ± 2.22 роки; зріст 187.04 ± 5.36 см; маса тіла 74.09 ± 5.04 кг) зазнав процедури із застосуванням технології 3D захоплення рухів, аналізу сили реакції опори та поверхневої електроміографії. До ключових предикторів належали каденція (кроки/хв), нахил таза (°), обертання таза (°) та асиметрія активації м'язів (% різниця в амплітуді ЕМГ між кінцівками). Класифікація травм відповідала консенсусним критеріям Міжнародного олімпійського комітету, причому анамнез травм був підтверджений медичними записами. Після кореляційного аналізу проведено логістичну регресію за методологією LASSO (оператор найменшого абсолютного скорочення та відбору) із перехресним затверджуванням послідовного виключення одного спостереження. Результативність моделі оцінювали за допомогою показника AUC (area under ROC curve — площі, обмеженої ROC-кривою і віссю частки помилкових позитивних класифікацій), чутливості, специфічності, прогностичних значень, показника F1, нахилу калібрування, точки перетину та оцінки Браєра.

Результати. У підсумковій моделі було збережено чотири змінні: каденція (OR = 1.60, p = 0.021), нахил таза (OR = 1.48, p = 0.033), обертання таза (OR = 1.36, p = 0.072) та асиметрія активації м'язів (OR = 1.66, p = 0.018). Модель продемонструвала помірну дискримінативну здатність (AUC = 0.78, 95% ДІ: 0.64–0.92), чутливість 0.75 та специфічність на рівні 0.71. Однак калібрування виявилось субоптимальним (нахил = 0.24, точка перетину = 0.47, оцінка Браєра = 0.21), що вказує на недооцінювання ризику та потенційне перенавчання.

Висновки. Асиметрія м'язової активації, каденція та кінематичні відхилення таза були пов'язані з підвищеним ризиком травмування нижніх кінцівок у спортсменів зі стрибків у висоту. Отримані результати підкреслюють важливість нервово-м'язового балансу та стабільності попереково-тазового відділу хребта при скринінгу травм. Попри наявність попередніх даних про доцільність використання отриманих результатів, невеликий розмір вибірки та обмеження калібрування потребують валідації у більших проспективних когортах перед клінічним застосуванням.

Ключові слова: стрибок у висоту, біомеханіка, прогнозування травм, асиметрія активації м'язів, логістична регресія.

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Original Scientific Article

An Analytical Programmed Tool for Improving the Reliability of the Figure-of-8 Walk Test in Inclusive Physical Education

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Abstract

Objectives. The purpose of the study was to determine the reliability of the Figure-of-8 Walk Test in inclusive physical education using a newly developed analytical programmed tool.

Materials and Methods. The study was conducted at both theoretical and empirical levels. A pedagogical experiment was carried out using the Figure-of-8 Walk Test (F8W). The sample consisted of first-year university students who had sustained war-related injuries, including blast-induced traumatic brain injury (TBI) and blast TBI combined with acoustic trauma.

Results. The findings of the study are implemented in the newly developed analytical programmed tool designed to support the execution of the F8W. Its core component is a wireless autonomous data collection system that integrates an inertial measurement unit (IMU), a sensor system supported by a neural network, a processing unit, and a Portenta H7 controller—providing a combination of technological integration and artificial intelligence.

The IMU was attached to the participant's body during the execution of the F8W. In real time, measurements of acceleration, velocity, and position were transmitted via Bluetooth. As the participant moved along the test course, the sensor system – supported by the neural network and processing unit – recorded detailed movement data and transmitted it to the microcontroller platform. The Portenta H7 platform aggregated the test parameters from the IMU and sensor system with flexible activation and data-buffering capabilities.

The wireless autonomous data collection system processed the output control data while the participant performed the F8W and displayed the information on a PC interface. Statistical verification of the obtained data confirmed that the analytical programmed tool ensures high reliability and validity of F8W measurements. In contrast, traditional recording methods demonstrated low reliability and validity, primarily due to the influence of the human factor.

Conclusions. The study demonstrated that the developed analytical tool for real-time assessment of mobility parameters in students with war-related injuries provides excellent measurement reliability compared to conventional Figure-of-8 Walk Test procedures. The tool offers substantial advantages over traditional methods of manual data recording, enhancing accuracy, objectivity, and reproducibility of F8W performance evaluation.

Keywords: student, war injuries, physical education, inclusion, control, testing, Figure of 8 Walk Test.

Introduction

In a situation of active combat operations on the territory of Ukraine for more than 10 years in a row and the amount of artillery weapons currently in use, which is unprecedented in the history of wars, there is almost no chance for soldiers to avoid injury. However, being in the rear does not protect against war injuries. Along with a large number of military personnel, a significant number of civilians are exposed to shock waves affecting the brain as a result of daily shelling. Most often, the shock wave causes a concussion (Latin: commotio, English: concussion, or equivalent name – mild Traumatic Brain Injury (mTBI) (Romeu-Mejia, Giza & Goldman, 2019), which may be accompanied by complications – blast TBI with acoustic trauma (Weppner, Linsenmeyer & Ide, 2019; Phipps et al., 2020). Such injuries may lead to long-term consequences and significantly complicate life (Denby et al., 2020; Haarbauer-Krupa et al., 2021; Sepehry, Schultz & Mallinson, 2024; Leland et al., 2016).

The war has forced the professional community of higher education institutions to pay additional attention to this problem. In higher education, inclusive physical education helps restore students' impaired functions (Pellerin, Wilson & Haegele, 2022; Lieberman, Houston-Wilson & Grenier, 2024).

In this regard, it should be noted that the level of physical activity is determined by factors that influence the quality of life related to health after injuries (Brittain & Green, 2012; Galeno et al., 2022; Lorenz et al., 2018). Conversely, a lack of physical activity, as claimed (Shirazipour, Aiken & Latimer-Cheung, 2017; Rosa et al., 2025; Jamieson & Wijesundara 2025), poses a significant problem for the health of injured individuals.

Given the above arguments, we position the quality of inclusive physical education in higher education as a factor in effectively overcoming the physical consequences of students' lost functions due to injuries in order to improve their condition, mobility, and quality of life.

Analysis of recent research and publications. Scientists claim that balance and mobility disorders are the most common disorders after mTBI (Alashram, Padua & Annino, 2022; Denby et al., 2020); after blast TBI with acoustic trauma (Shvets, Podolian & Holinko, 2020; Haarbauer-Krupa et al., 2021; Blavt & Gurtova, 2024).

Data from numerous scientific sources (Willingham et al., 2024) indicate that physical activity plays a leading role in the recovery of impaired functions. In particular, it improves balance, mobility, and eliminates unsteadiness after mTBI (Bland, Zampieri & Damiano, 2011), after blast TBI with acoustic trauma (Weppner, Linsenmeyer & Ide, 2019; Phipps et al., 2020; Blavt & Gurtova, 2024).

It is argued (Phipps et al., 2020; Wellons et al., 2022) that the consequences of injuries in terms of impaired coordination, balance, mobility, and gait parameters have certain patterns. However, as researched (Vander Vegt et al., 2022; O'Neil et al., 2019; Romeu-Mejia, Giza & Goldman, 2019), the course of these disorders will be individual.

Research has shown that the impact of inclusive physical education on the recovery process requires objective monitoring (Blavt et al., 2023; Maher, van Rossum & Morley, 2023; Kuntjoro et al., 2024). It has been established (Rosa, 2025; Jamieson & Wijesundara 2025; Xu et al., 2024) that such monitoring provides valuable information and feedback, tracks progress, and contributes to the development and evaluation of future programs

It has been proven that due to the numerous complex and diverse impairments associated with trauma (Romeu-Mejia, Giza & Goldman, 2019; Brassel et al., 2021), it is possible to implement such monitoring by applying innovative technologies (de Miguel-Fernández et al., 2023; Koenig et al., 2023; Chaparro-Cárdenas et al., 2019).

As established (Jones, DeRuyter & Morris, 2020; Jantz, P.B., Davies & Bigler, 2014; Santilli et al., 2025), innovative technologies are a factor in the effectiveness of physical education (Zhong et al., 2025; Xu et al., 2024), the process of recovery, prevention of regression, tracking changes, and ensuring a healthy lifestyle.

Scientific works (Bolatuly Omarov, Zhunusbekov & Aliyev, 2025; Chao, Yi, Min & Long, 2024; Zhong et al., 2025) confirm that the quality of physical education in general, and inclusive physical education in particular (Toto et al., 2024; Li, 2025; Adeleye, Eden & Adeniyi, 2024) is currently determined by the quality of control implemented by the latest tools, including artificial intelligence tools (Zhou et al., 2024; Wu et al., 2025; Vasco Delgado et al., 2025).

The purpose of the study is to establish the reliability of the Figure-Of-8 Walk Test in inclusive physical education using the developed analytical programmable tool.

Materials and Methods

Research Methods

To achieve the set goal, the research was carried out in two stages: theoretical and empirical. The theoretical stage involved the collection of scientific information on the specific research topic in the field of inclusive physical education and innovative technological developments in this area of knowledge. To form the theoretical basis of the study, methods of analysis, synthesis, and generalization were used.

The empirical stage involved the implementation of the research idea using design methods to create a digital tool, a pedagogical experiment at the stage of collecting the necessary data using testing, and mathematical analysis of the data obtained.

Testing was carried out using the Figure of 8 Walk Test (F8W). The choice of F8W for our study was due to the suitability of this test for monitoring walking skills in everyday life (Hess et al., 2010). In addition, the F8W is an easy-to-use tool for monitoring the walking skills of people

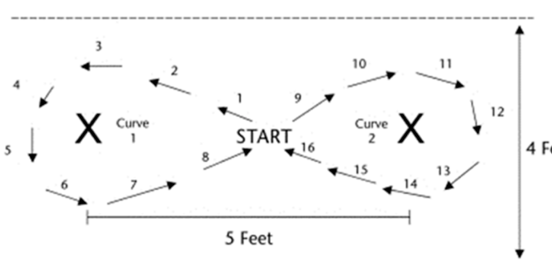

Fig. 1. Scheme of the Figure-of-8 Walk (Hess et al., 2010)

with disabilities, as it correlates with functional mobility, walking speed, and balance (Soke et al., 2023).

The test procedure. The F8WT uses a path where the participant is asked to walk a figure of eight shape around two cones. Scores are recorded in three areas: speed (time for completion), number of steps taken and pace (Figure of 8 Walk Test).

Study Participants

The study involved 28 male students who had suffered war-related injuries and who had enrolled in the first year of study at y Lviv Polytechnic National University, Lviv State University of Physical Culture named after Ivan Boberskyj, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Drohobych Ivan Franko State Pedagogical University, Kamianets-Podilskyi National Ivan Ohiienko University, Lutsk National Technical University.

The students' ages ranged from 18 to 23 years. Criteria for inclusion of students in the study: presence of war-related trauma, written consent to participate in the study. Criteria for exclusion of students from the study: refusal to participate in the study; presence of any concomitant diseases, musculoskeletal, neurological, or cardiopulmonary diseases as a result of trauma, or exacerbation of the consequences of trauma.

All participants in the study sample were involved in the experiment on the basis of anonymity and confidentiality. Voluntary written consent to participate in the testing was obtained.

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

Before the experiment, the participants in the study sample were instructed on the testing conditions. After the experiment, the data obtained were reanalyzed and compared, and a final experimental conclusion was made. The experimental process was implemented as part of a university physical education course. The study was a comparative experiment, in which the experimental factor was the method of recording the test results. In the first case, the recording method required instrumental control using a specially developed tool, and in the second case, a stopwatch was used.

The maximum speed was measured twice, and the average time result was used for analysis. To determine the F8W pace, the number of measured F8W steps was divided by the F8W time.

Statistical Analysis

The analysis of the research results involved the use of mathematical statistics methods. The correlation analysis method was used to measure the strength of the relationship based on the determination of the intraclass correlation coefficient (rtt) (Riemann & Lininger, 2018) and the coefficient of variation (V) between experimental repetitions. The correlation coefficient was used to establish the reliability and validity of F8WT, the results of which were interpreted based on the experimental factor in accordance with the numerical values obtained.

The time taken to cover the F8W distance, the number of F8W steps, and the speed of F8W performance were dependent variables. The significance level was set at $p<0.05$.

Mathematical statistics methods were used to process, analyze, and interpret the experimental data using SPSS Version 22.0 (IBM Corporation).

Results

In conducting the experimental study, we were guided by the thesis that accurate control of balance and gait parameters is the basis for assessing the risk of injury after blast TBI (Sepehry, Schultz & Mallinson, 2024).

The results of our scientific research are presented in a developed analytical programmable tool for implementing F8W. The central element of the developed tool is a wireless autonomous data collection system. The latter is based on an inertial measurement unit, a sensor system with a neural network and a processing unit, and a Portenta H7 controller, which combines the advantages of technological integration and artificial intelligence.

The inertial measurement unit consists of gyroscopes, accelerometers, and inclinometers (Mykytyuk et al., 2024). These components work together to give us a complete understanding of the student's movement over the distance. Using such a unit provides continuous measurements, making them ideal for tracking movement or body segments in space, for calculating position, speed, and orientation over time.

A distinctive feature of the wireless autonomous data collection system is its flexibility to changing operating conditions, which is critical in dynamic environments. This ensured accurate measurements during the student's movement while performing F8W.

The combination of sensors in the inertial measurement unit is implemented at several levels based on artificial intelligence: obtaining data from several sensors, integrating processed data from different sensors, and combining conclusions made by individual sensor systems (Mykytyuk et al., 2021).

The next element of the developed analytical programmable tool for implementing F8W is a system of sensors with a neural network and a processing unit, which are located along the test distance. The sensor system includes acoustic sensors, spatial position sensors, and proximity sensors. Such a system is an intelligent source of information of a new generation, characterized by high accuracy and stability of measurements at any distance and under any conditions.

The new original Portenta H7 controller is one of the latest platforms focused on low power consumption, high computing power, machine learning capabilities, and real-time communication. The Portenta H7 design involves the use of machine learning algorithms and streaming video. A distinctive feature of Portenta H7 is its high performance and computing speed.

The developed analytical programmable tool for F8W implementation is used as follows (fig. 2.). An inertial mea-

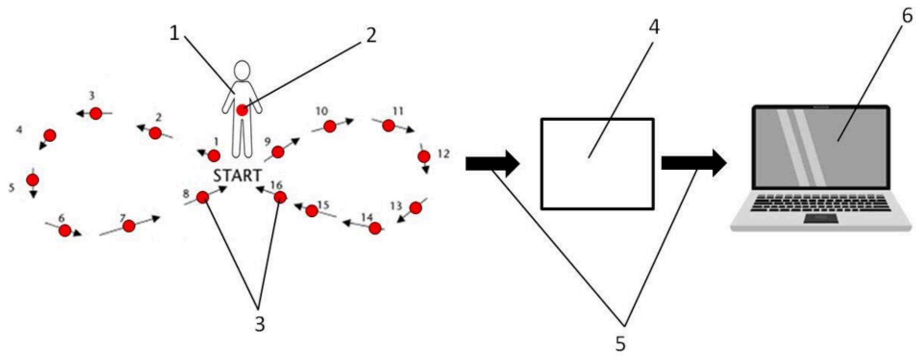

Fig. 2. Scheme of Figure-of-8 Walk implementation using a: 1 – student, 2 – inertial measurement unit, 3 – sensor system, with a neural network and processing unit, 4 – microcontroller platform, 5 – infrared communication lines, 6 – PC

Table 1. Reliability of the of the F8W for students who had suffered war-related injuries (n = 28)

Statistical parameters	Test tasks stepping and measurement results					
	F8WT time (sec)		F8WT steps (number)		Pace (number/sec)	
	T	DT	T	DT	T	DT
M	8.55	8.22	15.7	14.4	1.83	1.75
S	1.31	0.73	2.11	1.92	0.29	0.35
V (%)	29.4	21.7	27.5	20.1	31.0	20.5
			Rtt			
reliability	0.401	0.902	0.352	0.855	0.378	0.885
validity	0.255	0.599	0.227	0.581	0.217	0.613

surement unit is placed on the body of the student performing F8W. In real time, signals measuring the student's acceleration, speed, and position are transmitted via Bluetooth. As the student moves along the distance, the sensor system, with a neural network and processing unit, records information about the student's movement along the distance in real time and transmits it to the microcontroller platform.

The central computing element of the developed device is the Portenta H7 microcontroller platform, which performs the functions of collecting test parameters from the inertial measurement unit and sensor system with flexible activation, data buffering support, wireless transmission, and adaptation to various conditions of use.

The wireless autonomous data collection system, having received the initial control data during the student's performance of the F8W, provides their visualization on the PC screen, auditory feedback through voice outputs, or vibrotactile feedback to the inertial measurement unit.

In the second stage of our research, the developed analytical programmable tool for implementing F8W was tested in practice. The empirical data obtained are presented in Table 1.

According to the data obtained, which underwent statistical verification, the effectiveness of using the analytical programmable tool for implementing F8W is confirmed by the numerical values of the correlation coefficient (Rtt), which were found to be "high" in determining the reliability and validity of F8W.

In contrast, when the results were recorded with a stopwatch, the reliability and validity values of F8W for students who had suffered war injuries were at the «low» and «acceptable» levels.

Discussion

The level of physical activity is determined by factors that determine the quality of life related to the health status of various categories of individuals, such as military personnel (Krushynska, Kohut & Goncharenko 2023; Leland et al., 2016), veterans with disabilities (Brittain & Green, 2012; Caddick & Smith, 2014; Shirazipour, Aiken & Latimer-Cheung, 2017), individuals with blast TBI (Lorenz et al., 2018; Blavt & Gurtova, 2024). In turn, we agree with our own research (Pellerin, Wilson & Haegele, 2022; Kuntjoro et al., 2022; Lieberman, Houston-Wilson & Grenier, 2024) that the quality of inclusive physical education is recognized as a factor in restoring students' health.

Our research is supported by information that innovative technologies currently play an important role in inclusive physical education (Toto et al., 2024; Li, 2025; Adeleye, Eden & Adeniyi, 2024). We agree with the opinion (Alashram, Padua & Annino, 2022; Jamieson & Wijesundara 2025; Chaparro-Cárdenas et al., 2018) that the use of innovative technological tools, in particular AI (Rosa, 2025; Chao, Yi, Min & Long, 2024), has the potential to improve the management of complex injuries and conditions, making it more efficient and effective (Brassel et al., 2021; Pilipović et al., 2025).

According to the results of research (O'Neil et al., 2019; Romeu-Mejia, Giza & Goldman, 2019), the introduction of innovative technologies into the process of restoring bodily functions lost as a result of trauma has been expanded. These technologies make it possible to individualize this process (Farid et al., 2020; Vander Vegt et al., 2022) and objectify functional assessment (Marmor et al., 2022; Santilli et al., 2025; Wellons et al., 2022) based on individual monitoring (Blavt et al., 2023; Jagos et al., 2017; Zhong et al., 2025). Thus, information on vestibular rehabilitation (Galeno et al., 2022; Jantz, Davies & Bigler, 2014; Kalderon et al., 2024) and gait parameter control as a correlator of the vestibular apparatus (Thorman et al., 2022; Wellons et al., 2022; Blavt et al., 2024).

Our study is consistent with information (Willingham et al., 2024; Kalderon et al., 2024) on the formation of research directions that will shape the future of strategies for the precise care of people with disabilities. In particular, AI is emerging as a promising tool for addressing these issues (Rosa, 2025; Jones, DeRuyter & Morris, 2020), including in rehabilitation after TBI (Pilipović et al., 2025).

We support scientific approaches (Jamieson & Wijesundara 2025; Santilli et al., 2024; Zhou et al., 2024) that the dynamic relationship between AI and the health recovery process of people with disabilities continues to evolve, offering future opportunities to increase inclusiveness in physical education for students based on monitoring and assessment data (Wu et al., 2025; Perdomo & González, 2025; Vasco Delgado et al., 2025).

The reliability of F8W has been investigated in populations of older adults (Hess et al., 2010; Coyle et al., 2020; Nualyong & Siriphorn, 2022); adults aged 60–69 years of different gender groups (Jude & Muskaan, 2024); with stroke (Wong, Yam & Ng, 2013; Horata et al., 2025; Kim & Lim, 2012), in neurological disorders (Triolo et al., 2025), with Parkinson's disease (Lowry et al., 2022; Soke et al., 2023); with multiple sclerosis (Fatih et al., 2022; Katirci Kirmaci et al., 2023).

F8W was tested for the first time to monitor the mobility of students who had suffered war-related injuries in inclusive physical education, and an intelligent programmable tool developed for F8W was also used for the first time.

Conclusions

War is usually associated with life-threatening situations, which in turn cause a whole range of injuries to both military and civilian personnel. In the current war with russia, many Ukrainian military and civilians are injured, in particular as a result of blast waves or artillery shells. The war in Ukraine, which has been going on for more than 10 years, despite being a significant and ambiguous layer of history, is a driving force for science.

To ensure the reliability of F8W in inclusive physical education in terms of impartiality and timeliness of control data, an analytical programmable tool has been developed for students who have suffered injuries as a result of the war. The design solution of the analytical programmable tool presented in the work involved the use of an inertial measurement unit and a microcontroller platform using machine learning. We used the combination of sensors in a measuring unit based on artificial intelligence and machine learning as a modern, powerful approach to maximizing the advantages, with the possibility of local execution of algorithms for recognizing student movement patterns during exercise.

The research proved that the developed tool for analyzing the mobility parameters of students who have suffered war injuries in real time is characterized by excellent accuracy and reliability of measurements. The effectiveness of F8W measurement was confirmed based on statistical analysis. At the same time, the low level of reliability and validity of measurements using traditional means has been proven, which is obviously due to the influence of the human factor.

In conclusion, we have grounds to conclude that the introduction of modern technologies into the process of monitoring inclusive physical education of students who have suffered war-related injuries has significant advantages over traditional methods of recording test results.

Conflict of Interest

The author declares no conflict of interest with any other authors or related research findings.

References

Romeu-Mejia, R., Giza, C. C. & Goldman, J. T. (2019). Concussion Pathophysiology and Injury Biomechanics. *Curr Rev Musculoskelet Med,* 12, 105-116. https://doi.org/10.1007/s12178-019-09536-8

Weppner, J., Linsenmeyer, M., & Ide, W. (2019). Military blast-related traumatic brain injury. *Current Physical Medicine and Rehabilitation Reports, 7*(4), 323-332. https://doi.org/10.1007/s40141-019-00241-8

Phipps, H., Mondello, S., Wilson, A., Dittmer, T., Rohde, N. N., Schroeder, P. J., Nichols, J., McGirt, C., Hoffman, J., Tanksley, K., Chohan, M., Heiderman, A, Abou Abbass, H., Kobeissy, F., & Hinds, S. (2020). Characteristics and impact of US military blast-related mild traumatic brain injury: a systematic review. *Frontiers in neurology,* 11, 559318. https://doi.org/10.3389/fneur.2020.559318

Denby, E., Murphy, D., Busuttil, W., Sakel, M., & Wilkinson, D. (2020). Neuropsychiatric outcomes in UK military veterans with mild traumatic brain injury and vestibular dysfunction. *J. Head Trauma Rehabil,* 35, 57-65. https://doi.org/10.1097/HTR.0000000000000468

Haarbauer-Krupa, J., Pugh, M. J., Prager, E. M., Harmon, N., Wolfe, J., & Yaffe, K. (2021). Epidemiology of Chronic Effects of Traumatic Brain Injury. *J Neurotrauma, 38*(23), 3235-3247. https://doi.org/10.1089/neu.2021.0062

Sepehry, A. A., Schultz, I. Z., & Mallinson, A. I. N. (2024). LongridgeChronic Vestibular System Dysfunction After mTBI: Neuropsychology, Neuropsychiatry, Neuroscience and Treatment. *Psychol. Inj. and Law,* 17, 152-173. https://doi.org/10.1007/s12207-024-09506-7

Leland, A., Tavakol, K., Scholton, J., Libin, A. V., & Ryerson, S. (2016). High-level vestibular impairment in a veteran with mild traumatic brain injury. *International Journal of Therapy and Rehabilitation, 23*(2), 91-96

Pellerin, S., Wilson, W. J., & Haegele, J. A. (2022). The experiences of students with disabilities in self-contained physical education. *Sport, Education and Society, 27*(1), 14-26. https://doi.org/10.1080/13573322.2020.1817732

Lieberman, L. J., Houston-Wilson, C., & Grenier, M. (2024). *Strategies for inclusion: Physical education for everyone.* Human Kinetics.

Brittain, I., & Green, S. (2012). Disability sport is going back to its roots: rehabilitation of military personnel receiving sudden traumatic disabilities in the twenty-first century. *Qualitative Research in Sport, Exercise and Health, 4*(2), 244-264. https://doi.org/10.1080/2159676X.2012.685100

Galeno, E., Pullano, E., Mourad, F., Galeoto, G., & Frontani, F. (2022). Effectiveness of Vestibular Rehabilitation after Concussion: A Systematic Review of Randomised Controlled Trial. *Healthcare (Basel),* 28, 11(1), 90. https://doi.org/10.3390/healthcare11010090

Lorenz, L. S., Charrette, A. L., O'Neil-Pirozzi, T. M., Doucett, J., & Fong, J. (2018). Healthy Body, Healthy Mind: A Mixed Methods Study of Outcomes, Barriers and Supports for Exercise by People Who Have Chronic Moderate-to-Severe Acquired Brain Injury. *Disabil. Health J,* 11, 70-78. https://doi.org/10.1016/j.dhjo.2017.08.005

Shirazipour, C. H., Aiken, A. B., & Latimer-Cheung, A. E. (2017). Exploring strategies used to deliver physical activity experiences to Veterans with a physical disability. *Disability and Rehabilitation, 40*(26), 3198-3205. https://doi.org/10.1080/09638288.2017.1377297

Rosa, J. P. P. (2025). The potential role of artificial intelligence to promote the participation and inclusion in physical exercise and sports for people with disabilities: A narrative review. *J Bodyw Mov Ther,* 42, 127-131. https://doi.org/10.1016/j.jbmt.2024.12.024

Jamieson, A. R., & Wijesundara, H. D. (2025). A review of adaptive equipment and technology for exercise and sports activities for people with disabilities. *Disabil Rehabil Assist Technol, 20*(1), 33-45. https://doi.org/10.1080/17483107.2024.2372323

Alashram, A. R., Padua, E., & Annino, G. (2022). Virtual reality for balance and mobility rehabilitation following traumatic brain injury: A systematic review of randomized controlled trials. *J Clin Neurosci,* 105, 115-121. https://doi.org/10.016/j.jocn.2022.09.012

Shvets, A. V., Podolian, Y. V., & Holinko, M. I. (2020). Features of functional state restoration among military personnel after traumatic brain injury combined with acubarotrauma. *Zaporozhye Medical Journal, 22*(3). Available from: http://zmj.zsmu.edu.ua/article/view/20490

Blavt, O., & Gurtova, T. (2024). Physical Education in the Restoration of Damaged Functions in Students After Blast Tbi Complicated By Acuborotrauma. *Journal of Learning Theory and Methodology, 5*(2), 56-63. https://doi.org/10.17309/jltm.2024.5.2.02

Willingham, T. B., Stowell, J., Collier, G., & Backus, D. (2024). Leveraging Emerging Technologies to Expand Accessibility and Improve Precision in Rehabilitation and Exercise for People with Disabilities. *Int J Environ Res Public Health, 10, 21*(1), 79. https://doi.org/10.3390/ijerph21010079

Bland, D. C., Zampieri, C., & Damiano, D. L (2011). Effectiveness of physical therapy for improving gait and balance in individuals with traumatic brain injury: a systematic review. *Brain Inj, 25*(7-8), 664-79. https://doi.org10.3109/02699052.2011.576306

Wellons, R. D., Duhe, S. E., MacDowell, S. G., Hodge, A., Oxborough, S., & Levitzky, E. E. (2022). Estimating the minimal clinically important difference for balance and gait outcome measures in individuals with vestibular disorders. *J Vestib Res, 32*(3), 223-233. https://doi.org/10.3233/VES-201630

Vander Vegt, C. B., Hill-Pearson, C. A., Hershaw, J. N., Loftin, M. C., Bobula, S. A., & Souvignier, A. R. (2022). A Comparison of Generalized and Individualized Vestibular Rehabilitation Therapy in a Military TBI Sample. *J Head Trauma Rehabil, 37*(6), 380-389. https://doi.org/10.1097/HTR.0000000000000777

O'Neil, J., Egan, M., Marshall, S., Bilodeau, M., Pelletier, L., & Sveistrup, H. (2019). Remotely Supervised Home-Based Intensive Exercise Intervention to Improve Balance, Functional Mobility, and Physical Activity in Survivors of Moderate or Severe Traumatic Brain Injury: Protocol for a Mixed Methods Study. *JMIR Res Protoc, 8*(10), e14867. https://doi.org/10.2196/14867

Blavt, O., Iedynak, G., Galamanzhuk, L., Zhygulova, E., Mykhalska, Yu., Khomych, A., & Sovtisik, D. (2023). Test Control of Inclusive Physical Education: Assessment Using the Newest Electronics. *Physical Education Theory and Methodology, 23*(6), 940-946. https://doi.org/10.17309/tmfv.2023.6.17

Maher, A., van Rossum, T., & Morley, D. (2023). Assessing the learning of pupils with special educational needs and disabilities in mainstream school physical education. *British Educational Research Journal, 49*(1), 110-125. https://doi.org/10.1002/berj.3832

Kuntjoro, B. F. T., Soegiyanto, S., Setijono, H., & Suhiharto, S. (2022). Inclusion of students with disability in physical education: analysis of trends and best practices. *AJPESH, 2*(2), 88-94. https://doi.org/10.15294/ajpesh.v2i2.64840

Xu, Y., Peng, J., Jing, F., & Ren, H. (2024). From wearables to performance: how acceptance of Iot devices influences physical education results in college students. *Sci Rep UK,* 14, 23776. https://doi.org/10.1038/s41598-024-75071-3

Brassel, S., Power, E., Campbell, A., Brunner, M., & Togher, L. (2021) Recommendations for the Design and Implementation of Virtual Reality for Acquired Brain Injury Rehabilitation: Systematic Review. *J Med Internet Res, 30, 23*(7), e26344. https://doi.org/10.2196/26344

de Miguel-Fernández, J., Lobo-Prat, J., Prinsen, E., Font-Llagunes, J. M., & Marchal-Crespo, L. (2023). Control strategies used in lower limb exoskeletons for gait rehabilitation after brain injury: a systematic review and analysis of clinical effectiveness. *Journal of neuroengineering and rehabilitation, 20*(1), 23. https://doi.org/10.1186/s12984-023-01144-5

Koenig, A., Omlin, X., Bergmann, Zimmerli, L., Bolliger, M., Müller, F., & Riener, R. (2011). Controlling patient participation during robot-assisted gait training. *J NeuroEngineering Rehabil,* 8, 14. https://doi.org/10.1186/1743-0003-8-14

Chaparro-Cárdenas, S. L., Lozano-Guzmán, A. A., Ramirez-Bautista, J. A., & Hernández-Zavala, A. (2018). A review in gait rehabilitation devices and applied control techniques. *Disability and Rehabilitation: Assistive Technology, 13*(8), 819-834.

Jones, M., De Ruyter, F., & Morris, J. (2020). The Digital Health Revolution and People with Disabilities: Perspective from the United States. *Int J Environ Res Public Health, 7, 17*(2), 381. https://doi.org/10.3390/ijerph17020381

Jantz, P. B., Davies, S. C., & Bigler, E. D. (2014). *Working with Traumatic Brain Injury in Schools: Transition, Assessment,* *and Intervention* (1st ed.). Routledge. https://doi.org/10.4324/9780203080849

Santilli, G., Mangone, M., Agostini, F., Paoloni, M., Bernetti, A., Diko, A.,. & Gimigliano, F. (2024). Evaluation of rehabilitation outcomes in patients with chronic neurological health conditions using a machine learning approach. *Journal of Functional Morphology and Kinesiology, 9*(4), 176. https://doi.org/10.3390/jfmk9040176

Zhong, Q., Jiang, J., Bai, W., Yin, Z., Liao, Z., & Zhong, X. (2025). Application of digital-intelligent technologies in physical education: a systematic review. *Front. Public Health,* 13, 1626603. https://doi.org/10.3389/fpubh.2025.1626603

Bolatuly Omarov, N., Zhunusbekov, Z., & Aliyev, I. (2025). Tecnologías Innovadoras en la Educación Física y su Impacto en el Desarrollo de las Habilidades Motoras de los Estudiantes: Revisión Sistemática de la Literatura. *Retos,* 67, 643-658. https://doi.org/10.47197/retos.v67.113225

Chao, Z., Yi, L., Min, L., & Long, Y. Y. (2024) IoT-Enabled Prediction Model for Health Monitoring of College Students in Sports Using Big Data Analytics and Convolutional Neural Network. *Mobile Netw Appl.* https://doi.org/10.1007/s11036-024-02370-4

Toto, G. A., Marinelli, C. V., Cavioni, V., di Furia, M., Traetta, L., Iuso, S., & Petito, A. (2024). What is the role of Technologies for Inclusive Education? A systematic review. *In International Conference on Higher Education Learning Methodologies and Technologies Online,* 533-565. Springer, Cham. https://doi.org/10.1007/978-3-031-67351-1_36

Li, R. (2025). The Impact of Artificial Intelligence on Inclusive Physical Education in Harbin Universities. *Uniglobal Journal of Social Sciences and Humanities, 4*(2), 116-124. https://doi.org/10.53797/ujssh.v4i2.14.2025

Adeleye, O. O., Eden, C. A., & Adeniyi, I. S. (2024). Innovative teaching methodologies in the era of artificial intelligence: A review of inclusive educational practices. *World Journal of Advanced Engineering Technology and Sciences, 11*(2), 069-079. https://doi.org/10.30574/wjaets.2024.11.2.0091

Zhou, T., Wu, X. L., Wang, Y. D., Wang, Y. L., & Zhang, S. A. (2024). Application of artificial intelligence in physical education: a systematic review. *Educ Inf Technol,* 29, 8203-20. https://doi.org/10.1007/s10639-023-12128-2

Wu, Q., Li, S., Xin, S., Hou, Q., & Li, P. (2025). A study on students' behavioural intention and use behaviour of artificial intelligence-generated content in physical education: Employing an extended the unified theory of acceptance and use of technology model. *Journal of Hospitality, Leisure, Sport & Tourism Education,* 36, 100547. https://doi.org/10.1016/j.jhlste.2025.100547

Vasco Delgado, J. C., Macas Padilla, B. A., Vasco Delgado, L. A., & Vasco Delgado, L. J. (2025). Diseño y validación de un modelo evaluativo de Educación Física mediado por inteligencia artificial. *Retos,* 70, 1446-1460. https://doi.org/10.47197/retos.v70.116530

Hess, R. J., Brach, J. S., Piva, S. R., & VanSwearingen, J. M. (2010). Walking skill can be assessed in older adults: validity of the Figure-of-8 Walk Test. *Phys Ther, 90*(1), 89-99. https://doi.org/10.2522/ptj.20080121

Soke, F., Erkoc Ataoglu, N. E., Ozcan Gulsen, E., Yilmaz, O., Gulsen, C., Kocer, B., Kirteke, F., Basturk, S., Comoglu, S. S., & Tokcaer, A. B. (2023). The psychometric properties of the figure-of-eight walk test in people with Parkinson's disease. *Disabil Rehabil, 45*(2), 301-309. https://doi.org/10.1080/09638288.2022.2028020

Figure of 8 Walk Test. Available from: https://www.physiopedia. com/Figure_of_8_Walk_Test?utm_source=physiopedia&utm_medium=related_articles&utm_campaign=ongoing_internal

Riemann, B. L., & Lininger, M. R. (2018). Statistical Primer for Athletic Trainers: The Essentials of Understanding Measures of Reliability and Minimal Important Change. *J Athl Train, 53*(1), 98-103. https://doi.org/10.4085/1062-6050-503-16

Mykytyuk, Z. M., H. I. Barylo, I. P. Kremer, Y. M. Kachurak & O. Y. Shymchyshyn. (2024). Sensitive liquid crystal composites for optical sensors. *Molecular Crystals and Liquid Crystals 768*(2), 1-8. https://doi.org/10.1080/15421406.2023.223586

Mykytyuk, Z., Vistak, M., Kogut, I., & Petryshak, V. (2021). Highly sensitive active medium of sensor NO2 , based on cholesteric nematic mixture with impurities of carbon nanotubes. *Physics and Chemistry of Solid State, 22*(3), 426-431. https://doi.org/10.15330/pcss.22.3.426-431

Krushynska, N., Kohut, I., & Goncharenko, I. (2023). Impact of physical and sports rehabilitation on the level of physical fitness of combatants. *Slobozhanskyi Herald of Science and Sport. 27*(1), 42-47. https://doi.org/10.15391/snsv.2023-1.006

Caddick, N., & Smith, B. (2014). The impact of sport and physical activity on the well-being of combat veterans: A systematic review. *Psychology of Sport and Exercise, 15*(1), 9-18. https://doi.org/10.1016/j.psychsport.2013.09.011

Pilipović, K., Janković, T., Rajič Bumber, J., Belančić, A., & Mršić-Pelčić, J. (2025). Traumatic Brain Injury: Novel Experimental Approaches and Treatment Possibilities. *Life (Basel), 30, 15*(6), 884. https://doi.org/10.3390/life15060884

Farid, L., Jacobs, D., Do Santos, J., Simon, O., Gracies, J. M., & Hutin, E. (2020). FeetMe Monitor-connected insoles are a valid and reliable alternative for the evaluation of gait speed after stroke. *Topics in Stroke Rehabilitation, 28*(2), 127-134. https://doi.org/10.1080/10749357.2020.1792717

Marmor, M. T., Grimm, B., Hanflik, A. M., Richter, P. H., Sivananthan, S., Yarboro, S, R. & Benedikt J. (2022). Braun Use of Wearable Technology to Measure Activity in Orthopaedic Trauma Patients: A Systematic Review. *JOIO,* 56, 1112-1122. https://doi.org/10.1007/s43465-022-00629-0

Jagos, H., Pils, K., Haller, M., Wassermann, C., Chhatwal, C., Rafolt, D., & Rattay, F. (2017). Mobile gait analysis via eSHOEs instrumented shoe insoles: a pilot study for validation against the gold standard GAITRite. *Journal of Medical Engineering & Technology, 41*(5), 375-386. https://doi.org/10.1080/03091902.2017.1320434

Kalderon, L., Kaplan, A,. Wolfovitz, A., Gimmon, Y., & Levy-Tzedek, S. (2024). Do we really need this robot? Technology requirements for vestibular rehabilitation: Input from patients and clinicians. *International Journal of Human-Computer Studies,* 192. https://doi.org/10.1016/j.ijhcs.2024.103356

Thorman, I., Loyd, B., Clendaniel, R., Dibble, L. & Schubert, M. (2022). The minimal clinically important difference for gait speed in unilateral vestibular hypofunction after vestibular rehabilitation. *Journal of Otology,* 18. https://doi.org/10.1016/j.joto.2022.11.001

Blavt, O., Galamanzhuk, L., Huska, M., Iedynak, G., Pityn, M., Kachurak, Y., Faidevych, V., & Turka, R. (2024). Using Programmable Device Installations to Control Students with Disabilities after Blast Traumatic Brain Injury in 10 Meter Walking Test. *Physical Education Theory and Methodology, 24*(3), 433-441. https://doi.org/10.17309/tmfv.2024.3.12

Perdomo, B., & González, O. A. (2025). Inteligencia artificial en educación superior: revisión integrativa de la literatura. *Cuadernos de Investigación Educativa, 16*(2). https://doi.org/10.18861/cied.2025.16.2.4034

Coyle, P. C., Perera, S., Shuman, V., VanSwearingen, J., & Brach, J. S. (2020). Development and validation of person-centered cut-points for the figure-of-8-walk test of mobility in community-dwelling older adults. *The Journals of Gerontology: Series A, 75*(12), 2404-2411. https:/doi.org/10.1093/gerona/glaa035

Nualyong, T., & Siriphorn, A. (2022). Accuracy of the figure of 8 walk test with and without dual-task to predict falls in older adults. *Journal of Bodywork and Movement Therapies,* 30, 69-75. https://doi.org/10.1016/j.jbmt.2022.02.001

Jude, D., & Muskaan, J. (2024) Establishing normative reference values for figure of eight walk test in adults aged 60–69 years in Mumbai and Navi Mumbai – A cross-sectional study. *Indian J Phys Ther Res,* 6, 164-7. https://doi.org/10.4103/ijptr.ijptr_13_24

Wong, S. S. T., Yam, M. S., & Ng, S. S. M. (2013). The Figure-of-Eight Walk test: reliability and associations with stroke-specific impairments. *Disability and Rehabilitation, 35*(22), 1896-1902. https://doi.org/10.3109/09638288.2013.766274

Horata, E. T., Çakıcı, G. K., Arıkan, Z., Eken, F., Baskan, E., & Erel, S. (2025). Reliability and validity of the single- and dual-task Figure-of-8 Walk tests in stroke patients. *Neurological Research, 47*(7), 637-645. https://doi.org/10.1080/01616412.2025.2495939

Kim, Y. -H. & Lim, J. -H. (2012). The Reliability and Validity of Figure-of-8 Walk Test in Patients with Stroke. *Journal of the Korean Academy of Clinical Electrophysiology,* 10, 29-37. https://doi.org/10.5627/KACE.2012.10.1.029

Triolo, G., Lombardo, R., Ivaldi, D., Quartarone, A., & Lo Buono, V. (2025). An Overview About Figure-of-Eight Walk Test in Neurological Disorders: A Scoping Review. *Neurology International, 17*(7), 112. https://doi.org/10.3390/neurolint17070112

Lowry, K., Woods, T., Malone, A., Krajek, A., Smiley, A., & Van Swearingen, J. (2022). The Figure-of-8 Walk Test used to detect the loss of motor skill in walking among persons with Parkinson's disease. *Physiother Theory Pract, 38*(4), 552-560. https://doi.org/10.1080/09593985.2020.1774948

Fatih, Ö., Özkeskin, M., Ar, E., & Yüceyar, N. (2022). Gait assessment in shaped pathways: The test-retest reliability and concurrent validity of the figure of eight test and L test in multiple sclerosis patients without mobility aids. *Multiple Sclerosis and Related Disorders,* 65, 103998 https://doi.org/10.1016/j.msard.2022.103998

Katirci Kirmaci, Z. I., Adiguzel, H., Erel, S., Inanç, Y, & Tuncel Berktas, D. (2023). The reliability and validity of the Figure of 8 walk test in mildly disabled persons with multiple sclerosis. *Mult Scler Relat Disord,* 69, 104430. https://doi.org/10.1016/j.msard.2022.104430

Аналітичний програмований засіб покращення достовірності тесту ходьби за схемою «вісімка» у інклюзивному фізичному вихованні

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Реферат. Стаття: 9 с., 1 табл., 2 рис., 69 джерел.

Мета дослідження полягала в установлення достовірності тесту ходьби за схемою «Вісімка» у інклюзивному фізичному вихованні з використанням розробленого аналітичного програмного засобу.

Матеріал та методи. Дослідження реалізовано на теоретичному та емпіричному рівні. Педагогічний експеримент передбачав використання тесту ходьби за схемою «Вісімка». Досліджувана вибірка складалась із 28 студентів 1-го курсу після легкої вибухової черепно-мозкової травми та після легкої вибухової черепно-мозкової травми, ускладненою акуборотравмою, які набули травми внаслідок війни.

Результати. Результати нашого наукового пошуку представляємо у розробленому аналітичному програмованому засобі для реалізації тесту ходьби за схемою «Вісімка». Центральним елементом котрого є бездротова автономна система збору даних, яка побудована на базі інерційного вимірювального блоку, системи датчиків з нейромережею, блоку обробки та контролеруPortenta H7 й яка акумулює переваги технологічної інтеграції та штучного інтелекту.

Інерційний вимірювальний блок розміщується на тілі студента, який виконує тест ходьби за схемою «Вісімка». В реальному часі сигнали вимірювання прискорення, швидкості та положення студента з наступною передачею даних через інтерфейс Bluetooth. При пересуванні студента по дистанції, система датчиків, з нейромережею та блоком обробки фіксує інформацію, про переміщення студента по дистанції в реальному часі та передає на мікроконтролерну платформу Portenta H7, яка виконує функції збору інформації з інерційного вимірювального блоку та системи датчиків з гнучкою активацією. Бездротова автономна система збору даних отримавши вихідні дані контролю при виконання студентом тесту, забезпечує їхню візуалізацію на екрані персонального комп'ютера.

Відповідно до отриманих даних, що пройшли статистичну перевірку, ефективність використання аналітичного програмованого засобу для реалізації тесту ходьби за схемою «Вісімка»засвідчено числовими значеннями показників надійності та валідності на рівні «високий» Водночас установлено низький рівень надійності та валідності вимірювань з використанням традиційних засобів внаслідок впливу людського чинника.

Висновки. Реалізованим дослідженням доведено, що розроблений засіб для аналізу параметрів мобільності студентів, які отримали травми внаслідок війни, в режимі реального часу характеризується високим рівнем достовірністі вимірювань з використанням тесту ходьби за схемою «Вісімка» та має значні переваги порівняно з традиційними методами фіксації результатів тестування.

Ключові слова: студент, травми війни, фізичне виховання, інклюзія, контроль, тестування, тест ходьби за схемою «Вісімка», достовірність.

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Original Scientific Article

Development and Validation of an Instrument for Assessing Student's Attitudes Towards the Use of Video-based Media in Physical Educationn

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Abstract

Background. The integration of digital media, particularly video-based technologies, has become an important element of contemporary education. While teachers' attitudes toward digital media are well researched, students' attitudes toward the use of video in physical education remain underexplored. Existing instruments capture only selected components of attitudes and do not fully represent the cognitive, affective, and behavioral structure. Therefore, a validated and comprehensive instrument is needed to assess students' attitudes toward video-based media in PE.

Objectives. To develop, refine, and validate a questionnaire measuring students' attitudes toward the use of video-based media in physical education, based on an extended Technology Acceptance Model (TAM).

Materials and Methods. The initial questionnaire consisted of 33 items covering cognitive, affective, and behavioral attitude components. A sample of 202 eighth-grade students (M = 13.26; SD = 0.54) participated. A series of confirmatory factor analyses (CFA) was conducted to optimize the factor structure. Internal consistency (ω, α), factor loadings, model fit indicators (CFI, RMSEA), and convergent/discriminant validity were evaluated.

Results. The final scale includes 21 items forming a three-component structure: cognitive (ω = .74), affective (ω = .81), and behavioral (ω = .87). The factor model demonstrated acceptable fit (CFI = .82; RMSEA = .10). Significant correlations among subcomponents confirmed convergent validity, while the absence of substantial associations with demographic characteristics supported discriminant validity.

Conclusions. The developed scale is a reliable and valid instrument for comprehensively measuring students' attitudes toward the use of video-based media in physical education. It can be applied in future research on technology acceptance and in designing pedagogical interventions aimed at optimizing the use of video in PE lessons.
Keywords: physical education, video-based media, attitudes, scale validation, Technology Acceptance Model, questionnaire.

Introduction

As it is true for almost every aspect of our everyday life, digital media influences the culture of human motion, play, and sport. Consequently, physical education (PE) lessons that are centered on the daily life of students must strongly consider the use of digital media, particularly since the digitization of schools is now established as a cross-sectional task at an international level (KMK, 2016). This way, educational institutions are addressing their social responsibility of promoting competencies that enable learners to participate responsibly, confidently, and actively in the digitalized world (KMK 2021, p. 6). Whereas media usage increased massively in the last two decades (Rideout & Robb, 2020), the impression that the young generation generally has a positive attitude towards the use of digital media in school and likes to use it for learning purposes may be outdated (Oblinger & Oblinger, 2005). Research has shown that this is a rather superficial view of children's and adolescents' attitudes towards the use of digital media at school, and researchers demand a more nuanced consideration of these interconnections (Jones et al., 2010). Therefore, the examination of media-related attitudes is gaining importance as a prerequisite for empirically testing intended effects in this area. The didactic relevance of students' attitudes towards the use of video-based media in physical education unfolds both in and out of school: From the knowledge of students' attitudes and their genesis, consequences for the didactic staging of the use of video-based media in physical education can be derived. In addition, it has not yet been clarified to what extent the reference to movement in the subject of physical education influences the attitudes of the students, so that the question of subject-specificity and generalizability of their genesis cannot yet be answered on the basis of evidence. Since digital media plays a central role in this extracurricular culture today (e.g., Wendeborn, 2019), the media-related attitudes of students do not only concern media use in school contexts, where the choices are often limited by the lesson design and the framework conditions. In terms of promoting physical activity, findings also indicate that the sports-related media use of young people has an increasing influence on the amount of sports activity (Braumüller & Hartmann-Tews, 2017). In recent years, computer-related attitudes of students have been examined increasingly (e.g., Petko et al., 2018). The results provide evidence that media use in school can positively influence students' attitudes towards digital media. Nevertheless, the findings show that students' attitudes toward media use at school are not as fundamentally positive as previously assumed (Jones et al., 2010). Although previous research shows ambiguous results, it seems that the media-related attitudes of students are a relevant criterion for media use within and outside of school contexts (Al-Qaysi et al., 2020; Granić & Marangunić, 2019) and are therefore the target perspective of media didactic efforts. However, there is a significant research gap concerning the topic of students´ attitudes towards digital media in PE.

Studies on the use of digital media in PE are characterized by a great heterogeneity in the operationalized goals of media use in PE, ranging from physical, social, cognitive to affective goals. However, despite thorough research, we are not aware of any reliable data on the quantity of media use in PE lessons. The connection between digital media and physical goals of physical education, which is probably the most dominant goal level in PE overall, has been researched the most (Jastrow et al., 2022). With regard to the development of physical goals in digitally supported PE, a distinction can be made between two categories: increasing physical activity and developing sport-specific skills (Jastrow et al., 2022). In many cases, it has been shown that increasing physical activity through the use of digital media in PE lessons is often unsuccessful, whereas the development of sport-specific skills with the help of digital media can often be successful under suitable conditions. Feedback and demonstration videos are primarily used, with video feedback being the best researched for motor learning (e.g., Mödinger et al., 2021). The underlying theory is the motor approach, based on the information theory approach, according to which movement representations can be stored centrally and retrieved as needed (Schmidt, 1975). During the learning process, movement representations are reinforced and parameterized (Mödinger et al., 2021). Both forms of video use for motor learning are forms of learning via video modelling. Feedback videos differ from demonstration videos in that they can be described as 'a form of observational learning with the distinction that the observed and the observer, object, and subject, are the same person' (Dowrick, 2012). This form is therefore also referred to as video self-modelling (Casey & Jones, 2011; O'Loughlin et al., 2013). Therefore, the term video-based media includes both feedback and instructional videos and thus distinguishes itself from activity enhancement technologies such as trackers etc. in the context of the physical goals of media use in PE. Based on this, digital media is specified as video-based media in this study.

Attitudes and Attitude Measurement

A key part of the study is the psychological construct of attitude. Attitudes are general evaluations that can refer to oneself, others, or objects and situations (Mummendey & Grau, 2014) and are based on experience. Attitudes consist of a cognitive, an evaluative (affective), and a behavioral component, with an emphasis on the evaluative component of attitude (Rosenberg & Hovland, 1960). In accordance, attitude is defined as a learned tendency to evaluate classes of objects or people 'favorably' or 'unfavorably' as a function of one's beliefs and feelings (Zimbardo & Gerrig 1996, p. 521). In this multidimensional attitude construct, the cognitive component refers to a person's beliefs, thoughts, and knowledge about video-based media in PE (e.g., usability, usefulness). Thus, this dimension refers to cognitive representations of the world that can be true or false, influencing a person's behaviors (Cuéllar, 2022). The evaluative component is often used synonymously with the term "attitude" itself, leading to ambiguities and misinterpretations (Johnson et al., 2022). However, in line with the cognitive (and behavioral) dimension, the affective dimension is only on aspect of the whole construct of the attitude. The evaluative component refers to a person's emotional response or feeling towards the video-based instruction (favorable or unfavorable), reflecting favor or disfavor along an evaluative continuum (Johnson et al., 2022). The behavioral component refers to a person's tendency to act in a certain way towards video-based media (e.g., the actual use of or engagement with video-based digital media). While attitudes are formed through a combination of cognition, emotion, and behavior, and are automatically activated upon exposure to the entity in question (Jain, 2014), they are naturally interrelated (Fishbein & Ajzen, 1977), leading to medium and even high correlations or regression analytic effect sizes (e.g., Farley & Stasson, 2003).

There have been numerous studies on students' attitudes toward PE (e.g., Li et al., 2014; Ntovolis et al., 2015; Subramaniam & Silverman, 2000). Most of these studies focus on the influence of PE-related attitudes and participation in extracurricular sports, with students' attitudes towards media use in PE not playing a role so far. For example, research shows that positive attitudes toward PE can help students create healthy, active lifestyles that extend beyond adolescence (Haible et al., 2019) and into adulthood (Subramaniam & Silverman, 2007). Regarding the changeability of PE-related attitudes, it appears that they can be influenced by meaningful experiences, relationships, and increased self-efficacy (Digelidis et al., 2003).

Attitudes are explicitly measured with subjective measures (semantic differentials or short statements) rated on scales (Hair et al., 2019). These ratings provide information about how people are attuned/disposed with respect to defined topics. However, measurements of attitudes in the context of PE and video-based media use have been conducted rudimentarily and with only a few items (Davis, 1989; Venkatesh et al., 2012). The most popular instrument for assessing students' attitudes toward PE, the SAtPE (Students Attitudes Toward Physical Education Questionaire; Subramaniam & Silverman, 2000), works with a two-component view on attitudes, involving cognitive and evaluative components (usefulness and enjoyment), and includes a total of 20 items (Subramaniam & Silverman, 2000). Thus, it measures only a subset of possible variables that can be assigned to the evaluative or cognitive component and does not consider the behavioral component. It has been used in numerous studies with secondary school students, and an adapted version is available for elementary school students (Phillips & Silverman, 2012). From a psychological perspective, using a more comprehensive questionnaire that covers all components of the attitude construct in more detail is appropriate (Zimbardo & Gerrig, 1996).

Media Related Attitudes

In the context of PE, recently there have been numerous studies on various aspects of digital media, including exemplary studies on the Digital Video Games Approach (Price et al., 2022), the use of digital media in elementary school (Greve et al., 2022), and the motivational effects of digital media on students in PE (Mackenbrock & Kleinert, 2023). However, empirical findings on students' attitudes toward video-based media in PE are lacking, and students' technology-related attitudes and beliefs, as well as their genesis, have not been comprehensively clarified (Petko et al., 2018). However, technology acceptance models (TAM; Davis, 1989; Venkatesh, et al., 2012; Alsharida & Hammond, 2021), developed based on the Theory of Planned Behavior (Fishbein & Ajzen, 1977), suggest that attitudes play a central role in predicting future media-related actions (see Figure 1). Therefore, the study employs the Technology Acceptance Model (TAM), which will be discussed in more detail.

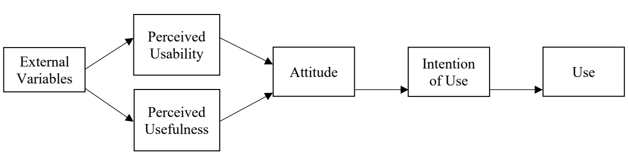

Fig. 1. Technology Acceptance Model (own representation)

The TAM serves as a basis for validating students' attitudes toward the use of video-based media in PE for two reasons: (1) the model outlines that external variables can influence the emergence of attitudes, and (2) the TAM can reflect the three-component structure of the psychological construct of attitudes. According to the TAM, external variables affect the cognitive component of attitudes that are reflected in terms of perceived usability/usefulness in prior TAM versions. This cognitive component affects the evaluative component. Considering general ambiguities regarding the definition of the evaluative component of attitudes discussed above, this evaluative facet is often defined as "attitude" in prior TAM versions. The evaluative component further affects the behavioral component (intention to use and actual use).

However, previous TAMs show inconsistencies, especially regarding the conceptualization and dimensionality of attitudes (e.g., Davis, 1989; Park, 2009). For example, the evaluative component is synonymously referred as "attitude" although this is merely a partial component of the actual attitude. Furthermore, prior research provided little focus on this evaluative component of the attitude, which is only partially addressed in individual studies (Al-Rahmi et al., 2021), although it can be of crucial importance (Rosenberg & Hovland 1960). In the "unified theory of acceptance and use of technology model" developed based on the TAM (e.g., Chao, 2019), not all three components of attitude are explicitly surveyed as well. In particular, the cognitive component is not explicated. Thus, it is difficult to make comprehensive statements about the influence of attitudes on usage behavior. Doubts about the general validity of the model are increasingly expressed, and the necessary adaptations to the respective application context are demanded (Al-Emran & Granic, 2021). Therefore, the TAM was updated in the context of this study to capture students' attitudes toward video-based media use in PE. To do so, additional sub-constructs have to be taken into account and should be explicitly included in the TAM. Every attitude component was enriched by additional sub-constructs in order to holistically assess all relevant aspects of the attitude dimensions. All relevant constructs are thus, described and discussed below.

Relevant Scale Constructs

Attitude components, as well as most sub-constructs, are based on research on attitudinal constructs from a psychological perspective, in addition to previous research regarding the TAM. However, since this study has a strong focus on PE, additional variables need to be considered.

Cognitive Component

First, the cognitive component was divided into "perceived usefulness" and "perceived usability" (obtained from prior TAM versions; e.g., Park, 2009) since perceived usefulness as well as usability served as major influencing variable on intention to use or course acceptance in prior research (e.g., Selim 2003). Further, studies on the media-related attitudes of PE teachers revealed subject-specific characteristics that have to be included as a sub-construct of the cognitive component because they might be relevant for students as well. There is a belief that PE should primarily serve physical activity (motion preference or primacy of movement; Roth, 2022). Consequently, the use of video-based media might disrupt the goals of PE since media reception could leave less time for the activity. In this context, the teacher plays a central role in guiding the focus by means of individual feedback (Mödinger et al., 2021). Consequently, both teachers and students may doubt that video-based instruction is appropriately designed for sport-related instructional purposes because the lack of individual feedback by the teacher cannot be compensated for by feedback options provided by videos. Thus, the variables “motion preference” and “adequate design” were included as well.

Evaluative Component

There was a focus on the evaluative component of the attitude since prior research often neglected this component (e.g., Al-Rahmi et al., 2021). Consequently, the evaluative component was included, and both positive and negative evaluations were considered. Positive evaluation is defined as positive affective attitudes towards video-based media use, negative evaluation is defined as negative affective attitudes. Both variables were considered separately since students might have both, positive affections and negative affective attitudes towards differentiated aspects regarding video use in PE which would be not visible within one single scale (e.g., Cacioppo, 1994). The evaluative component was explicitly included since Park (2009) found that the evaluative component mediated the relationship between the cognitive and behavioral component.

Behavioral Component

The behavioral component encompasses the intended use rather than the actual use. Students do not have autonomy over the use of media, as this is determined by the teachers. Therefore, the students’ perspective is insufficient, given their limited or decision-making power in this context. Consequently, it is crucial to emphasize that the behavioral component can only be considered to a limited extent.

To summarize, the main goal of this study is to develop an instrument that can validly survey the attitudes of students towards the use of video-based media in PE. In this vein, the latent construct of this attitude with its components will be operationalized in order to use this instrument in subsequent studies to, for example, analyse structural relationships between attitude dimensions or to test which variables determine the attitude. An example of how these variables can be included in the TAM is presented in Figure 2.

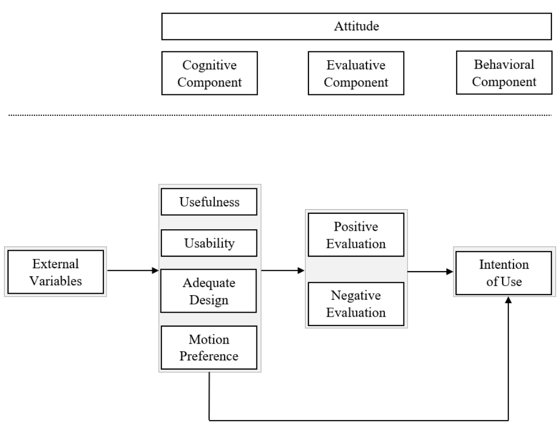

Fig. 2. Adapted Technology Acceptance Model

Materials and Methods

Scale Development

There is evidence that rating scales are useful in recent studies on (general) attitude measurement (e.g., Reschke & Jude, 2022) and can explicitly account for all dimensions through specific item formulation. It must be considered that attitudes may be implicit; however, it is possible that effects of social desirability regarding sensitive topics prevent attitude measurement from being bias-free when using differentials (Garms-Homolová, 2020). Nevertheless, attitudes regarding media use or attitudes toward media content can be considered non-sensitive constructs, which recommend the use and sensitivity of semantic differentials (SD) (Neumann et al., 2018). Since we aimed to measure a specific attitude, attitude toward video-based media use in PE, an appropriate scale was created and validated following recommendations from various methodologists (e.g., DeVellis & Thorpe, 2022).

In the first step, the authors developed 33 items: 17 items for sub-facets of the cognitive component, 8 items for sub-facets of the evaluative component, and 8 items for the behavioral facet (see Appendix A). These items measured the cognitive facet (perceived usefulness, perceived usability, adequate design, motion preference), the evaluative facet (positive and negative evaluation), and the behavioral facet (intention of use). This was preceded by an extensive literature review regarding the TAM. The authors referred to prior literature (e.g., Park, 2009; Natasia et al., 2022) to formulate the items as precisely as possible. Additionally, new items were created to include constructs relevant to PE didactics (i.e., motion preference). In this regard, PE didactic publications with regard to attitudes towards the use of digital media in PE were reviewed (e.g., Roth, 2022) to create adequate items. According to this literature research, each subscale mostly consisted of two to four items, as prior research outlined that constructs could be measured reliably even with a short number of items (Davis, 1989; Venkatesh et al., 2012). Items were adopted and, in some cases, reformulated to reflect the context of video-based media. The term video-based media is not differentiated in the questionnaire with regard to video feedback, so that in addition to video feedback the term also includes other video-based aspects. One example are demonstration videos, which are increasingly finding their way into PE as an alternative to “demonstrating” movements. Each item presented a short statement (e.g., “Videos are not useful for physical education.”). The participants assessed the items based on a 5-point Likert-type scale (1 = fully agree; 2 = tend to agree; 3 = neutral; 4 = tend to disagree; 5 = do not agree at all).

Data Curation

The questionnaire was validated using a sample of secondary school students. This sample has high practical relevance for the research questions to be investigated because these students actively and regularly attend PE classes. Overall, 202 8th-grade students (Mean age = 13.26; Age Standard Deviation = 0.54) participated in the study. Forty-nine percent of the participants were female. Students were recruited from secondary schools in and around the cities of Freiburg and Dortmund. This sample was chosen because scale validation with a confirmatory factor analysis (CFA; Lance & Vandenberg, 2002) requires large sample sizes. In line with recommendations from methodologists (e.g., Koran, 2016), a ratio of 8-11:1 (participants to items) was used to determine the appropriate sample size for the CFA. Since three separate CFAs were conducted (for the cognitive component, the evaluative component, and the behavioral component), a sample size of 202 participants was adequate for CFAs with a maximum of 17 items.

Data were collected using two methods: (1) Since some secondary schools did not have a sufficient internet connection, the questionnaire, including all items, was provided in a paper-pencil format. (2) The questionnaire was also made available digitally using the open-source survey software LimeSurvey. During regular school lessons, students were given either the printed or the digital version of the questionnaire. Prior research outlined mode effects regarding the administration of surveys as paper pencil tests vs. digital tests, most differences emerge in terms of completion or response rate (e.g., Weigold et al., 2019) and in terms of data quality for sensitive or personal questions (e.g., Swartz et al., 2007). However, since teachers were present in order to ensure that every student worked on the questionnaire till the end and since no sensitive questions were asked, we argue that mode effects were negligible for this questionnaire.

Initially, students provided their informal consent for participation and were instructed about the study's purpose. Afterward, demographic data were collected. Before the participants completed the main questionnaire, a sample item was presented to instruct how a rating scale should be used. Subsequently, the participants answered the questionnaire with all 33 items. All instructions are displayed in Appendix B. The entire study took approximately 10-15 minutes. Since questionnaires were presented in a paper-pencil format, some students inadvertently skipped items, for example, by accidentally skipping a page during the study. Overall, data from 16 students were incomplete. Seven participants skipped one or more single items without a systematic pattern and nine participants skipped a page. To avoid excluding these subjects, multiple imputation was conducted (Murray, 2018) to fill in missing data. For this, all available variables were used as predictors, as well as the variables that needed to be imputed. Using a linear imputation model, five iterations were conducted, and the mean values of these iterations were used to fill in the missing values.

Analysis Plan

Four confirmatory factor analyses (CFAs) were performed using maximum likelihood estimation. CFAs were conducted for the cognitive component (four potential factors: perceived usefulness, perceived usability, adequate design, motion preference), the evaluative facet (two potential factors: positive and negative evaluation), and the behavioral component (one-factor model: intention of use). It was assumed that the factors were correlated. Varimax rotation was applied. Based on the results of the factor loadings, items were selected to be included in the final questionnaire for model validation. In general, it is assumed that an item can be deleted due to (1) a poor factor loading (< 0.50; Mertler & Vannatta, 2001), and/or (2) cross-loadings (> 0.40, considering a sample size of around 200; Hair et al., 2009). The Comparative Fit Index (CFI) and the root mean square error of approximation (RMSEA) were reported for each analysis. Values greater than 0.90 are usually interpreted as an acceptable fit and values greater than 0.95 are interpreted as good fit for the CFI (Bentler, 1990). Concerning the RMSEA, the value should not exceed the cut-off 0.10 (Browne and Cudeck, 1992).

After conducting the CFAs, the remaining items of the subscales were examined in terms of reliability. In line with current developments regarding scale development, internal consistency was conducted as reliability score (McDonald's ω; McDonald, 1999, or Cronbach's α; Cronbach, 1951, when only two items remained since ω can only be computed for three or more items).

Finally, an overall CFA was conducted using maximum likelihood estimation to check if the three attitude components (3 factors) are reflected as significant factors with regard to the final items. Again it was assumed that the factors were correlated.

To further investigate validity of the scale, the validity concept of the AERA (2014) was applied. According to the authors, validity is the measure "to which evidence and theory support the interpretation of test scores for proposed uses of tests" (AERA, 2014, p. 11). Thus, validity is not understood as a property of a test, but as a criterion regarding the admissibility of test score interpretations, which in turn depend on the intended use of the test (Hartig et al., 2020). With the test instrument to be developed, we intended to measure the components of the attitude towards the use of video-based media in PE in order to use this instrument in future studies to assess relations between the components and to investigate how relevant variables affect the components. With this goal in mind and following the argumentation-based validity concept of Kane (2013), we aimed to test for construct validity. Since no other (related ort unrelated) scales were implemented, validity can only be investigated exploratory. In this vein, the sub-constructs from all attitude components were correlated to examine convergent validity. Since prior research outlined medium to large correlations between the attitude components (e.g., Farley & Stasson, 2003), correlation analyses aimed to replicate these effects to interpret convergent validity. Discriminant validity was carried out regarding demographic variables: gender, age, type of school. This approach was chosen since prior research outlined that demographic variables like gender and age only marginally correlate with attitudes towards physical education (e.g., Luke & Sinclair, 1991; Lepir et al., 2010) as well as media use in education (e.g., Ramirez-Correa et al., 2015). Thus, it was to be expected that no relevant correlations would occur here ($r < .25$; Greiff et al., 2015) which can be interpreted as support for discriminant validity. However, it has to be mentioned that results regarding secondary students (based on the TAM or not) are rare. The Pearson correlation coefficient was used and interpreted according to the conventions from Senthilnathan (2019; $0 < r < 0.20$: negligible; $0.20 < r < 0.35$: weak but considerable; $0.35 < r < 0.50$: moderate; $0.50 < r < 0.70$: strong; $0.70 < r < 1$: very strong).

The final scale (after item exclusion) with all item characteristics can be found in Table 1.

Table 1. Descriptive values and factor loadings of the items of the confirmatory factor analysis for all attitude components.

Factor/Item	Mean (*SD*) [Difficulty]	Skewness	Kurtosis	Inter-item correlation	Factor loading
Cognitive component					
Factor 1 (usefulness)					
Videos will improve learning in Physical Education classes. (UF2)	3.69 (1.00) [0.74]	-0.43	-0.35	.58	.51
The content of Physical Education classes is unsuitable for video-based teaching. (UF4)	3.82 (1.00) [0.76]	-0.57	-0.34	.58	.98
Factor 2 (usability)					
It's easy to learn how to use videos in Physical Education. (U2)	3.22 (1.03) [0.64]	0.003	-0.47	.70	.63
The use of videos in physical education is complicated. (U3)	3.25 (1.12) [0.65]	-0.16	-0.67	.70	.88
Factor 3 (adequate design)					
I see the most important things better when someone shows them to me than when I watch a video. (AD3)	3.45 (1.12) [0.69]	-0.19	-0.70	.81	.50
I would rather be taught sports by real teachers than by videos. (AD4)	3.51 (1.13) [0.70]	-0.16	-0.87	.69	.85
I think videos are just as good as teachers in providing knowledge in sports. (AD5)	3.09 (1.11) [0.62]	-0.17	-0.45	.80	.55
Teachers can convey information in physical education much better than videos. (AD6)	3.62 (0.97) [0.72]	-0.09	-0.59	.72	.81
Factor 4 (motion preference)					
When we use videos in gym class there is less time for me to move. (MP1)	3.31 (1.17) [0.66]	-0.22	-0.83	.48	.50
I exercise less when I watch videos in gym class. (MP3)	2.91 (1.28) [0.58]	0.10	-1.06	.48	.78
Affective Component					
Factor 1 (positive evaluation)					
I think it's good that videos are used in Physical Education. (PE1)	3.21 (1.21) [0.64]	-0.21	-0.83	.74	.85
Learning things about sports with a video is a good idea. (PE2)	3.41 (1.17) [0.68]	-0.30	-0.66	.71	.77
I don't see anything positive about videos in Physical Education. (PE3)	3.53 (1.17) [0.71]	-0.54	-0.51	.58	.61
Factor 2 (negative evaluation)					
I don't think videos in Physical Education are bad in general. (NE1)	2.55 (1.18) [0.51]	0.46	-0.55	.47	.98
The use of videos in Physical Education does not cause any particular dislike in me. (NE2)	2.42 (1.12) [0.48]	0.35	-0.65	.47	.42
Behavioral Component					
Factor 1 (intention of use)					
I would like to know more about videos in Physical Education. (IU2)	2.91 (1.31) [0.58]	0.05	-1.12	.50	.54
I wonder why I should continue to engage with videos in Physical Education. (IU4)	3.08 (1.32) [0.62]	-0.05	-1.09	.48	.51
I would like to see more videos in Physical Education class. (IU5)	3.07 (1.32) [0.61]	-0.13	-1.07	.76	.84
In the next Physical Education lesson, I would like to see a video. (IU6)	2.84 (1.32) [0.57]	0.09	-1.10	.74	.80
My teacher should not use videos in Physical Education. (IU7)	3.26 (1.31) [0.65]	-0.31	-1.03	.75	.82
I don't want videos to be used in Physical Education. (IU8)	3.34 (1.41) [0.67]	-0.32	-1.19	.74	.80

Results

Cognitive Component

The CFA included 17 items (four for perceived usefulness, four for perceived usability, six for adequate design, and three for motion preference). Bartlett's test of sphericity (Bartlett's $\chi^2(136) = 1385.94$, $p < 0.001$) confirmed the sample fit for factor analysis, CFI = .82, RMSEA = .10. Overall, 49.40% of the variance could be explained considering the factor structure. The entire rotated factor matrix is displayed in Appendix C. The data revealed that the postulated factor structure could not be supported. Consequently, the entire scale was reworked. Eight items were deleted (two items for perceived usefulness, two items for perceived usability, two items for adequate design, and one item for motion preference). In Appendix C, these variables are marked in red. Consequently, these items were removed from the scales. An updated CFA with the remaining 10 items confirmed the sample fit for factor analysis (Bartlett's $\chi^2(45) = 772.86$, $p < 0.001$) with 62.43% of the explained variance, CFI = .97, RMSEA = .06. The entire rotated factor matrix is displayed in Appendix C. Reliabilities of the subscales were satisfactory: $\alpha = .74$ for usefulness, $\alpha = .82$ for usability, $\omega = .82$ for adequate design, and $\alpha = .75$ for motion preference. The inter-item correlations were in acceptable range.

Evaluative Component

The CFA included 8 items (four for positive evaluation, four for negative evaluation). Bartlett's test of sphericity (Bartlett's $\chi^2(28) = 821.85$, $p < 0.001$) confirmed the sample fit for factor analysis, CFI = .91, RMSEA = .14. Overall, 56.05% of the variance could be explained considering the factor structure. The entire rotated factor matrix is displayed in Appendix D. The data revealed that three items (one item for positive evaluation, two items for negative evaluation) did not fit the postulated factor structure. In Appendix D, these variables are marked in red. Consequently, these items were removed from the scales. An updated CFA with the remaining 5 items confirmed the sample fit for factor analysis (Bartlett's $\chi^2(10) = 343.31$, $p < 0.001$) with 62.80% of the explained variance, CFI = 1.00, RMSEA = .00. The entire rotated factor matrix is displayed in Appendix D. Reliabilities of the subscales were satisfactory for positive evaluation: $\omega = .83$. However, it should be noted that reliability for negative evaluation was slightly restricted: $\alpha = .64$. The inter-item correlations were in acceptable range.

Behavioral Component

The CFA included 8 items for intention of use (one-factor structure). Bartlett's test of sphericity (Bartlett's $\chi^2(28) = 837.41$, $p < 0.001$) confirmed the sample fit for factor analysis, CFI = .77, RMSEA = .22. Overall, 46.07% of the variance could be explained considering the factor structure. The unrotated factor matrix is displayed in Appendix E (since no rotation could be conducted for one factor). The data revealed that two items did not fit the postulated factor structure. In Appendix E, these variables are marked in red. Consequently, these items were removed from the scales. An updated CFA with the remaining 6 items confirmed the sample fit for factor analysis (Bartlett's $\chi^2(15) = 600.55$, $p < 0.001$) with 53.51% of the explained variance, CFI = .92, RMSEA = .16. The updated factor matrix is displayed in Appendix E. The reliability of the scale for intention of use was satisfactory: $\omega = .87$. The inter-item correlations were in acceptable range.

Overall CFA

The overall CFA included the remaining 21 items. Bartlett's test of sphericity (Bartlett's $\chi^2(186) = 593.24$, $p < 0.001$) confirmed the sample fit for factor analysis, CFI = .82, RMSEA = .10. Overall, 56.65% of the variance could be explained considering the factor structure. The entire rotated factor matrix is displayed in Appendix F. Overall, the factor loadings were acceptable. Please note that negative factor loadings for motion preference, adequate design and negative evaluation arise since items are formulated inverse in contrast to the other constructs. Reliabilities of the subscales were satisfactory: $\omega = .74$ for the cognitive component, $\omega = .81$ for the evaluative component, and $\omega = .87$ for the behavioral component.

Validation

The correlation matrix is displayed in Appendix G. All correlations reached significance. Within the attitude components, sub-facets correlated with at least considerable effect sizes. For example, perceived usability and usefulness showed a large correlation ($r = 0.52$). Perceived usefulness and usability showed significant negative correlation with design concerns and motion preference ($-0.48 \leq r \leq -0.33$), indicating a fit with theoretical assumptions. Furthermore, there are at least medium effect sizes between the attitude components. High scores on variables in the cognitive component are thus associated with high scores in the evaluative ($|r| \geq 0.34$) as well as behavioral component ($|r| \geq 0.47$). The same pattern could be observed with regard to the correlations between the evaluative and behavioral component ($|r| \geq 0.47$). In summary, convergent validity could be assumed. Discriminant validity could be assumed as well since all correlations between the attitude dimensions and the demographic variables were: $|r| \leq 0.23$.

Discussion

Results have shown that the created scale sufficiently fulfills all relevant quality criteria. All sub-scales exhibited high reliability, with the exception of negative evaluation, which had slightly lower reliability, as will be discussed in the limitations section. These findings indicate a high level of measurement accuracy. The presence of sufficient inter-item correlations further supports this claim.

Regarding the scale's validity, two procedures were adapted. First, factor analyses revealed that consistent sub-facets were defined within attitude components, and these sub-facets individually contributed to each attitude component. Second, exploratory correlation analyses demonstrated that convergent and discriminant validity could be assumed, as significant correlations of considerable sizes were found. However, additional studies need to be conducted to utilize further scales and compare them with the subscales used here in order to strengthen assumptions about validity. With regard to the results this exploratory study, it can be argued that the scale created is reliable and valid for measuring attitudes toward (video-based) media use in PE.

The strength of the scale lies in its multidimensional approach to recording attitudes, bridging the fields of PE didactics and psychology. Furthermore, the sub-facets of the attitude components have been specified and optimized based on research regarding the TAM, psychological research, and concepts from PE didactics. This ensures that the scale is optimally adapted to the didactical context. The results can serve as an encouragement to initiate intervention studies based on the validated scale. The scale has been shown to be reliable and valid, and thus, can be used to further investigated media related attitudes in physical didactics. As discussed, media use, particularly video feedback, holds great instructional potential for motor learning in PE (e.g., Mödinger et al., 2021). Additionally, the attitudes of students towards the use of video-based media in PE should be a relevant focal point.

The educational significance of students' attitudes toward using video-based media in physical education is evident both within and outside the school setting. Insights into these attitudes and their development can inform how video-based media is integrated into physical education lessons. Moreover, the extent to which the movement component in physical education influences students' attitudes remains unclear, leaving open the question of whether these attitudes are specific to the subject or generalizable. The use of the questionnaire can help to make didactic decisions that take into account any existing scepticism about the use of digital media in physical education lessons by students. It also makes it possible to map the extent to which interventions can change attitudes towards the use of video-based media in PE lessons.

Limitations and Future Research

Four methodological limitations need to be discussed. Firstly, the reliability of the negative evaluation scale was relatively low. This might provide an additional explanation for the absence of a connection between negative evaluation and the intention of use. Future research could focus on delve into individual relationships within our model and measure each construct with more items and to reformulate the negative evaluation scale. However, since we aimed to examine the model as a whole, we measured each sub-construct with only a few items to avoid overwhelming the secondary students.

Second, the items were formulated with regard to "video-based" media. We choose this approach to ensure that students could actually have a comparable association, and not just use the abstract term "media", where each student could have their own association of what is meant. Thus, future research could replicate our finding by using different media in the context of PE. Since our items were formulated in a way that the term "video-based" could easily be replaced with another term without changing the wording in general, this might be a promising approach for future research.

Third, no external scales were used to validate the instrument. Validity could thus, only exploratory be analyzed by correlating dimensions of the attitude with each other and with demographic variables. Follow-up studies should build on these exploratory analyses. Future studies should further validate the overall structure of the scale with confirmatory factor analyses and validity should be verified with additional scales related (or unrelated) to the developed scale.

Fourth, the behavioral facet could only be considered to a limited extend since students do not have autonomy over the use of media. Consequently, only the intention of use could be considered. Further studies should foster on additional samples. For example, teachers could be investigated. The scale could therefore, be adapted and an additional sub-scale for the actual use could be integrated.

Conflict of Interest

I declare that I and all Co-Authors have no conflict of interest.

References

KMK [Kultusministerkonferenz] (2016). *Bildung in der digitalen Welt. Strategie der Kultusministerkonferenz.* Berlin: Kultusministerkonferenz

KMK [Kultusministerkonferenz] (2021). *Lehren und Lernen in der digitalen Welt. Ergänzung zur Strategie der Kultusministerkonferenz "Bildung in der digitalen Welt".* Berlin: Kultusministerkonferenz

Rideout, V., & Robb, M.B. (2020). *The Common Sense census: Media use by kids age zero to eight, 2020.* San Francisco, CA: Common Sense Media.

Oblinger, D.G. & Oblinger, J.L. (2005). *Is it age oder IT: First steps toward understanding the net generation.* In D.G. Oblinger & J.L. Oblinger (Ed.), Educating the Net Generation (pp. 2.1-2.20). EDUCAUSE.

Jones, C., Ramanau, R., Cross, S. & Healing, G. (2010). *Net generation or Digital Natives: Is there a distinct new generation entering university?* Computers & Education, 54, (3), 722-732. https://doi.org/10.1016/j.compedu.2009.09.022

Wendeborn, T. (2019). *Digitalisierung als (weiteres) Themenfeld für die Sportpraxis? Status quo einer notwendigen Diskussion.* SportPraxis. Digitale Medien im Sportunterricht. 60, 4-6.

Braumüller, B., & Hartmann-Tews, I. (2017). Jugendliche als mediatisierte Stubenhocker? Eine Analyse der Zusammenhänge zwischen sportlichem und medialem Handeln von Jugendlichen aus Geschlechterperspektive. Diskurs Kindheits- und Jugendforschung / Discourse. *Journal of Childhood and Adolescence Research, 12*(1), 49-70. https://doi.org/10.3224/diskurs.v12i1.05

Petko, D., Cantieni, A., & Prasse, D. (2018). Was beeinflusst die Einstellungen von Schülerinnen und Schülern zum Lernen mit digitalen Medien? Eine Analyse der Befragungen von PISA 2012 in der Schweiz. *Schweizerische Zeitschrift für Bildungswissenschaften, 40* (2018) 2, S. 373-390. https://doi.org/10.24452/sjer.40.2.5066

Al-Qaysi, N., Mohamad-Nordin, N., & Al-Emran, M. (2020). Employing the technology acceptance model in social media: A systematic review. *Education and Information Technologies,* 25, 4961-5002. https://doi.org/10.1007/s10639-020-10197-1

Granić, A., & Marangunić, N. (2019). Technology acceptance model in educational context: A systematic literature review. *British Journal of Educational Technology, 50*(5), 2572-2593. https://doi.org/10.1111/bjet.12864

Jastrow, F., Greve, S., Thumel, M., Diekhoff, H., & Suessenbach, J. (2022). Digital technology in physical education: a systematic review of research from 2009 to 2020. *German Journal of Exercise and Sport Research, 52*(4), 504-528. https://doi.org/10.1007/s12662-022-00848-5

Mödinger, M., Woll, A. & Wagner, I. (2021). Video-based visual feedback to enhance motor learning in physical education-a systematic review. *German Journal of Exercise and Sport Research, 52*(3), 447-460. https://doi.org/10.1007/s12662-021-00782-y

Schmidt, R.A. (1975). A schema theory of discrete motor skill learning. *Psychological review, 82*(4), 225-260. https://doi.org/10.1037/h0076770

Dowrick, P.W. (2012). Self modeling: expanding the theories of learning. *Psychology in the Schools, 49*(1), 30-41. https://doi.org/10.1002/pits.20613

Casey, A., & Jones, B. (2011). Using digital technology to enhance student engagement in physical education. *Asia-Pacifc Journal of Health, Sport and Physical Education, 2*(2), 51-66. https://doi.org/10.1080/18377122.2011.9730351

O'Loughlin, J., Chróinín, D. N., & O'Grady, D. (2013). Digital video: the impact on children's learning experiences in primary physicaleducation. *European Physical Education Review, 19*(2), 165-182. https://doi.org/10.1177/1356336X13486050

Mummendey, H. & Grau, I. (2914). *Die Fragebogenmethode.* Hogrefe.

Rosenberg, M.J. & Hovland, C.I. (1960). *Cognitive, affective, and behavioral components of attitudes*. In Hovland, C.I. & Rosenberg, M.J. (Hrsg.), Attitude organization and change: An analysis of consistency among attitude components, New Haven, CT: Yale University Press, S. 1-14.

Zimbardo & Gerrig (1996). *Psychologie*. (7th ed). Springer.

Cuéllar, L. (2022). *Attitudes and Beliefs*. In: Arsuffi, L. (Ed.) Social Psychology in Forensic Practice, 91-115. https://doi.org/10.4324/9781315560243-5

Johnson, B., Martinez-Berman, L., & Curley, C. (2022, September 15). *Formation of Attitudes: How People (Wittingly or Unwittingly) Develop Their Viewpoints*. Oxford Research Encyclopedia of Psychology. https://doi.org/10.1093/acrefore/9780190236557.013.812

Jain V. (2014). 3D model of attitude. *International Journal of Advanced Research in Management and Social Sciences, 3*(3), 1-12.

Fishbein, M. & Ajzen, I. (1977). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Farley, S.D., & Stasson, M.F. (2003). Relative influences of affect and cognition on behavior: Are feelings more related to blood donation intentions? *Experimental Psychology, 50*(1), 55-62. https://doi.org/10.1027//1618-3169.50.1.55

Li, F., Chen, J., & Baker M. (2014). University students' attitudes toward physical education teaching. *Journal of Teaching in Physical Education, 33*(2), 186-212. https://doi.org/10.1123/jtpe.2012-0187

Ntovolis, Y., Barkoukis, V., Michelinakis, E., & Tsorbatzoudis, H. (2015). An application of the trans-contextual model of motivation in elementary school physical education. *Physical Educator, 72*(5), 123-141. https://doi.org/10.18666/TPE-2015-V72-I5-5111

Subramaniam, P.R., & Silverman, S. (2000). The development and validation of an instrument to assess student attitude toward physical education. *Measurement in Physical Education and Exercise Science, 4*(1), 29-43. https://doi.org/10.1207/S15327841Mpee0401_4

Haible, S., Volk, C., Demetriou, Y., Honer, O., Thiel, A., Trautwein, U., & Sudek, G. (2019). Promotion of physical activity-related health competence in physical education: Study protocol for the GEKOS cluster randomized controlled trial. *BMC Public Health, 19*(396), 1-15. https://doi.org/10.1186/s12889-019-6686-4

Subramaniam, P.R., & Silverman, S. (2007). Middle school students' attitudes toward physical education. *Teaching and Teacher Education, 23*(5), 602-611. https://doi.org/10.1016/j.tate.2007.02.003

Digelidis, N., Papaioannou, A., Laparidis, K., & Christodoulidis, T. (2003). A one-year intervention in 7th grade physical education to change motivational climate and attitudes towards physical education. *Psychology of Sport and Exercise, 4*(3), 195-210. https://doi.org/10.1016/S1469-0292(02)00002-X

Hair, J.F., LDS Gabriel, M., Silva, D.D., & Braga, S. (2019). Development and validation of attitudes measurement scales: fundamental and practical aspects. *RAUSP Management Journal,* 54, 490-507. https://doi.org/10.1108/RAUSP-05-2019-0098

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 19*(2), 319-340.

Venkatesh, V., Thong, J.Y. & Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS quarterly, 36*(1), 157-178. https://doi.org/10.2307/41410412

Alsharida, R., Hammood, M., & Al-Emran, M. (2021). Mobile Learning Adoption: A Systematic Review of the Technology Acceptance Model from 2017 to 2020. *International Journal of Emerging Technologies in Learning (IJET), 16*(5), 147-162. https://doi.org/10.3991/ijet.v16i05.18093

Phillips, S.R., & Silverman, S. (2012). Development of an instrument to assess fourth and fifth grade students' attitudes toward physical education. *Measurement in Physical Education and Exercise Science, 16*(4), 316-327. https://doi.org/10.1080/1091367X.2012.693359

Price, A., Beckey, A., & Collins, D. (2024). Developing a love for playing games: A clarification of why Digital Video Games Approach is not gamification. *Physical Education and Sport Pedagogy, 29*(6), 558-572. https://doi.org/10.1080/17408989.2022.2125946

Greve, S., Thumel, M., Jastrow, F., Krieger, C., Schwedler, A. & Süßenbach, J. (2022) The use of digital media in primary school PE - student perspectives on product-oriented ways of lesson staging. *Physical Education and Sport Pedagogy, 27*(1), 43-58. https://doi.org/10.1080/17408989.2020.1849597

Mackenbrock, J. & Kleinert, J. (2023). Motivational effects of digital media on students in physical education: a scoping review. *Journal of Physical Education and Sport, 23*(8), Art 243, pp. 2115-2126.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 19*(2), 319-340. https://doi.org/10.2307/249008

Park, S.Y. (2009). An Analysis of the Technology Acceptance Model in Understanding University Students' Behavioral Intention to Use e-Learning. *Educational Technology & Society, 12*(3), 150-162.

Al-Rahmi, A.M., Shamsuddin, A., Alturki, U., Aldraiweesh, A., Yusof, F.M., Al-Rahmi, W.M., & Aljeraiwi, A.A. (2021). The influence of information system success and technology acceptance model on social media factors in education. *Sustainability, 13*(14), 7770. https://doi.org/10.3390/su13147770

Rosenberg, M. J. & Hovland, C. I. (1960). *Cognitive, affective, and behavioral components of attitudes.* In Hovland, C. I. & Rosenberg, M. J. (Hrsg.), Attitude organization and change: An analysis of consistency among attitude components, New Haven, CT: Yale University Press, S. 1–14.

Chao C-M (2019). Factors Determining the Behavioral Intention to Use Mobile Learning: An Application and Extension of the UTAUT Model. *Front. Psychol,* 10:1652. https://doi.org/10.3389/fpsyg.2019.01652

Al-Emran, M., & Granić, A. (2021). *Is it still valid or outdated? A bibliometric analysis of the technology acceptance model and its applications from 2010 to 2020.* In Recent advances in technology acceptance models and theories (pp. 1-12). Springer, Cham. https://doi.org/10.1007/978-3-030-64987-6_1

Selim, H.M. (2003). An empirical investigation of student acceptance of course web sites. *Computers & Education,* 40, 343-360. https://doi.org/10.1016/S0360-1315(02)00142-2

Roth, A.-C. (2022). Digitalisierung aus der Sicht von Sportlehrer*innen. Eine Rekonstruktion metaphorischer Konzepte als soziale Deutungsmuster. *Zeitschrift für sportpädagogische Forschung, 10*(2), 183-200. https://doi.org/10.5771/2196-5218-2022-2

Cacioppo, J.T., & Berntson, G.G. (1994). Relationship between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. *Psychological bulletin, 115*(3), 401-423. https://doi.org/10.1037//0033-2909.115.3.401

Reschke, K., & Jude, N. (2022). Implizite Theorien: Messinstrumente in verschiedenen Kontexten. *Zeitschrift für Pädagogische Psychologie,* 1-15. https://doi.org/10.1024/1010-0652/a000341

Garms-Homolová, V. (2020). *Messung von Einstellungen.* In Sozialpsychologie der Einstellungen und Urteilsbildung (pp. 47-59). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-62434-0_4

Neumann, J., Hoffmann, L., & Baumgarten, K. (2018). *Digitalisierung in Bildungseinrichtungen des Handels. Fallstudien als IST-Stands-Analyse im BMBF-Verbundprojekt VOM_Handel.* Dresden: Technische Universität Dresden.

DeVellis, R.F., & Thorpe, C.T. (2022). Scale development: Theory and applications (5th ed.). Sage Publications.

Natasia, S.R., Wiranti, Y.T., & Parastika, A. (2022). Acceptance analysis of NUADU as e-learning platform using the Technology Acceptance Model (TAM) approach. *Procedia Computer Science,* 197, 512-520. https://doi.org/10.1016/j.procs.2021.12.168

Lance, C.E., & Vandenberg, R.J. (2002). *Confirmatory factor analysis.* In F. Drasgow & N. Schmitt (Eds.), Measuring and analyzing behavior in organizations: Advances in measurement and data analysis (pp. 221-254). Jossey-Bass.

Koran, J. (2016). Preliminary proactive sample size determination for confirmatory factor analysis models. *Measurement and Evaluation in Counseling and Development, 49*(4), 296-308. https://doi.org/10.1177/0748175616664012

Weigold, A., Weigold, I.K., & Natera, S.N. (2019). Response rates for surveys completed with paper-and-pencil and computers: using meta-analysis to assess equivalence. *Social Science Computer Review, 37*(5), 649-668. https://doi.org/10.1177/0894439318783435

Swartz, R.J., De Moor, C., Cook, K.F., Fouladi, R.T., Basen-Engquist, K., Eng, C., & Carmack Taylor, C.L. (2007). Mode effects in the center for epidemiologic studies depression (CES-D) scale: personal digital assistant vs. paper and pencil administration. *Quality of Life Research,* 16, 803-813. https://doi.org/10.1007/s11136-006-9158-0

Murray, J.S. (2018). Multiple imputation: a review of practical and theoretical findings. *Statistical Science,* 33, 142-159. https://doi.org/10.1214/18-STS644

Mertler, C.A., & Vannatta, R.A. (2001). *Advanced and multivariate statistical methods: Practical applications and interpretation.* Pyrczak Publishing.

Hair, J.F., Black, W.C., Babin, B.J., & Anderson, R.E. (2009). *Multivariate Data Analysis.* 7th Edition. Pearson Prentice Hall

Bentler, P.M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin,* 107, 238-246. https://doi.org/10.1037//0033-2909.107.2.238

Browne, M.W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research,* 21, 230-258. https://doi.org/10.1177/0049124192021002005

McDonald, R.P. (1999). *Test theory: A unified treatment.* Erlbaum.

Cronbach, L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297-334. https://doi.org/10.1007/BF02310555

American Educational Research Association (AERA), American Psychological Association (APA) & National Council on Measurement in Education (NCME). (2014). *Standards for Educational and Psychological Testing.* Washington, DC: American Psychological Association.

Hartig, J., Frey, A. & Jude, N. (2020). *Validität von Testwertinterpretationen.* In H. Moosbrugger & A. Kelava (Hrsg.), Testtheorie und Fragebogenkonstruktion (S. 529-544). Heidelberg: Springer Berlin. https://doi.org/10.1007/978-3-662-61532-4_21

Kane, M.T. (2013). Validating the interpretations and uses of test scores. *Journal of Educational Measurement,* 50, 1-73. https://doi.org/10.1111/jedm.12000

Luke, M.D., & Sinclair, G.D. (1991). Gender differences in adolescents' attitudes toward school physical education. *Journal of Teaching in physical Education, 11*(1), 31-46. https://doi.org/10.1123/jtpe.11.1.31

Ramírez-Correa, P. E., Arenas-Gaitán, J., & Rondán-Cataluña, F. J. (2015). Gender and acceptance of e-learning: a multi-group analysis based on a structural equation model among college students in Chile and Spain. *PloS one, 10*(10), e0140460. https://doi.org/10.1371/journal.pone.0140460

Greiff, S., Stadler, M., Sonnleitner, P., Wolff, C., & Martin, R. (2015). Sometimes less is more. Comparing the validity of complex problem solving measures. *Intelligence,* 50, 100-113. https://doi.org/10.1016/j.intell.2015.02.007

Appendix A: Original Questionnaire with 33 Items

Code	Original Item	Translated Item
Cognitive component: usefulness		
UF1	Videos sind nicht nützlich für den Sportunterricht.	Videos are not useful for Physical Education.
UF2	Videos werden den Lernerfolg im Sportunterricht verbessern.	Videos will improve learning in Physical Education classes.
UF3	Videos machen es einfacher, die Inhalte des Sportunterrichts zu lernen.	Videos make it easier to learn the content of Physical Education.
UF4	Die Inhalte des Sportunterrichts sind für videobasierte Lehre ungeeignet.	The content of Physical Education classes is unsuitable for video-based teaching.
Cognitive component: usability		
U1	Videos sind im Sportunterricht einfach zu nutzen.	Videos are easy to use in Physical Education classes.
U2	Es ist leicht zu lernen, wie man Videos im Sportunterricht nutzt.	It's easy to learn how to use videos in Physical Education.
U3	Die Bedienung von Videos im Sportunterricht ist kompliziert.	The use of videos in Physical Education is complicated.
U4	Man kann schnell lernen, wie man Videos im Sportunterricht nutzt.	You can quickly learn how to use videos in Physical Education.
Cognitive component: adequate design		
AD1	Auf Videos kann ich wichtige Aspekte des Unterrichts möglicherweise nicht erkennen.	I may not be able to see important aspects of the lesson on videos.
AD2	Die Gestaltung von Videos für den Sportunterricht stelle ich mir schwierig vor.	I consider the design of videos for Physical Education to be difficult.
AD3	Ich sehe die wichtigsten Sachen besser, wenn sie mir jemand zeigt, als wenn ich ein Video schaue.	I see the most important things better when someone shows them to me than when I watch a video.
AD4	Ich möchte lieber von echten Lehrer*innen, als von Videos im Sport unterrichtet werden.	I would rather be taught sports by real teachers than by videos.
AD5	Ich finde Videos genau so gut wie Lehrer*innen bei der Wissensvermittlung im Sport.	I think videos are just as good as teachers in providing knowledge in sports.
AD6	Lehrer*innen können im Sportunterricht deutlich besser Informationen vermitteln, als Videos.	Teachers can convey information in Physical Education much better than videos.
Cognitive component: motion preference		
MP1	Wenn wir Videos im Sportunterricht nutzen bleibt mir weniger Zeit, mich selbst zu bewegen.	When we use videos in Physical Education there is less time for me to move.
MP2	Videos im Sportunterricht sorgen dafür, dass ich mich auch selbst mehr bewege.	Videos in Physical Education make me move more.
MP3	Ich treibe weniger Sport, wenn ich mir Videos im Sportunterricht ansehe.	I exercise less when I watch videos in Physical Education.
Evaluative component: positive evaluation		
PE1	Ich finde es gut, dass Videos im Sportunterricht eingesetzt werden.	I think it's good that videos are used in Physical Education.
PE2	Mit einem Video Sachen über Sport zu lernen ist eine gute Idee.	Learning things about sports with a video is a good idea.
PE3	Ich kann den Videos im Sportunterricht nichts Positives abgewinnen.	I don't see anything positive about videos in Physical Education.
PE4	Ich bin mir nicht sicher, ob ich den Videos im Sportunterricht gegenüber positiv gestimmt bin.	I'm not sure I'm positive about the videos in Physical Education class.
Evaluative component: negative evaluation		
NE1	Ich finde Videos im Sportunterricht nicht prinzipiell schlecht.	I don't think videos in Physical Education are bad in general.

Appendix A (continued). Original Questionnaire with 33 Items

Code	Original Item	Translated Item
NE2	Der Einsatz von Videos im Sportunterricht ruft bei mir keine besondere Abneigung hervor.	The use of videos in Physical Education does not cause any particular dislike in me.
NE3	Ich finde Videos im Sportunterricht nicht gut.	I don't think videos are good in Physical Education class.
NE4	Ich bin dem Einsatz von Videos im Sportunterricht gegenüber negativ gestimmt.	I am negative about the use of videos in Physical Education.
Behavioral component: intention of use		
IU1	Ich möchte mich gerne zum Videoeinsatz im Sportunterricht informieren.	I would like to get information about the use of video in Physical Education.
IU2	Zu Videos im Sportunterricht würde ich gern mehr wissen.	I would like to know more about videos in Physical Education.
IU3	Ich fände es nicht interessant mich weiter mit Videos im Sportunterricht zu beschäftigen.	I would not find it interesting to continue dealing with videos in Physical Education.
IU4	Ich frage mich, warum ich mich weiter mit Videos im Sportunterricht beschäftigen sollte.	I wonder why I should continue to engage with videos in Physical Education.
IU5	Ich möchte mehr Videos im Sportunterricht sehen.	I would like to see more videos in Physical Education class.
IU6	In der nächsten Sportstunde möchte ich ein Video sehen.	In the next Physical Education lesson, I would like to see a video.
IU7	Meine Lehrer*in sollte keine Videos im Sportunterricht einsetzen.	My teacher should not use videos in Physical Education.
IU8	Ich will nicht, dass Videos im Sportunterricht eingesetzt werden.	I don't want videos to be used in Physical Education.

Appendix B: Overview about all instructions

"Students' Attitudes Towards the Use of Video-Based Digital Media in Physical Education (EdiSU)"

With the ongoing process of digitalization, digital teaching and learning resources are becoming increasingly important. This applies not only to classroom lessons but also to physical education. Videos, in particular, are often used in physical education. With this survey, we aim to find out what your attitudes are towards the use of video-based digital media in physical education. The survey will take approximately 15 minutes. In addition to information about yourself (e.g., gender and age), we will ask about your attitudes towards the use of video-based digital media in physical education. The results will be evaluated completely anonymously, meaning that your responses cannot be traced back to you. The questionnaires you fill out will only be processed by us as project staff and will not be published later. Some of the questions may seem very similar or identical at times. This is because we need to determine which wording is best suited for our study. Therefore, please try to answer all the questions.

Thank you very much for your cooperation!

Information About You

What gender do you identify with?
How old are you?
Which grade are you in?
What type of school do you attend?
What is the name of your school?
Do you have any special educational needs?
If yes, which?

Filling in the Questionnaire

You are about to read several statements. Please assess to what extent these statements apply to you personally. There are no right or wrong answers. Simply follow your first impression as you read the statements. You will rate the statements on a scale that ranges from 'Strongly agree' to 'Strongly disagree.' Just mark the option that applies to you.

Here is an example:

Stimme voll und ganz zu	Stimme eher zu	teils / teils	Stimme eher nicht zu	Stimme überhaupt nicht zu
☐	☐	☐	☐	☐

I like eating pizza.

If you fully agree with the statement 'I like eating pizza,' then mark 'Fully agree.' If you mostly like eating pizza, then mark 'tend to agree.' If you like eating pizza sometimes and sometimes not, then mark 'Neutral,' and so on.

Again, there are no right or wrong answers; just follow your first impression. Please mark your choices clearly. If you need to make a correction, fill in the box with the incorrect mark completely, and place your mark in another box.

You can now turn the page and start the questionnaire.

Appendix C: Rotated Factor Loadings of the CFA for the Cognitive Component

Before Item Exclusion				
	Factors			
	1	2	3	4
UF1	.385	-.133	.484	-.395
UF2	.642	-.150	.254	-.162
UF3	.552	-.139	-.104	-.268
UF4	.755	.001	.234	-.089
U1	-.263	.170	-.184	.395
U2	.356	-.156	.750	-.077
U3	.295	-.181	.707	-.280
U4	.375	-.159	.231	-.126
AD1	-.449	.336	-.190	-.011
AD2	-.510	.247	-.111	.203
AD3	-.265	.502	-.108	.213
AD4	-.209	.807	-.230	.124
AD5	-.075	.514	-.363	.191
AD6	-.173	.798	-.093	.209
MP1	-.147	.287	-.200	.532
MP2	.024	.312	-.462	.127
MP3	-.147	.127	-.121	.709

Extraction: Maximum Likelihood; Rotation: Varimax with Kaiser-Normalization

After Item Exclusion				
	Factors			
	1	2	3	4
UF2	-.239	.289	.511	-.161
UF4	-.064	.181	.976	-.100
U2	-.246	.629	.341	-.089
U3	-.226	.882	.184	-.245
AD3	.502	-.165	-.150	.223
AD4	.850	-.176	-.136	.126
AD5	.545	-.279	-.067	.158
AD6	.812	-.081	-.075	.160
MP1	.328	-.137	-.165	.504
MP3	.155	-.143	-.076	.783

Extraction: Maximum Likelihood; Rotation: Varimax with Kaiser-Normalization

Appendix D: Rotated Factor Loadings of the CFA for the Evaluative Component

Before Item Exclusion		
	Factors	
	1	2
PE1	.672	-.485
PE2	.597	-.544
PE3	.763	-.148
PE4	.462	-.176
NE1	-.176	.664
NE2	-.208	.545
NE3	-.834	.296
NE4	-.739	.396

Extraction: Maximum Likelihood; Rotation: Varimax with Kaiser-Normalization

After Item Exclusion		
	Factors	
	1	2
PE1	.851	-.265
PE2	.769	-.304
PE3	.610	-.145
NE1	-.186	.982
NE2	-.300	.422

Extraction: Maximum Likelihood; Rotation: Varimax with Kaiser-Normalization

Appendix E: Factor Loadings of the CFA for the Behavioral Component

Before Item Exclusion	
	Factor
	1
IU1	.483
IU2	.580
IU3	.478
IU4	.518
IU5	.839
IU6	.785
IU7	.815
IU8	.797

Extraction: Maximum Likelihood

After Item Exclusion	
	Factor
	1
IU2	.543
IU4	.513
IU5	.841
IU6	.797
IU7	.816
IU8	.801

Extraction: Maximum Likelihood

Appendix F: Factor Loadings for the Overall CFA

Factor		Loading	SE	z-value	p	95% Confidence Intervall Lower	Upper
Factor 1	UF2	0.550	0.068	8.149	< .001	0.418	0.682
	UF4	0.500	0.069	7.237	< .001	0.365	0.635
	U2	0.698	0.066	10.596	< .001	0.569	0.828
	U3	0.802	0.071	11.376	< .001	0.664	0.940
	AD3	-0.596	0.076	-7.804	< .001	-0.745	-0.446
	AD4	-0.780	0.073	-10.682	< .001	-0.924	-0.637
	AD5	-0.664	0.073	-9.053	< .001	-0.807	-0.520
	AD6	-0.610	0.065	-9.444	< .001	-0.737	-0.484
	MP1	-0.666	0.079	-8.472	< .001	-0.820	-0.512
	MP3	-0.599	0.088	-6.772	< .001	-0.772	-0.425
Factor 2	PE1	1.031	0.070	14.786	< .001	0.895	1.168
	PE2	1.014	0.066	15.324	< .001	0.885	1.144
	PE3	0.696	0.077	9.020	< .001	0.545	0.847
	NE1	-0.602	0.080	-7.556	< .001	-0.758	-0.446
	NE2	-0.491	0.077	-6.340	< .001	-0.642	-0.339
Factor 3	IU2	0.681	0.089	7.677	< .001	0.507	0.855
	IU4	0.703	0.089	7.939	< .001	0.529	0.876
	IU5	1.105	0.076	14.462	< .001	0.955	1.255
	IU6	1.029	0.079	12.956	< .001	0.873	1.184
	IU7	1.056	0.078	13.539	< .001	0.903	1.209
	IU8	1.161	0.083	14.013	< .001	0.999	1.324

Appendix G: Correlation matrix for all attitude components and sub-facets

		cognitive component				affective component		behavioral component
		usefulness	usability	adequate design	movement preference	positive evaluation	negative evaluation	intention of use
cognitive component	usefulness	-	.52*	-.33*	-.32*	.53*	-.37*	.47*
	usability		-	-.48*	-.39*	.65*	-.40*	.66*
	adequate design			-	.45*	-.65*	-.40*	.66*
	movement preference				-	-.55*	.34*	-.50*
affective component	positive evaluation					-	-.48*	.79*
	negative evaluation						-	-.47*
behavioral component	intention of use							-

Pearson correlation coefficients are displayed; *p < .05

		sex	age	type of school
cognitive component	usefulness	-.13	.01	-.23*
	usability	-.13	.01	-.08
	adequate design	.15*	.02	.01
	movement preference	.03	.06	.07
affective component	positive evaluation	-.06	-.02	-.09
	negative evaluation	.16*	-.03	.20*
behavioral component	intention of use	-.14*	-.03	-.12

Pearson correlation coefficients are displayed; *p < .05

Розроблення та валідизація інструменту для оцінювання ставлення учнів до використання відео-базованих медіа у фізичному вихованні

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 15 с., 1 табл., 2 рис., 70 джерел.

Історія питання. Використання цифрових медіа, зокрема відео-базованих технологій, стає важливою складовою сучасного освітнього процесу. Хоча ставлення вчителів до цифрових технологій активно досліджується, ставлення учнів до застосування відео у фізичному вихованні залишається малодослідженим. Наявні інструменти оцінювання охоплюють лише окремі компоненти ставлення та не відображають повністю когнітивний, емоційний і поведінковий аспекти. Це створює потребу у валідованому вимірювальному інструменті, який відображав би комплексну структуру ставлення учнів до відео-базованих медіа.

Мета. Розробити, удосконалити та валідизувати опитувальник для оцінювання ставлення учнів до використання відео-базованих медіа на уроках фізичної культури, базуючись на розширеній моделі прийняття технологій (TAM).

Матеріали і методи. Початкову версію опитувальника складали 33 пункти, що охоплювали когнітивний, афективний і поведінковий компоненти ставлення. У дослідженні взяли участь 202 учні 8-х класів (M = 13.26; SD = 0.54). Було проведено серію підтверджувальних факторних аналізів (CFA) для оптимізації структури інструмента. Оцінювали внутрішню узгодженість підшкал (ω, α), факторні навантаження, відповідність моделей критеріям CFI та RMSEA, а також конвергентну й дискримінантну валідність.

Результати. Після оптимізації інструмент включає 21 пункт, що формують трикомпонентну структуру: когнітивний (ω = .74), афективний (ω = .81) та поведінковий (ω = .87) компоненти. Показники факторної моделі свідчать про прийнятну відповідність даним (CFI = .82; RMSEA = .10). Виявлено значущі кореляції між субкомпонентами ставлення (конвергентна валідність) та відсутність значущих зв'язків із демографічними характеристиками (дискримінантна валідність).

Висновки. Розроблений інструмент є надійним і валідним засобом для комплексного вимірювання ставлення учнів до використання відео-базованих медіа на уроках фізичної культури. Він може бути використаний для подальших досліджень прийняття технологій та для планування педагогічних інтервенцій, спрямованих на оптимізацію використання відео в освітньому процесі.

Ключові слова: фізична культура, відео-базовані медіа, ставлення, валідизація шкали, модель прийняття технологій, опитувальник.

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Original Scientific Article

The Development and Validation of a Low-Cost Timing Gate Prototype as an Alternative to a Stopwatch in Agility Testing

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Abstract

Background. Agility, defined as the physical attribute that enables individuals to swiftly alter their direction, is assessed through various tests, including body type assessments and sport-specific evaluations. It encompasses rapid alterations in the entire body, movements, and limb orientation. Agility plays a pivotal role in sports such as basketball, soccer, and racquetball, where prompt directional changes and precise body control are indispensable. Notably, the 505 test stands as the most reliable agility test, exhibiting a correlation with acceleration but not with speed. It monitors both speed and agility development. However, the prohibitive cost and accessibility challenges associated with the timing gate technology in Indonesia restrict its widespread application. Consequently, local sports practitioners continue to employ conventional stopwatches for their assessments.

Objectives. The objective of this study was to develop a low-cost timing gate prototype that will be validated and approved by local users in Indonesia. The study evaluated the agreement between the 505 Agility Test measures, which utilize a stopwatch and a timing gate device that was constructed by the authors of the present study.

Materials and Methods. The test protocol was administered to 40 fifth-semester students (9 females and 31 males) from the physical education study program in Indonesia.

Results. The timing gate prototype was 0.19 seconds faster than the stopwatch measurement results ($p < 0.05$). The prototype has also demonstrated excellent reliability. The Intraclass Correlation Coefficient (ICC) was found to be 0.920, with a 95% Confidence Interval (CI) of 0.848–0.958. Bland-Altman plots revealed a good level of agreement with the prototype.

Conclusions. The findings indicate that the timing gate prototype is a potential replacement with a low cost for measuring timing results from conventional 505 agility tests using a stopwatch.

Keywords: 505 agility test, agility, timing gate, prototype.

Introduction

The physical ability to quickly change direction is known as agility (Lockie et al., 2003; Lockie et al., 2017; Spencer et al., 2005). Several types of tests can be used to measure the agility of an athlete, including a variety of body types and sport-specific tests (Firdausi & Simbolon, 2021). Agility was traditionally defined as the ability to change direction quickly and accurately, but some authors have defined agility as a change in the direction of the entire body as well as rapid movements and changes in the direction of the limbs (Sheppard & Young, 2006). Agility is the ability to change the position and direction of the body quickly and efficiently (Hoeger, 2008). Agility is a rapid change in the direction or speed of the whole body in response to an activity that requires a stimulus (Dawes & Roozen, 2012). Agility is one of the most commonly measured variables during athlete performance testing (Miranda et al., 2016). Agility is important in sports such as basketball, soccer, and racquetball, where participants must change direction quickly and also maintain proper body control (Hoeger, 2008). The 505 test is the most valid agility test because it produces the highest correlation with acceleration in the reverse phase of the test; however, this test is not highly correlated with speed (Sheppard & Young, 2006). The purpose of this test is to monitor the development of the athlete's speed and agility (Mackenzie, 2008).

The procedure for implementing the 505 agility test requires assistance in operating a stopwatch (Mackenzie, 2008). The innovation called the timing gate basically already exists, but this technology is still difficult for people in Indonesia to reach. The electronic timing gates (Witty Timer, Bolzano, Italy) for 2,012.4 pounds sterling was employed in earlier research (Balsalobre-Fernández et al., 2019; Stojanović et al., 2019). An electronic timing gate (PR1aW, Alge-Timing GmbH, Austria) with an accuracy of one hundredth of a second used in previous studies, costs 482.5 euros only for one part photocell (Hůlka et al., 2018). Another study measured agility using a Brower timing system (Brower Timing System, Salt Lake City, UT, USA) costing USD 1,358 (Spasic et al., 2013). The purchase price of this technology is expensive and must be imported from abroad, so sports practitioners still take conventional measurements using a stopwatch.

Although infrared distance measuring technology has been widely employed in a variety of scientific sectors, it is currently underutilized in the field of sports testing and assessments. Infrared sensors are currently being employed in the construction of measuring devices on a national scale (Pribadi & Haryono, 2011). The leg power measurement gadget that uses infrared technology has a high validity value and a very high reliability value, according to statistical calculations (Haryono & Pribadi, 2012). This demonstrates how infrared technology may be used and developed in sports testing and monitoring. The aim of this research is to create a low-cost timing gate product. So that this timing gate product can be accepted by local users, we tested its validity.

Materials and Methods

Study Participants

The sample consisted of 40 fifth-semester students (9 female and 31 male) from the physical education study program at in Indonesia. Ethical approval has been obtained from the review board of the research and community service institutions of Padang State University and Muhammadiyah University of Bangka Belitung. With number 02.01/KEPK-UNP/II. The sample understands well the procedures for carrying out the 505 agility test.

Test Protocol

The 505 agility test is used to assess an athlete's speed and agility when performing a 180-degree turn (Mackenzie, 2008). The following (Figure 1) is the procedure for performing the 505 agility test with the timing gate system: (1) Athletes line up 10 meters from the laser timing system sensor device at the starting line; (2) Athletes sprint from the starting line to the 10-meter line (using a laser timing system) (at this distance the athlete increases speed); (3) The timer will begin automatically when the athlete passes the laser on the 10-meter line; (4) The athlete runs to the 15-meter line (turn line), then circles back to the starting line; (5) The timer will automatically stop when the athlete passes the laser on the 10-meter line again; and (6) The time is recorded as a result of the 505 agility test. Meanwhile, measurements are carried out with a stopwatch operated by an experienced tester.

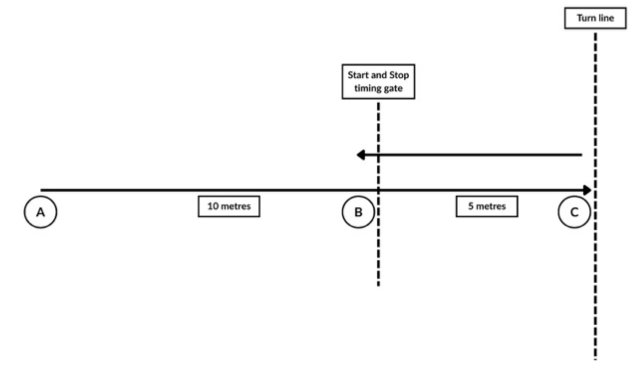


Fig. 1. The track of 505 agility test

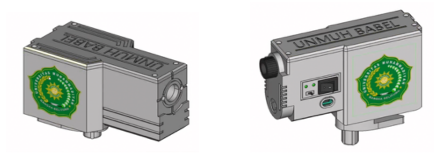
Data Collection and Analysis

We evaluated the agreement between the 505 Agility Test measures using a stopwatch that we utilized and a timing gate device that we constructed. Reliability between timing gate and stopwatch product readings based on the intraclass correlation coefficient (ICC) (Manson et al., 2014; Peebles et al., 2018). If the ICC value between measurements was greater than 0.50, the tested measuring device was considered to have appropriate stability; if it was greater than or equal 0.80, it was considered to have high stability (Rusdiana et al., 2021). A 0.9 ICC rating was considered excellent, a 0.9 to 0.75 value was considered good, a 0.75 to 0.5 value was considered moderate, and a value less than 0.5 was considered poor (Koo & Li, 2016; Peebles et al., 2018; Rusdiana et al., 2021). The paired t-test was performed to identify the two differences measurements mean performance (Parente et al., 2019; Perrotta et al., 2023; Rusdiana et al., 2021). A statistical tool called the Bland-Altman plot is used to compare two measurement methods (Alzahrani et al., 2015; Bravi et al., 2023; Hui et al., 2018). A Bland-Altman Plot can be used for this assessment (Bian et al., 2022). Bland-Altman analysis shows systematic error (bias) of the measurement results (Bruzzo et al., 2020; Gupta et al., 2009; Maeda et al., 2023; Stitt et al., 2021). SPSS (Version 26) was used for all statistical analysis, with significance set at 0.05.

Results

The laser-assisted 505 agility test instrument product is made according to the initial planning and design. The product is made up of several parts, including a laser transmitter and receiver (Figure 2), and a smartphone application (Figure 3).

The Transmission Control Protocol/Internet Protocol (TCP/IP) facilitates communication between sensor devices and applications on smartphones. The Transmission Control Protocol/Internet Protocol (TCP/IP) suite is a fundamental set of communication protocols that underpin



(a) (b)

Fig. 2. Laser Receiver (a) and Transmitter (b)

the Internet and private networks, including intranets and extranets (Feng et al., 2025). It consists of multiple layers, each with its own set of protocols, such as Wi-Fi, IP, TCP, and HTTP, which work together to facilitate data transmission (Alsahli et al., 2024). TCP/IP is designed to ensure reliable, ordered, and error-free data delivery between client and server (Moradiya & Popat, 2024). The signal is transmitted from the smartphone application to the sensor through the server, indicating that the sensor is prepared for operation. Upon the testee's commencement of jogging and upon crossing the ten-meter mark, the sensor transmits a signal to initiate timing via the server to the smartphone application. Similarly, when completing a 180-degree turn at the 15-meter mark and passing the sensor at the ten-meter mark, the sensor transmits a signal through the server to the smartphone application to halt and log the testee's time. The smartphone application presents time in milliseconds, seconds, and minutes. So that the outcomes of the testee's travel throughout the 505-agility test may be objectively assessed.

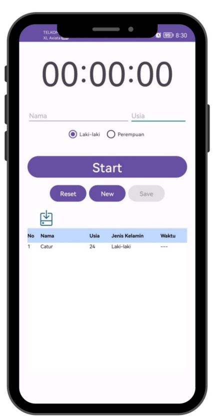


Fig. 3. The app display on smart phone

Table 1. The 505 agility test data description

	505 Agility Test	
	Stopwatch (Test 1)	The Prototype (Test 2)
n	40	40
Mean	3.15	2.96
Median	3.05	3.02
Mode	3.04	3.01
Standard Deviation	0.73086	0.55472
Range	2.97	1.99
Minimum	2.05	2.05
Maximum	5.02	4.04
Sum	126	118.64

Table 2 shown the timing gates product has excellent reliability (ICC = 0.920) on average measures with 95% Confidence Interval (CI = 0.848 – 0.958). Meanwhile, in single measures with 95% Confidence Interval (CI = 0.736 – 0.918) the timing gates product has strong correlation (ICC = 0.851). values between 0.75 and 0.9 indicate strong correlation or good reliability (Kerdaoui et al., 2021; Moradiya & Popat, 2024).

Table 2. The intraclass correlation coefficient

	Intraclass Correlation	95% Confidence Interval	
		Lower Bound	Upper Bound
Single Measures	.851	0.736	0.918
Average Measures	.920	0.848	0.958

Based on the findings of the investigation utilizing the paired t-test (Table 3), there is a significant difference (p <0.05) between the measurement results using timing gates product and stopwatch.

Table 3. The paired samples test

Paired Differences		
	Mean	-0.18400
	Std. Deviation	0.35386
	Std. Error Mean	0.05595
95% Confidence Interval of the Difference	Lower	-0.29717
	Upper	-0.07083
	t	-3.289
	df	39
	Sig. (2-tailed)	0.002

Figure 4 shows Bland-Altman plots with bias of difference (mean diff = 0.184), upper limit (+1.96 SD = 1.750), and lower limit (-1.96 SD = -1.382). The Bland-Altman test results show good agreement between measurements. Inter-observer agreement tests on measurements of 40 samples between the prototype and stopwatch for 505 agility tests showed that there were differences in mean differences. However, a difference of >95% means it is still within that area (mean ± 1.96 SD). These results indicate that the use of timing gates prototype has a high level of stability.

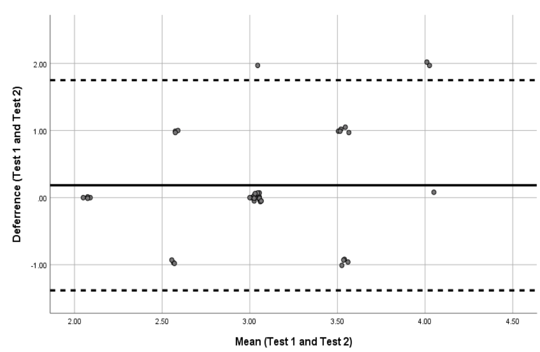


Fig. 4. The Bland–Altman Plots of 505 Agility Test Using Stopwatch (Test 1) and Timing Gate Prototype (Test 2)

Discussion

Based on the results of the paired t-test, differences were found between the measurement results using a stopwatch and the timing gate prototype. The timing gate prototype is 0.19 seconds faster than the stopwatch measurement results. We determined that a human mistake during the stopwatch operation during the 505 agility test was the cause of this. When compared between measurements using a timing gate and a stopwatch, it shows that measurements using a stopwatch have an average error of 0.17 seconds (Hribernik et al., 2021). The average measurement result using the prototype timing gate is 2.96 seconds. According to other studies, the average 505 agility test score was 2.7 seconds (Sonesson et al., 2020). The results of other studies show an average test result of 4.32 seconds (Stojanović et al., 2019). Differences in subjects influence differences in 505 agility test results, the criteria for agility measurement results must be adjusted to the characteristics of each subject.

The timing gates prototype has excellent reliability (ICC = 0.920), these results are in accordance with several previous studies. In 505 agility test measurements, prior research employing a timing gate (Browser TC Timing System, Biederitz, Germany) established an ICC = 0.85 (Kadlubowski et al., 2020). After assessing 505 agility tests using an electronic timing system (Microgate, Bolzano, Italy) and a test-retest method, it was discovered that ICC = 0.80 (Kerdaoui et al., 2021). Similarly, reported ICC of 0.92, 0.82, and 0.88 (Bakalár et al., 2020; Hopper et al., 2017; Sonesson et al., 2020). Lastly, there is a great degree of stability when using a timing gate prototype. The Bland-Altman test results provide good agreement across measurements, and the mean discrepancies between the prototype and stopwatch for the 505 agility tests are shown in the inter-observer agreement tests, suggesting strong stability.

Conclusions

A potential alternative for assessing the results of time records from the 505 agility test is the timing gate prototype. The timing gate prototype exhibited a time difference of 0.19 seconds, illustrating the capacity of the measurement data to generate more objective outcomes. Furthermore, the utilization of local manufacture and components confers a cost advantage to the prototype in development.

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Conflict of Interest

The authors declare there is no conflict of interest.

References

Lockie, R.G., Murphy, A.J., & Spinks, C.D. (2003). Effects of resisted sled towing on sprint kinematics in field-sport athletes. *Journal of Strength & Conditioning Research,* 17, 760-767.

Lockie, Robert G., Farzad, J., Orjalo, A.J., Giuliano, D.V., Moreno, M.R., & Wright, G.A. (2017). A methodological report: Adapting the 505 change-of-direction speed test specific to American football. *Journal of Strength and Conditioning Research, 31*(2), 539-547. https://doi.org/10.1519/JSC.0000000000001490

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities: Specificto field-based team sports. *Sports Medicine,* 35, 1025-1044. https://doi.org/10.2165/00007256-200535120-00003

Firdausi, D.K. A., & Simbolon, M.E. M. (2021). Development of Automated " Hexagonal Obstacle Test " in Sports Agility Measurement. *Indonesian Journal of Electronics and Instrumentation Systems (IJEIS), 11*(1), 61-70. https://doi.org/10.22146/ijeis.64434

Sheppard, J.M., & Young, W.B. (2006). Agility literature review : Classifications , training and testing. *Journal of Sports Sciences, 24*(9), 919-932. https://doi.org/10.1080/02640410500457109.

Hoeger, W.W. K. (2008). *Principles and Labs for Physical Fitness* (6th ed.). Thomson Wadsworth.

Dawes, J., & Roozen, M. (2012). *Developing Agility and Quickness* (1st ed.). Human Kinetic.

Miranda, D.L., Hsu, W., Gravelle, D.C., Petersen, K., Ryzman, R., Niemi, J., & Lesniewski-laas, N. (2016). Sensory enhancing insoles improve athletic performance during a hexagonal agility task. *Journal of Biomechanics,* 1-6. https://doi.org/10.1016/j.jbiomech.2016.02.022

Mackenzie, B. (2008). *101 Performance Evaluation Test.* Electric Word.

Balsalobre-Fernández, C., Bishop, C., Beltrán-Garrido, J.V., Cecilia-Gallego, P., Cuenca-Amigó, A., Romero-Rodríguez, D., & Madruga-Parera, M. (2019). The validity and reliability of a novel app for the measurement of change of direction performance. *Journal of Sports Sciences, 37*(21), 2420-2424. https://doi.org/10.1080/02640414.2019.1640029

Stojanović, E., Aksović, N., Stojiljković, N., Stanković, R., Scanlan, A.T., & Milanović, Z. (2019). Reliability, Usefulness, and Factorial Validity of Change-of-direction Speed Tests in Adolescent Basketball Players. *Journal of Strength and Conditioning Research, 33*(11), 3162-3173. https://doi.org/10.1519/JSC.0000000000002666

Hůlka, K., Weisser, R., & Bělka, J.A. N. (2018). Verification of speed and agility k-test in junior football players. *Journal of Physical Education and Sport, 18*(2), 1187-1191. https://doi.org/10.7752/jpes.2018.s2176

Spasic, M., Uljevic, O., Coh, M., Dzelalija, M., & Sekulic, D. (2013). Predictors of agility performance among early pubescent girls. *International Journal of Performance Analysis in Sport, 13*(2), 480-499. https://doi.org/10.1080/24748668.2013.11868664

Pribadi, F.S., & Haryono, S. (2011). Rancang Bangun Alat Ukur Ketinggian Lompatan dengan Sensor Infra Merah. *Jurnal Teknik Elektro, 3*(1), 20-25. https://doi.org/10.15294/jte.v3i1.1557

Haryono, S., & Pribadi, F.S. (2012). Pengembangan Jump Power Meter Sebagai Alat Pengukur Power Tungkai. *Jurnal Media Ilmu Keolahragaan Indonesia, 2*(1), 15-27. https://doi.org/10.15294/miki.v2i1.2550

Manson, S.A., Brughelli, M., & Haris, N.K. (2014). Physiological Characteristics of International Female

Soccer Players. *Journal of Strength and Conditioning Research, 28*(2), 308-318. https://doi.org/10.1519/JSC.0b013e31829b56b1

Peebles, A.T., Maguire, L.A., Renner, K.E., & Queen, R.M. (2018). Validity and Repeatability of Single-Sensor Loadsol Insoles during Landing. *Sensors, 18*(12), 1-10. https://doi.org/10.3390/S18124082

Rusdiana, A., Mulyana, B., Nurjaya, D.R., Badaruzman, Imanudin, I., Fauziah, E., & Syahid, A.M. (2021). 3D Biomechanical Analysis of Swimming Start Movements Using a Portable Smart Platform With Android Pie. *Journal of Engineering Science and Technology, 16*(1), 571-585.

Koo, T.K., & Li, M.Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine, 15*(2), 155-163. https://doi.org/10.1016/J.JCM.2016.02.012

Parente, J.D., Dhamodharan, A., Hensler, S., Kuhlbach, C., Mueller, M.M., & Möller, K. (2019). Automatic Image Analysis System to Measure Wound Area in Vitro. *Current Directions in Biomedical Engineering, 5*(1), 421-424. https://doi.org/10.1515/cdbme-2019-0106

Perrotta, A.S., Day, B.D., Wafai, I., Oates, R.P., Peterson, M.L., Scott, A.J., Barker, R.C., Garedakis, A.B., & Seaborn, K.A. (2023). Concurrent validity and reliability of photoelectric and accelerometer technology for calculating vertical jump height in female athletes. *Sports Engineering, 26*(1). https://doi.org/10.1007/s12283-023-00440-6

Alzahrani, A., Hu, S., Azorin-Peris, V., Barrett, L., Esliger, D., Hayes, M., Akbare, S., Achart, J., & Kuoch, S. (2015). A multi-channel opto-electronic sensor to accurately monitor heart rate against motion artefact during exercise. *Sensors (Switzerland), 15*(10), 25681-25702. https://doi.org/10.3390/s151025681

Bravi, M., Santacaterina, F., Bressi, F., Morrone, M., Renzi, A., Di Tocco, J., Schena, E., Sterzi, S., & Massaroni, C. (2023). Instrumented treadmill for run biomechanics analysis: A comparative study. *Biomedizinische Technik, 68*(6), 563-571. https://doi.org/10.1515/bmt-2022-0258

Hui, S.C. N., Zhang, T., Shi, L., Wang, D., Ip, C.-B., & Chu, W.C. W. (2018). Automated segmentation of abdominal subcutaneous adipose tissue and visceral adipose tissue in obese adolescent in MRI. *Magnetic Resonance Imaging,* 45, 97-104. https://doi.org/10.1016/j.mri.2017.09.016

Bian, C., Ye, B., & Mihailidis, A. (2022). The Development and Concurrent Validity of a Multi-Sensor-Based Frailty Toolkit for In-Home Frailty Assessment. *Sensors, 22*(9), 1-19. https://doi.org/10.3390/s22093532

Bruzzo, J., Perkins, N.C., & Mikkola, A. (2020). Embedded inertial measurement unit reveals pole lean angle for cross-country skiing. *Sports Engineering, 23*(1), 1-10. https://doi.org/10.1007/s12283-019-0316-3

Gupta, P., Mittal, L., Rizzo, R.A., Bikkina, M., & Debari, V.A. (2009). In-use comparison of blood pressure measurements from an automated blood pressure instrument with those from a mercury sphygmomanometer. *Biomedical Instrumentation and Technology, 43*(2), 158-163. https://doi.org/10.2345/0899-8205-43.2.158

Maeda, Y., Okawara, H., Sawada, T., Nakashima, D., Nagahara, J., Fujitsuka, H., Ikeda, K., Hoshino, S., Kobari, Y., Katsumata, Y., Nakamura, M., & Nagura, T. (2023). Implications of the Onset of Sweating on the Sweat Lactate Threshold. *Sensors, 23*(7), 1-11. https://doi.org/10.3390/s23073378

Stitt, D., Draper, N., Alexander, K., & Kabaliuk, N. (2021). Laboratory validation of instrumented mouthguard for use in sport. *Sensors, 21*(18), 1-13. https://doi.org/10.3390/s21186028

Feng, X., Li, Q., Sun, K., Xu, K., & Wu, J. (2025). Exploiting Cross-Layer Vulnerabilities: Off-Path Attacks on the TCP/IP Protocol Suite. *Communications of the ACM, 68*(3), 48-59. https://doi.org/10.1145/3689819

Alsahli, R.S., Alobud, R.F., Alsuhaibani, L.A., Alabdulhafith, M., & Alfarraj, M.F. (2024). *LUBB: Augmented Reality (AR) Application for Learning Transmission Control Protocol/Internet Protocol (TCP/IP) Model*. In A.K. (Ed.), Lecture Notes in Networks and Systems: Vol. 1066 LNNS (pp. 408-426). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-66428-1_25

Moradiya, H., & Popat, K. (2024). Evaluating TCP Performance with RED for Efficient Congestion Control. In R.S., P.K., M.D., & B.S. (Eds.). *Communications in Computer and Information Science,* 2039, pp. 403-414. Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-59100-6_28

Kerdaoui, Z., Sammoud, S., Negra, Y., Attia, A., & Hachana, Y. (2021). Reliability and time-of-day effect on measures of change of direction deficit in young healthy physical education students. *Chronobiology International, 38*(1), 103-108. https://doi.org/10.1080/07420528.2020.1839091

Hribernik, M., Keš, E., Umek, A., & Kos, A. (2021). Sensor Based Agility Assessment in Sport. *Procedia Computer Science,* 187, 440-446. https://doi.org/10.1016/j.procs.2021.04.082

Sonesson, S., Lindblom, H., & Hägglund, M. (2020). Performance on sprint, agility and jump tests have moderate to strong correlations in youth football players but performance tests are weakly correlated to neuromuscular control tests. *Knee Surgery, Sports Traumatology, Arthroscopy,* 0123456789. https://doi.org/10.1007/s00167-020-06302-z

Kadlubowski, B., Keiner, M., Stefer, T., Kapsecker, A., Hartmann, H., & Wirth, K. (2020). Influence of linear-sprint performance, concentric power and maximum strength on change of direction performance in elite youth soccer players. *German Journal of Exercise and Sport Research,* March. https://doi.org/10.1007/s12662-020-00692-5

Bakalár, I., Šimonek, J., Kanásov, J., Krčmárová, B., & Krčmár, M. (2020). Multiple athletic performances, maturation, and Functional Movement Screen total and individual scores across different age categories in young soccer players. *Journal of Exercise Rehabilitation, 16*(5), 432-441. https://doi.org/10.12965/jer.2040546.273

Hopper, A., Haff, E.E., Barley, O.R., Joyce, C., Lloyd, R.S., & Haff, G.G. (2017). Neuromuscular training improves movement competency and physical performance measures in 11-13-year-old female netball athletes. *Journal of Strength and Conditioning Research, 31*(5), 1165-1176. https://doi.org/10.1519/JSC.0000000000001794

Розроблення та валідація бюджетного прототипу часового селектора як альтернативи секундоміру при тестуванні спритності

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Реферат. Стаття: 6 с., 3 табл., 4 рис., 39 джерел.

Історія питання. Спритність, що визначається як фізична властивість, завдяки якій людина може швидко змінювати напрямок руху, оцінюється за допомогою різних тестів, включаючи аналіз типу статури та визначення специфічних для виду спорту показників. Вона передбачає швидку зміну положення всього тіла, рухів та орієнтування кінцівок. Спритність відіграє ключову роль у таких видах спорту, як баскетбол, футбол та ракетбол, де необхідні швидкі зміни напрямку руху та точний контроль положення тіла. Слід зазначити, що тест 505 є найнадійнішим тестом на спритність, який демонструє кореляцію з прискоренням, а не зі швидкістю. Він контролює розвиток як швидкості, так і спритності. Однак висока вартість та проблематика доступності, пов'язані з технологією часового селектора в Індонезії, обмежують широке застосування зазначеної методики. Як наслідок, місцеві фахівці у галузі спорту продовжують використовувати звичайні секундоміри для проведення аналізу.

Мета дослідження. Метою цього дослідження було розроблення бюджетного прототипу часового селектора, що проходитиме валідацію та випробовування місцевими користувачами в Індонезії. У дослідженні проведено оцінку узгодженості між показниками тесту 505 на спритність, для якого використовуються секундомір і пристрій часового селектора, сконструйований авторами представленого дослідження.

Матеріали та методи. Протокол тестування застосовано до 40 студентів п'ятого семестру (9 осіб жіночої статі та 31 особа чоловічої статі), які навчалися за програмою фізичного виховання в Індонезії.

Результати. Прототип часового селектора був на 0.19 секунди швидшим за результати вимірювання секундоміром ($p < 0.05$). Прототип також продемонстрував високу надійність. Коефіцієнт внутрішньокласової кореляції (ICC) становив 0.920, з довірчим інтервалом (ДІ) 95% від 0.848 до 0.958. Діаграми Бланда-Альтмана показали хороший рівень узгодженості з прототипом.

Висновки. Результати дослідження свідчать, що прототип часового селектора є потенційним бюджетним замінником для вимірювання результатів часових показників у стандартних тестах 505 на спритність із використанням секундоміра.

Ключові слова: тест 505 на спритність, спритність, часовий селектор, прототип.

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Review Article

Fundamental Movement Skills Development in Children Aged 5–12: Theory, Evidence, and Pedagogical Models

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Abstract

Background. Fundamental movement skills (FMS) represent the foundational basis of children's motor development and determine their ability to successfully perform more complex sport-specific movements. FMS are strongly associated with physical activity levels, health indicators, sport proficiency, and the long-term trajectory of motor development. At the same time, substantial heterogeneity exists in definitions, pedagogical approaches, and assessment criteria, which complicates the standardization of training programs.

Objectives. To summarize contemporary theoretical, empirical, and pedagogical approaches to the development of fundamental movement skills in children aged 5–12 and to systematize evidence-based models of instruction in physical education and early sport training.

Materials and Methods. Literature searches were conducted in Scopus, Web of Science, PubMed, ERIC, and Google Scholar (2000–2025). Search terms included: "fundamental movement skills," "motor learning," "physical education," "instructional model," "manipulative skills," "early sport training." Additional snowball searches were carried out using the reference lists of key publications by Barnett, Ivashchenko, Khudolii, and Marchenko. Included sources comprised empirical studies, reviews, conceptual models, and programmatic reports; excluded were clinical samples and studies not reporting FMS-related data. Evidence synthesis was conducted by thematic domains.

Results. Four major research directions were identified: (1) Theoretical foundations of FMS: three categories of skills (locomotor, manipulative, stability), their coordinative basis, and contextual dependence on instructional conditions. (2) Associations between FMS, physical activity, and health: higher FMS levels are linked to increased physical activity, better fitness, and reduced obesity risk; manipulative skills are the strongest predictor of sport participation. (3) Pedagogical models of instruction: game-based interventions (GEL approach), sensory-integrative methods, structured repetition modes, and programmed instruction of complex actions demonstrate the highest effectiveness. (4) Manipulative and complex motor actions: development of throwing, catching, striking, and dribbling skills is essential for children's involvement in sports; optimized training loads (6 repetitions, 45–60 s rest) ensure maximal learning gains.

Conclusions. Development of FMS at ages 5–12 is a key component of physical education and early sport training. The most effective approaches combine game-based contexts, multisensory stimulation, and structured repetition modes. There is an urgent need to standardize FMS assessment criteria, unify testing instruments, and integrate modern digital movement-analysis tools.

Keywords: fundamental movement skills; motor competence; physical education; pedagogical models; early sport training.

Introduction

Fundamental movement skills (FMS) are defined as basic learned movement patterns that form the foundation for acquiring more complex technical and sport-specific motor actions (Barnett et al., 2016; Hulteen et al., 2018). The core categories of FMS include locomotor, manipulative, and stability skills, the acquisition of which is closely linked to the development of motor coordination (Cools et al., 2011). In international frameworks, FMS are viewed as a key component of motor competence underpinning children's physical development (Huang & Choosakul, 2025; Yunak et al., 2022; Barnett et al., 2025).

Research findings consistently show that insufficient FMS proficiency in childhood is associated with lower levels of physical activity, difficulties in mastering motor actions, and a higher likelihood of sedentary behavior (Lubans et al., 2010; Holfelder & Schott, 2014; Komaini et al., 2023). Barnett et al. (2009) demonstrated that FMS competence is a significant predictor of adolescents' long-term participation in physical activity and sport. Evidence from Mathisen (2016) and Fernández-Valero et al. (2021) further highlights the central role of manipulative skills and agility in determining overall motor competence in younger children.

Several key research directions underscore the relevance of studying FMS:

1. Associations between FMS, physical activity, and health (Lubans et al., 2010; Stodden et al., 2008; Samsudin et al., 2022).
2. Transfer of FMS to sport-specific skills (Barnett et al., 2016).
3. Instructional strategies for optimizing FMS learning, including Mosston's teaching styles and contemporary pedagogical models (Mosston & Ashworth, 2008; Logan et al., 2012; Lander et al., 2017).
4. Sensitivity periods of motor development (Robinson et al., 2015). Stodden et al. (2008) showed conceptually that motor competence and physical activity mutually reinforce each other throughout childhood.

The age range of 5–12 years is widely recognized as the most favorable developmental window for FMS acquisition. A systematic review by Basman (2019) identified this period as optimal for monitoring and improving FMS within physical education and early sport training. However, substantial international variability exists in defining and assessing FMS (Barnett et al., 2016; Lai et al., 2014), limiting the comparability of research findings and underscoring the need for standardized assessment tools for motor competence.

Parallel to theoretical developments, a rapidly growing body of research focuses on optimizing instructional models for FMS development. The effectiveness of game-based approaches has been confirmed in studies by Sulistiyono et al. (2021) and Samsudin et al. (2021), while sensory-integrative strategies have shown positive effects on motor learning in young children (Akbar et al., 2021). A meta-analysis by Logan et al. (2012) demonstrated that targeted pedagogical interventions lead to significant improvements in FMS. Previous research has provided a methodological foundation for optimizing repetition modes and managing training loads through the application of pattern-recognition methods, full factorial experiments, and discriminant analysis (Ivashchenko et al., 2018; Iermakov et al., 2021; Kruglov & Khudolii, 2022).

Despite the growing evidence base, several challenges remain unresolved: the absence of unified FMS assessment criteria (Basman, 2019), uneven methodological support for instruction, limited teacher readiness to apply modern approaches (Dudley et al., 2011), and insufficient integration of evidence-based findings into school and sport practice.

Therefore, there is a need to synthesize current evidence regarding: (1) the content and categories of FMS, (2) pedagogical approaches to their development, (3) the effectiveness of instructional models in early training, and (4) existing gaps in FMS assessment criteria.

The purpose of this review is to summarize modern theoretical and empirical evidence on the development of fundamental movement skills in children aged 5–12 within physical education and early sport training, to systematize findings across major thematic domains, and to outline methodological gaps requiring further investigation.

Materials and Methods

Scope and Eligibility

Population: children aged 5–12 years; preschoolers and primary school pupils.

Topics: fundamental movement skills, motor development, instructional models, sport training.

Types of publications: empirical articles, reviews, conceptual models, programmatic reports.

Languages: English and Ukrainian.

Timeframe: 2000–2025.

Inclusion criteria: studies reporting data on FMS, instructional models, or factors influencing skill development.

Exclusion criteria: clinical samples, adult populations, uncontrolled descriptive reports.

Search Strategy

The literature search was conducted in Scopus, Web of Science, PubMed, ERIC, and Google Scholar in October–November 2025. The following search terms and combinations were used: "fundamental movement skills", "motor learning", "physical education", "instructional model", "manipulative skills", "early sport training".

To expand the evidence base, a snowball search was additionally performed: the reference lists of key publications by Barnett et al., Ivashchenko et al., Khudolii et al., and Marchenko et al. were analyzed, allowing identification of further relevant studies on FMS development in children aged 5–12.

Search and Screening Procedure

The search process followed a structured narrative-review logic and included four stages: identification, screening, eligibility assessment, and thematic synthesis. The initial search across Scopus, Web of Science, PubMed, ERIC, and Google Scholar (October–November 2025) yielded 1,950 records. After removing duplicates (n = 520), titles and abstracts were screened, and 1,170 articles not related to FMS, motor development, or instructional models were excluded.

A full-text assessment was performed for 260 articles, of which 239 were excluded due to lack of FMS-specific outcome measures, insufficient methodological detail, absence of empirical data, or focus on clinical or adult populations.

A total of 21 studies met the inclusion criteria and were incorporated into the final synthesis. An additional 18 sources were identified through snowball searching of key publications (Barnett, Ivashchenko, Khudolii, Marchenko), resulting in a final dataset of 39 included references.

The relatively small number of included studies is explained by the strict inclusion criteria focusing exclusively on empirical research directly examining FMS development in children aged 5–12, while excluding conceptual papers, descriptive reports, and studies lacking clear methodological procedures.

This multi-step screening approach ensured consistency, transparency, and reproducibility of the evidence base used in the review.

Study Selection

Screening was conducted based on titles, abstracts, and full texts. Articles lacking empirical data or not addressing FMS were excluded. Only studies meeting the predefined inclusion criteria were retained for synthesis.

Synthesis Approach

A thematic synthesis was applied, organizing the evidence into key domains that reflect the structure and logic of contemporary approaches to FMS development. Inconsistencies in FMS definitions across sources were reconciled through repeated verification of original conceptual texts (Barnett et al., 2016).

Results

Domain 1. Theoretical Approaches to FMS and Their Categorization

According to Barnett et al. (2016), fundamental movement skills (FMS) are basic, intentionally learned movement patterns that do not emerge spontaneously but are formed through pedagogical influence and serve as the foundation for sport-specific motor skills. Three primary categories are distinguished:

- Locomotor skills – running, jumping, various forms of travel.
- Manipulative skills – throwing, catching, striking, dribbling.
- Stability skills – balance and postural control.

FMS are closely linked to motor coordination, which is a key component of overall motor competence (Mathisen, 2016).

In modern literature, FMS are consistently described as intentionally formed motor actions that create the basis for mastering more complex physical exercises and sport techniques. Barnett and colleagues emphasize that FMS are not natural expressions of spontaneous activity but products of structured learning within organized instructional environments (Barnett et al., 2016). Consequently, FMS are treated as a central element of motor competence and a major indicator of children's motor development.

Classical theoretical models of FMS converge on a three-component classification: locomotor, manipulative (object-control), and stability skills. Locomotor skills involve spatial movement of the body (running, jumping, traveling sideways), manipulative skills involve controlling external objects (throwing, catching, striking), and stability skills reflect the ability to maintain postural control and balance (Barnett et al., 2016; Lubans et al., 2010; Cools et al., 2011). This structure enables identification of typical movement patterns that serve as building blocks for more specialized motor actions.

A critical aspect of theoretical approaches is the link between FMS and motor coordination. Research (Mathisen, 2016; Cools et al., 2011; Marchenko, 2025; Marchenko & Fedotov, 2024) demonstrates that children's motor competence is determined not only by individual test results but by integrated development of agility, balance, and coordination. For example, according to Movement ABC assessments, a significant proportion of six-year-old children fall into "borderline" or "motor difficulty" categories, indicating the need for targeted intervention programs (Mathisen, 2016). Thus, coordination is not a background factor but a structural determinant of FMS.

Another theoretical dimension concerns the broader context of FMS development – the family environment, instructional conditions, cultural norms, and organizational features of physical education lessons. Cools et al. (2011) showed that preschool children's FMS levels correlate with family-related factors such as parents' physical activity, access to play spaces, and support for active behavior. Similar findings were reported by Hardy et al. (2010, 2012) and Foweather et al. (2015): insufficient FMS development is a systemic issue rather than an isolated individual characteristic. This broadens the theoretical perspective, situating FMS not merely as a child's attribute but also as an indicator of the quality of the environment in which the child learns and grows.

Work by Barnett et al. (2009, 2013, 2016) and Hulteen et al. (2018) integrates FMS into life-course models of motor competence. In these frameworks, FMS serve as a crucial intermediary between early physical activity, physical fitness, motivation, and long-term engagement in sport. Hulteen et al. (2018) propose a "Foundational Movement Skills" model in which FMS serve as prerequisites for developing more complex motor patterns during school years and later specialization in sport. Thus, FMS have predictive value: their level in early childhood influences future pathways of physical activity and participation.

However, a systematic review by Basman (2019) identified a major methodological challenge: the absence of unified and widely accepted FMS assessment criteria for children aged 5–12. Studies employ different tools – full standardized tests (e.g., TGMD), modified subtests, or isolated skill assessments – which hinders direct comparison of results and complicates interpretation of intervention effectiveness. This highlights the need for methodological unification of FMS concepts and assessment criteria.

In summary, theoretical approaches to FMS encompass:

1. Structural definition: classification into locomotor, manipulative, and stability skills.
2. Coordinative foundation: FMS as manifestations of integrated motor competence.
3. Contextual dependence: influence of family, school, cultural, and environmental factors.
4. Life-course trajectory: FMS as a basis for physical activity and sport participation across the lifespan.
5. Methodological challenges: heterogeneity of definitions, assessment instruments, and criteria.

This theoretical framework provides the foundation for analyzing empirical evidence on the relationships among FMS, physical activity, health, and instructional models, which are explored in the subsequent domains (table 1, 2).

Table 1. Theoretical Approaches to FMS and Their Categorization

Theoretical Aspect	Key Content / Approach	Authors	Significance for Understanding FMS
Basic Definition of FMS	FMS are learned–not spontaneous–movement actions; formed through intentional instruction and serve as the foundation for complex sports skills.	Barnett et al. (2009, 2016); Hulteen et al. (2018)	Emphasizes that FMS are targets of pedagogical intervention and justify their central role in physical education curricula.
Three-Component Classification	FMS are divided into locomotor, manipulative (object-control), and stability skills, each with typical movement patterns and assessment criteria.	Barnett et al. (2016); Lubans et al. (2010); Cools et al. (2011)	Supports structured instructional planning, skill-group–specific assessment, and program design.
FMS as Core of Motor Competence	FMS represent the central component of motor competence, including coordination, agility, balance, and object control.	Stodden et al. (2008); Cools et al. (2011); Mathisen (2016)	Explains why FMS predict physical activity and sport proficiency; links FMS to broader developmental models.
Coordinative Basis of FMS	FMS depend on coordination, agility, balance, synchronization; coordination is a structural determinant.	Mathisen (2016); Cools et al. (2011); Hardy et al. (2012)	Justifies integration of coordination training and testing in FMS programs.
Contextual Approach	FMS levels depend on family environment, cultural factors, PE organization, access to play spaces.	Cools et al. (2011); Hardy et al. (2010, 2012); Foweather et al. (2015)	Highlights the environmental nature of FMS development and the importance of supportive contexts.
Life-Course Perspective	FMS are a platform for lifelong participation in physical activity and sport.	Barnett et al. (2009, 2016); Hulteen et al. (2018)	Demonstrates predictive value of early FMS proficiency.
Methodological Issues	Lack of unified criteria, different tools and scales (TGMD, MABC), varied interpretations across countries.	Basman (2019); Lai et al. (2014); Lubans et al. (2010)	Explains challenges in comparing findings and stresses the need for standardization.

Table 2. Categories of FMS and Their Characteristics

FMS Category	Examples of Movements	Function in Motor Development	Typical Tests / Assessment Tools
Locomotor Skills	Running, jumping, hopping, galloping, sideways movement, changes of direction	Enable whole-body movement through space; form the basis for endurance and speed development	TGMD subtests (run, hop, gallop); standing long jump / vertical jump; speed and agility tests
Manipulative Skills (Object-Control Skills)	Throwing, catching, striking, dribbling	Form the foundation for invasion team sports, precision tasks, and interaction with objects	TGMD (throw, catch, strike, dribble); sport-specific ball-handling tests; team-based FMS assessments
Stability Skills (Balance)	Static and dynamic balance positions, posture control, various stances	Provide postural control and stability required for complex movement actions	MABC balance tasks; static/dynamic balance tests; instructional observations during PE lessons

Domain 2. Associations Between FMS, Physical Activity, and Health

In leading theoretical models of motor development, fundamental movement skills (FMS) are considered a critical determinant of children's physical activity levels and their ability to participate in health-enhancing and sport-related behaviors. The conceptual model proposed by Stodden et al. (2008) shows that motor competence, physical activity, physical fitness, and obesity risk are linked through cyclical and mutually reinforcing mechanisms. Children with low FMS proficiency are less likely to engage in dynamic forms of activity, which in turn reinforces deficits in competence and leads to a negative trajectory of motor development.

High-quality meta-analyses confirm that FMS are a prerequisite for active daily behavior rather than a mere outcome of physical activity. Lubans et al. (2010), in a systematic review, demonstrated that children with higher scores in locomotor and manipulative skill tests exhibit greater levels of moderate-to-vigorous physical activity. Holfelder and Schott (2014) further noted direct associations between FMS and health indicators, including cardiometabolic markers and risk profiles related to sedentary behavior. Well-developed motor competence facilitates regular engagement in both structured and unstructured physical activity.

Manipulative skills – one of the core categories of FMS – play an especially important role in children's participation in sports and in the development of movement confidence. Mathisen (2016) found that coordination abilities, including throwing and catching accuracy, are among the strongest predictors of general motor competence in children

Table 3. Associations Between FMS, Physical Activity, Physical Fitness, and Health

Aspect of Association	Key Content / Explanation	Authors	Significance for Understanding FMS
FMS and Physical Activity Levels	Higher FMS levels are associated with greater participation in moderate-to-vigorous physical activity (MVPA). Children with low motor competence participate less in active games and sport.	Stodden et al. (2008); Lubans et al. (2010); Barnett et al. (2009)	Demonstrates that FMS are a prerequisite – not merely a result – of physical activity; developing FMS is essential for increasing daily activity.
FMS and the "Negative Spiral" of Sedentary Behavior	Stodden model: low FMS → low activity → reduced physical fitness → further decline in competence → increased body mass.	Stodden et al. (2008); Hardy et al. (2010, 2012)	Explains how persistent sedentary patterns develop; highlights the need for early interventions to enhance FMS.
FMS and Physical Fitness	Higher FMS proficiency correlates with better aerobic fitness, muscular endurance, agility, and coordination. FMS serve as a threshold for effective fitness development.	Hardy et al. (2012); Lubans et al. (2010); Robinson et al. (2015)	Shows that without basic FMS, fitness-training programs are less effective; positions FMS as the foundation of physical fitness.
Manipulative Skills and Sport Participation	Manipulative skills (throwing, catching, striking, dribbling) are strongly linked to involvement in team sports and movement confidence.	Mathisen (2016); Fernández-Valero et al. (2021); Hardy et al. (2012)	Explains why deficits in manipulative skills often act as barriers to sport participation; justifies prioritizing their development at ages 5–12.
FMS and Health Profile (Obesity, Metabolic Risks)	Low FMS proficiency is associated with higher body mass, obesity risk, and unfavorable cardiometabolic indicators.	Stodden et al. (2008); Holfelder & Schott (2014); Hardy et al. (2010)	Highlights FMS as a health marker and a potential strategy for obesity prevention.
FMS, Self-Perception, and Motivation	Motor competence influences perceived physical competence, motivation for physical activity, and sport confidence.	Barnett et al. (2016); Robinson et al. (2015); Morgan et al. (2013)	Demonstrates that FMS development should be accompanied by motivational support to prevent avoidance of physical activity.
FMS as an Integrative Indicator of Development	FMS reflect the combined influence of biological, pedagogical, and social factors and represent a "snapshot" of a child's motor, functional, and psychosocial status.	Lubans et al. (2010); Stodden et al. (2008); Hulteen et al. (2018)	Supports the use of FMS for monitoring developmental progress and evaluating instructional and training programs.

Table 4. FMS and Key Health and Behavioral Outcomes

FMS Component	Typical Outcome at High Level	Typical Outcome at Low Level
Locomotor Skills	Regular participation in running, active games, physically engaging recess activities; better endurance and aerobic capacity	Avoidance of vigorous play; rapid fatigue; low tolerance for dynamic activities
Manipulative Skills (Object-Control Skills)	Confidence in ball games; successful participation in team sports; higher movement self-efficacy	Avoidance of games involving balls; difficulty joining team play; reduced opportunities to practice skills
Stability Skills (Balance/ Postural Control)	Good postural stability; readiness for complex actions (e.g., gymnastics, acrobatics, martial arts); safer movement execution	Poor balance; difficulty performing complex motor tasks; higher injury risk; hesitancy in dynamic actions
Overall Motor Competence	Higher levels of MVPA; greater interest in physical activity; positive long-term developmental trajectory	Sedentary tendencies; reduced activity; reinforcement of a negative developmental spiral
Motor Coordination	Effective learning of new skills; better synchronization and timing of movements	Difficulty mastering coordinated actions; slower learning pace
Self-Perception and Motivation	High perceived motor competence; strong motivation for physical activity; willingness to engage in sport	Low confidence; fear of failure; avoidance of PE lessons and sport activities
Health Profile	Favorable body composition; lower obesity risk; better cardiometabolic indicators	Higher body mass; increased obesity risk; poorer metabolic profile; long-term health vulnerabilities

aged 6–8. Fernández-Valero et al. (2021) reported that children who score higher on ball-handling tasks exhibit significantly greater daily moderate-to-vigorous physical activity (MVPA). Children with poor manipulative skill development tend to participate less in active games, limiting opportunities for natural motor practice.

FMS are also directly associated with physical fitness. Hardy et al. (2012) demonstrated that FMS proficiency in children aged 8–10 correlates with aerobic fitness, muscular endurance, and coordination. A minimal level of motor competence acts as a "threshold condition" for effective development of fitness components. Children with low coordination often demonstrate lower levels of physical fitness, which reduces sport participation and limits their developmental potential.

Particular attention has been given to the relationship among FMS, body mass, and obesity risk. Stodden et al. (2008) proposed that low FMS proficiency combined with low activity levels contributes to a "negative spiral," where increased body mass further impairs motor competence, which in turn reduces activity even more. Empirical findings from Hardy et al. (2010) support this model: children with lower FMS scores are more likely to have overweight or obesity, while their physical activity levels remain consistently below age norms. Motor inadequacy in childhood may serve as a long-term health risk factor.

The psychosocial dimension of FMS has also gained growing attention. Barnett et al. (2016) noted that motor competence influences movement-related self-esteem, motivation for physical activity, and perceived sport competence. Longitudinal studies show that children with higher perceived motor confidence are more likely to join sports programs and maintain high levels of activity throughout childhood.

Overall, scientific evidence indicates that FMS are not merely a set of isolated movement abilities but an important integrative characteristic shaping children's physical activity, fitness, health outcomes, and motivation to engage in physical and sport activities. Therefore, the development of FMS in children aged 5–12 is a fundamental task of physical education and early sport training (table 3, 4).

Domain 3. Pedagogical Models, Strategies, and Game-Based Interventions (EN)

Current research increasingly focuses not only on describing the levels of FMS development but also on identifying optimal pedagogical strategies for enhancing these skills within physical education and early sport training. The aim of most intervention programs is to create conditions in which children receive a sufficient volume of purposeful motor practice in a motivationally appealing format, ensuring both skill acquisition and sustained engagement in physical activity (Logan et al., 2012; Morgan et al., 2013). Effective pedagogical models combine structured instruction with game-based dynamics and controlled exercise repetition modes.

One of the most compelling directions involves game-based learning models, where the development of FMS occurs within the context of specially organized games. A study by Sulistiyono et al. (2021) demonstrated the effectiveness of the Game Experience Learning (GEL) model in training young football players: its four stages – game experience, reflection, conceptualization, and implementation – ensure not only improvements in technical-tactical skills but also the development of team interaction, social competencies, and responsible on-field behavior. The coach deliberately uses game situations as "material" for cultivating desired action patterns, combining physical load with moral-volitional and communicative influences.

Similar results have been reported in volleyball. Samsudin et al. (2021) developed a set of instructional models for teaching basic volleyball movements in primary school children, where the game-based approach served as the primary means of increasing interest, engagement, and the effectiveness of technical skill acquisition. The authors emphasize the importance of safety, discipline, and appropriately dosed task difficulty, enabling children to perform movements freely while avoiding injury risks. Testing results confirmed that game-based models significantly improve mastery of fundamental volleyball techniques compared to traditional approaches.

Another important direction is the integration of FMS development with sensory integration, particularly under remote or blended learning conditions. Akbar et al. (2021) show that early childhood motor development should be implemented through a game-based approach that purposefully stimulates auditory, visual, vestibular, tactile, and proprioceptive systems. The authors highlight that instructional videos and home-based activities can be effective if they include running, jumping, walking, throwing, balancing tasks and simultaneously activate multiple sensory channels. This supports the rationale for using multisensory stimulation as a means of optimizing motor development under conditions of limited mobility.

In addition to game-based and sensory-integrative models, considerable attention has been paid to the structuring of repetition modes. The FMS evidence base includes studies employing full factorial experiments and discriminant analysis to determine optimal numbers of repetitions, rest intervals, and exercise sequences for teaching target throwing with a small ball and complex coordination gymnastics elements (Ivashchenko et al., 2018; Iermakov et al., 2021). For example, among eight-year-old boys, a mode of six repetitions with a 60-second rest interval produced the highest overall learning gains, and classification analysis showed high accuracy in assigning pupils to appropriate loading-parameter groups.

Similar approaches are applied in the development of complex coordination movements—acrobatics and kicking techniques in martial arts. Research by Rukavytsia et al. (2022) and Marchenko et al. (2022, 2023, 2024) revealed that programmed instruction combined with pattern-recognition models enables a step-by-step construction of the learning process, taking into account individual differences among pupils. These approaches focus on managing not only the quantitative load parameters but also the structure of the motor task, which is particularly important for forming fine-grained coordination mechanisms.

A crucial component of pedagogical strategies is the professional preparation of teachers and coaches, as they implement instructional models in practice. In their systematic review, Dudley et al. (2011) emphasize that the most effective school physical education programs

Table 5. Pedagogical Strategies, Instructional Models, and Game-Based Interventions

Type of Pedagogical Strategy / Model	Key Characteristic / Didactic Logic	Key Authors and Studies	Main Effects and Conclusions
Game-Based Learning Models (GEL)	Development of FMS within specially organized game situations; structure "experience – reflection – conceptualization – implementation"; integration of technique, tactics, and social interaction.	Sulistiyono et al. (2021); Samsudin et al. (2021)	Increased technical–tactical skills, team interaction, motivation; improved manipulative skills and coordination in game-based sports.
Game Models for Primary School (small-sided formats 1×1, 2×2)	Creation of numerous repetitions of motor actions in simulated game episodes; high frequency of ball touches and decision-making.	Samsudin et al. (2021); Morgan et al. (2013)	Improved execution of basic elements (passing, striking, catching); active involvement of all children; reduced passive time during lessons/training.
Sensory-Integrative Approaches	Use of tasks that simultaneously stimulate several sensory systems (visual, auditory, vestibular, tactile, proprioceptive) in a game format; especially relevant for remote/blended learning.	Akbar et al. (2021)	Accelerated acquisition of basic FMS (running, jumping, throwing, balance); better adaptation to varied task conditions; increased interest in home-based motor tasks.
Structured Repetition Modes (load optimization)	Determination of optimal repetitions, duration, and rest intervals based on full factorial experiments and discriminant analysis; programmed load management.	Ivashchenko et al. (2018); Iermakov et al. (2021)	Identification of optimal modes (e.g., 6 repetitions with 60 s rest) for maximal learning; opportunities for individualized instruction; higher lesson/training efficiency.
Programmed Instruction of Complex Coordination Movements (acrobatics, martial-arts kicks)	Step-by-step construction of the motor action; use of pattern-recognition models; integration of analytical and holistic teaching methods.	Rukavytsia et al. (2022); Marchenko et al. (2022, 2023, 2024)	Accelerated acquisition of complex motor actions; reduction of technical errors; ability to predict individual learning trajectories.
Combined Models (game-based + structured repetition modes)	Integration of a game context with precisely dosed load parameters; alternation of game tasks and programmed exercise series.	Logan et al. (2012); Ivashchenko et al. (2018)	Concurrent high motivation and controlled skill gains; improved fatigue tolerance; better movement automatization.
Teacher and Coach Professional Development	Targeted professional training programs focused on FMS development; mastery of evidence-based instructional models.	Dudley et al. (2011); Lander et al. (2017)	PE and sport programs with an FMS component are effective only when educators are competent in the methodology; improved lesson and training quality.
Whole-School Programs (whole-school approach)	Integration of FMS into curricula, recess activities, extracurricular events; involvement of administration, parents, and coaches; promotion of an active school environment.	Morgan et al. (2013); Hardy et al. (2012)	Sustained improvement in FMS and physical activity; higher participation in sport; long-term community-level benefits.
Mosston & Ashworth's Spectrum of Teaching Styles	A universal model conceptualizing instruction as a continuum of pedagogical decisions; spans from reproductive styles (A–E: precision and control) to productive styles (F–K: inquiry, variability, learner autonomy). Implements a non-versus paradigm where styles complement each other.	Mosston & Ashworth (2008)	Provides a methodological framework for configuring FMS interventions – from controlled repetition modes to game-based and inquiry formats; aligns lesson goals, feedback type, and learner autonomy in FMS development.

combine: a clearly articulated curriculum, elements of direct instruction, whole-school strategies for supporting physical activity, and ongoing teacher professional development. Lander et al. (2017) further note that teacher training specifically focused on FMS development is essential for the successful implementation of intervention programs.

Within pedagogical models, an important theoretical foundation is the Mosston & Ashworth Spectrum of Teaching Styles, which conceptualizes the teaching of motor actions as a chain of pedagogical decisions involving a gradual shift from reproductive styles (A–E) – ensuring precision, control, and standardized technique – to productive styles (F–K), which promote exploration, variability, and autonomous movement problem-solving (Mosston & Ashworth, 2008). This logic of structured transfer of decision-making from teacher to pupil enables FMS development across diverse instructional formats – from guided instruction to game-based and inquiry-based interventions – ensuring coherence between lesson objectives, types of feedback, and the child's level of autonomy.

Thus, contemporary pedagogical strategies for developing FMS can be viewed as multicomponent models

Table 6. Strategy – What It Does – Purpose

Strategy	What It Does (Specific Actions)	Purpose / Main Effect
Spectrum of Teaching Styles (Mosston & Ashworth)	Organizes instruction as a continuum of styles ranging from full teacher control to high learner autonomy; defines a sequence of pedagogical decisions (who decides what and when).	Provides a universal framework for selecting FMS teaching styles for specific goals: from technical precision to creative, game-based, or autonomous performance of motor tasks.
Game-Based Learning (GEL)	Transfers FMS into real or simulated game situations.	Increases interest and engagement while simultaneously developing technique and tactics.
Sensory Integration	Combines FMS with multichannel sensory stimuli.	Improves movement perception and adaptation to different task conditions.
Structured Repetition Modes	Precisely regulates the number of repetitions and rest intervals.	Maximizes learning gains and lesson efficiency.
Programmed Instruction	Breaks down a complex motor action into stages and uses structured models.	Enables learning complex movements without chaotic trial-and-error attempts.
Teacher Professional Development	Trains teachers/coaches to work with FMS instructional models.	Ensures high-quality implementation of programs in practice.

that include game-based methods, sensory-integrative approaches, optimized repetition modes, and specialized teacher preparation. Their common features are reliance on quantitatively and qualitatively justified loading schemes, a high degree of instructional structure, and the preservation of a playful, emotionally engaging character of activities – elements that are critically important for children aged 5–12.

Domain 4. Development of Manipulative and Complex Motor Skills (EN)

Manipulative skills (ball control, catching, throwing, striking, dribbling) are recognized as one of the most critical components of fundamental movement skills, as they enable the transition from basic motor experience to participation in sport-specific activity. Research by Barnett et al. (2009, 2016) and Mathisen (2016) has demonstrated that the level of manipulative skill development is a powerful predictor of overall motor competence and sport success. Children who achieve high scores in object-control tests display greater involvement in active games, higher confidence in movement-related tasks, and elevated levels of physical activity.

Studies by Fernández-Valero et al. (2021) emphasize that ball-handling abilities—particularly throwing and catching—have the strongest association with overall physical activity levels among primary school children. Similarly, Hardy et al. (2012) found that children with low manipulative performance demonstrate lower endurance and reduced motivation to engage in sports activities. The FMS literature further notes that insufficient development of manipulative skills limits opportunities for natural motor practice in play settings, creating a secondary "experience deficit" and slowing the development of motor competence.

Within pedagogical strategies, instructional models aimed specifically at developing manipulative skills in sport-game formats have become increasingly widespread. Evidence-based interventions show that children acquire object control most effectively through specially designed game tasks that integrate technical execution, social interaction, and competitive elements. In volleyball (Samsudin et al., 2021) and football (Sulistiyono et al., 2021), game-based instructional models grounded in GEL principles have produced substantial improvements in ball-handling skills, movement accuracy, and team coordination. The FMS framework also notes that game-based techniques provide a natural learning environment for developing manipulative actions in younger children.

The formation of manipulative actions requires not only an enriched game environment but also clearly defined load parameters that determine repetition mode, task duration, and rest intervals. Ukrainian studies (Ivashchenko et al., 2018; Iermakov et al., 2021) on teaching target throwing with a small ball show that optimizing the number of repetitions and gradually regulating task complexity are essential for learning gains. Specifically, it has been established that a mode of six repetitions with regulated rest intervals results in the highest acquisition rates among children aged 7–10.

Research on the mechanisms underlying the development of more complex manipulative and coordination actions (martial-arts kicking, acrobatic skills, technical elements in game sports) relies on modelling the structure of the motor action. Studies by Rukavytsia et al. (2022) and Marchenko et al. (2022, 2023, 2024) show that the use of pattern-recognition methods and programmed instruction enables the step-by-step formation of complex motor elements while accounting for individual learner characteristics. Factor modelling has allowed researchers to identify optimal repetition parameters, instructional sequences, and load levels necessary for developing accuracy, rhythm, and coordinated movement patterns.

Finally, contemporary literature highlights the importance of multisensory integration in the development of manipulative skills. Akbar et al. (2021) demonstrated that combining tactile, vestibular, visual, and auditory stimuli substantially enhances the acquisition of basic movements (walking, running, jumping, throwing), particularly under remote or blended learning conditions.

In summary, manipulative skills are not merely a subcategory of FMS but a key mechanism enabling the transition from general motor development to sport participation. They allow children to engage in active games and team sports, form the foundation of technical preparedness, and determine subsequent motor development pathways. Multiple studies confirm that game-based models, optimized repetition modes, sensory integration, and step-

Table 7. Manipulative Skills: Effective Pedagogical Strategies and Evidence Base

Category of Manipulative Skills	Effective Pedagogical Strategies	Key Studies (High Level of Evidence)	Rationale / Main Conclusions
Throwing and Catching	- Game-based models (GEL) - Sensory-integrative approaches - Targeted exercises with regulated repetitions	Sulistiyono et al., 2021; Mathisen, 2016; Fernández-Valero et al., 2021	Game situations enhance accuracy and variability; sensory stimuli improve trajectory perception; optimal repetition modes increase learning efficiency.
Ball Striking (hands/feet)	- Game-based learning - Programmed instruction (step-by-step movement construction) - Video analysis and technique correction	Samsudin et al., 2021; Suprun et al., 2021; Medko & Khudolii, 2021	Game format enhances motivation; stepwise modelling develops technical stability; video analysis provides precise feedback.
Dribbling and Object Control	- Combined sensorimotor exercises - Variable training (changes in speed, amplitude, angle of attack) - Individualized load parameters	Akbar et al., 2021; Morgan et al., 2013; Hardy et al., 2012	Variability broadens motor experience; sensory integration improves spatial awareness and control; individualized modes ensure stable skill acquisition.
Precision Technical Manipulations (volleyball, basketball, baseball)	- Specialized game tasks - Small-sided games 1×1, 2×2 - Programmed error correction	Samsudin et al., 2021; Lander et al., 2017	Team game actions integrate technique and tactics; small-sided games increase ball-contact frequency; programmed drills minimize typical errors.
Coordination-Complex Manipulations (acrobatics, martial arts)	- Step-by-step action construction - Factor modelling of repetition modes - Pattern-recognition methods	Rukavytsia et al., 2022; Marchenko et al., 2022, 2023, 2024; Iermakov et al., 2021; Ivashchenko et al., 2018	Modelling identifies optimal load parameters; pattern recognition enables individualized formation of complex motor actions.
Integrated Manipulative–Locomotor Actions (active games)	- Mixed-skills training - Game tasks with role switching - Combination of manipulations and locomotion	Logan et al., 2012; Barnett et al., 2009; Hulteen et al., 2018	Combined movements create richer motor schemas; role switching enhances cognitive and social components; hybrid actions increase overall motor competence.

Table 8. Optimal Repetition Modes for Manipulative Skills (EN)

Age	Optimal Repetition Mode	Rest Interval	Type of Motor Task	Source
7–8 years	6 repetitions	45–60 s	Target throwing with a small ball	Ivashchenko et al., 2018
8–9 years	5–6 repetitions	60 s	Martial-arts strikes (strike formation stage)	Medko & Khudolii, 2021
9–10 years	6–8 repetitions	60–90 s	Technical volleyball elements	Samsudin et al., 2021

by-step motor-action modelling are among the most effective approaches to developing manipulative skills in children aged 5–12 (table 7, 8).

Domain 5. Key Gaps and Methodological Challenges (EN)

The assessment of fundamental movement skills is one of the most problematic and, at the same time, most essential aspects of FMS research. In a systematic review, Basman (2019) emphasized that the field currently lacks unified measurement standards, and researchers employ a wide variety of test batteries, making cross-study comparisons extremely difficult. The author notes that differences in theoretical approaches to defining FMS (locomotor, manipulative, stability skills) and the diversity of assessment methods create significant methodological barriers to developing coherent instructional programs.

The most commonly used assessment instruments are the Test of Gross Motor Development (TGMD-2 / TGMD-3), the Movement Assessment Battery for Children (MABC-2), and the Bruininks–Oseretsky Test of Motor Proficiency (BOT-2). Cools et al. (2011) highlight that the choice of test significantly shapes the interpretation of FMS levels, as each battery targets different skill components and uses different scoring approaches (criterion-referenced in TGMD vs. norm-referenced in MABC). The FMS evidence file also notes that MABC-2 often identifies a higher prevalence of motor impairments, whereas TGMD-2 focuses primarily on the qualitative characteristics of movement and specific performance components. Such inconsistencies in test content create a risk of misclassifying children's motor competence.

A critical issue is the alignment between test outcomes and children's real-life motor abilities. Mathisen (2016) demonstrated that pupils with low MABC-2 scores frequently exhibit problems with agility, balance, and object control in everyday movement situations. Hardy et al. (2012) confirm that low manipulative skills (catching, throwing) show the strongest association with general difficulties in physical development.

FMS assessment is closely linked to the challenge of identifying sensitive periods of motor development. According to Stodden et al. (2008), inadequate FMS levels in early childhood may lead to a "negative spiral": low skill level → low physical activity → reduced physical fitness → even lower motor competence. For this reason, many authors (Barnett et al., 2016; Logan et al., 2012) argue that early FMS screening is essential for identifying children at risk of motor insufficiency.

Moreover, digital and video-analytic methods of assessing FMS have gained increasing attention, enabling precise kinematic characterization of movement. The use of pattern-recognition and clustering algorithms (Ivashchenko et al., 2018; Iermakov et al., 2021) makes it possible not only to evaluate skill performance but also to predict optimal load parameters for each child. This aligns with current trends toward personalized instruction in physical education and sport.

However, despite technological advances, a major problem remains the absence of universally accepted criteria for determining FMS levels. Lai et al. (2014) and Hardy et al. (2012) show that different researchers apply different scales and thresholds to define "high" or "low" skill levels. This complicates meta-analyses and cross-study comparisons of interventions. The FMS evidence file also indicates that many school programs lack clear benchmarks for FMS assessment, limiting the ability to systematically track pupils' progress.

In summary, FMS assessment is a central component of both pedagogical and research practice. Testing not only reveals the current level of skill development but also identifies risk factors, predicts motor development trajectories, enables individualized instruction, and provides evidence-based monitoring of program effectiveness. However, to fully leverage the potential of FMS in educational settings, standardization of criteria, unification of test batteries, and wider implementation of digital assessment tools are essential (table 9, 10).

Table 9. Assessment, Testing, and Measurement Criteria for FMS

Aspect of FMS Assessment	Key Concept / Approach	Authors Represented in the Literature	Importance for Theory and Practice
Lack of unified assessment standards	Wide variety of tests and author-developed tools; absence of agreed-upon FMS level criteria for ages 5–12.	Basman (2019); Lai et al. (2014)	Complicates comparison of results; limits standardization of instructional programs and evaluation of their effectiveness.
TGMD (Test of Gross Motor Development)	Criterion-referenced assessment of locomotor and manipulative skills (movement patterns, key execution phases).	Ulrich (TGMD-2, TGMD-3); Lubans et al. (2010)	Enables detailed analysis of FMS technique; well-suited for pedagogical interventions and program evaluation.
MABC-2 (Movement Assessment Battery for Children)	Norm-referenced test; focuses on identifying motor impairments and "at-risk" groups; includes tasks for manipulation, balance, and agility.	Cools et al. (2011); Mathisen (2016)	Used for screening motor difficulties; identifies children needing special interventions.
BOT-2 and other comprehensive batteries	Extensive set of tests assessing fine and gross motor skills, coordination, strength, and agility; mainly used in clinical and research settings.	Bruininks & Bruininks; Holfelder & Schott (2014)	Provides a detailed motor development profile; useful for deep diagnostics but less practical for mass school testing.
Gap between test outcomes and real-life skills	Test results do not always reflect children's behavior in everyday motor situations; pedagogical observation is crucial.	Mathisen (2016); Hardy et al. (2012)	Highlights the need to complement formal testing with qualitative movement analysis in lessons and training sessions.
Early screening and sensitive periods	Assessing FMS at ages 5–9 allows identification of children at risk of motor insufficiency and prevents the development of the "negative spiral."	Stodden et al. (2008); Barnett et al. (2016); Logan et al. (2012)	Supports systematic early testing; justifies incorporating FMS screening into school PE programs.
Digital and video-analytic methods	Use of video, kinematic analysis, and pattern-recognition algorithms to assess complex movements.	Ivashchenko et al. (2018); Iermakov et al. (2021)	Enables detailed analysis of technique, personalized instruction, and prediction of skill acquisition success.
Problem of defining "high/low" FMS levels	Varying scales and thresholds across studies; lack of consensus for classifying children by FMS level.	Basman (2019); Lai et al. (2014); Hardy et al. (2012)	Hinders meta-analyses and unified recommendations; underscores the need for internationally agreed-upon norms.
FMS as a tool for program monitoring	FMS assessments used to evaluate the effectiveness of instructional/training programs and the quality of the educational environment.	Lubans et al. (2010); Hulteen et al. (2018)	Allows not only child diagnostics but also assessment of PE systems, schools, clubs, and coaching programs.

Table 10. Practical Guidelines for FMS Assessment

Practical Question	Recommended Approach
What should be used for school-based pedagogical interventions?	TGMD-2 / TGMD-3 + pedagogical observation of movement technique
How to identify children at risk of motor impairments?	MABC-2 / BOT-2 + teacher/parent questionnaires
How to assess complex movements (acrobatics, martial-arts strikes)?	Video analysis + movement pattern-recognition models (Ivashchenko, Iermakov, Khudolii et al.)
How to use FMS for monitoring school programs?	Periodic FMS testing (1–2 times per year) + analysis of class/school-level dynamics

Discussion

The aim of this review was to summarize contemporary theoretical and empirical evidence on the development of fundamental movement skills (FMS) in children aged 5–12, to systematize the findings across the leading thematic domains, and to identify methodological gaps requiring further investigation. The analysis showed that FMS constitute a key foundation of motor development and determine subsequent success in learning technical motor actions, engagement in physical activity, and sport specialization.

First, an analysis of theoretical models demonstrates that international authors consider FMS as an integrated construct that encompasses locomotor, manipulative, and stability skills and is shaped by a child's coordination preparedness. It is emphasized that FMS form the basis of motor competence, which in turn is associated with physical activity and sport participation. This is supported by evidence showing that a child's ability to master technically complex movements, progress toward specialized sport actions, and maintain physical activity across the lifespan depends on FMS levels. However, despite a well-developed theoretical foundation, the analysis revealed a substantial lack of unified FMS assessment criteria, which hinders standardization and international comparability.

Second, the synthesis of empirical data indicates a consistent relationship between FMS proficiency, physical activity, physical fitness, and health. Children with insufficient motor competence demonstrate lower participation in physical activity, reduced confidence during motor tasks, and limited access to team games. This aligns with the international "negative spiral" model, according to which low FMS levels in early school age may determine sedentary behavior in adolescence. The review also confirms that FMS serve as an indicator of the quality of the educational environment: they are used for monitoring the effectiveness of school programs, predicting children's engagement in sport, and assessing the motor culture of the school population.

Third, the analysis of pedagogical strategies reveals that the most effective approach to developing FMS involves combining game-based models (active games, situational exercises, GEL approaches) with structured repetition modes. Game-based models promote motivation, social interaction, and technical–tactical variability, whereas structured repetition modes ensure controlled learning progression. The evidence file emphasizes that the regulation of load parameters (number of repetitions, rest intervals, task sequencing) is a decisive factor in instructional effectiveness, especially for children aged 5–12. Empirical findings support the optimality of six-repetition modes with 60-second rest intervals, which yield the greatest improvements in manipulative skills in young children. Complementing these results, the Spectrum of Teaching Styles (Mosston & Ashworth) shows that effectiveness increases when game-based and repetition-based strategies are integrated into a coherent instructional decision chain—from reproductive styles emphasizing technical precision to productive styles fostering variability and autonomous movement decision-making.

Fourth, within the domain of programs designed to develop complex motor actions, the review identified strong effectiveness of sport-oriented interventions, including active games and exercises with elements of martial arts. These approaches contribute not only to technical skill development but also to improvements in physical qualities (strength, power) and social competencies. However, the effectiveness of such programs depends substantially on the professional competence of teachers and coaches, highlighting the need for specialized pedagogical training.

Fifth, the review identified the most significant methodological gaps. Chief among these are the absence of unified criteria for classifying FMS levels, inconsistencies across testing instruments, and insufficient validity of certain assessment procedures. Various scales (TGMD, MABC, BOT-2, Peabody, etc.) often produce divergent results for the same child population, making it impossible to construct a universal rating system. Additionally, many empirical studies have small sample sizes or insufficient statistical power, highlighting the need for further research with larger samples, clearly structured interventions, and controlled performance conditions.

In summary, the findings of this review fully align with the research objective. Theoretical approaches to FMS structure were synthesized, empirical evidence regarding their relationship with physical activity and health was systematized, effective pedagogical models and learning algorithms were described, and key methodological limitations impeding standardization in FMS development for children aged 5–12 were identified. The conclusions underscore the need for the development of internationally standardized assessment norms, more advanced intervention research, and closer integration of FMS into physical education and youth sports programs.

The review demonstrates that the development of fundamental movement skills in children aged 5–12 results from the interaction of three key factors: the structure of FMS themselves, the quality of pedagogical influence, and the characteristics of the educational environment. Their coordinated interaction ensures effective development of motor competence.

The discussion confirms that FMS represent the foundation for subsequent motor, physical, and sports activity; insufficient FMS proficiency in early school years is associated with the emergence of a "negative trajectory" of motor behavior. The strongest evidence relates to the effectiveness of combining game-based learning models with structured repetition modes, which support optimal learning gains and maintain children's motivation. The effectiveness of these models depends significantly on teacher competence and the availability of conditions for regular practice.

At the same time, the review identified a critical methodological gap – the absence of unified FMS assessment criteria, which complicates program comparison and the implementation of common standards. This highlights the need for further standardization of assessment tools and development of internationally harmonized norms.

Thus, the integrated model derived from the material positions FMS as a dynamic, manageable process that requires targeted pedagogical strategies, early screening, and a high-quality educational environment. It provides a conceptual foundation for designing effective school physical education programs and youth sport development pathways and requires further research.

Limitations

- This narrative review does not claim completeness, as it did not employ a full systematic protocol.
- Several studies included in the analysis had small sample sizes.
- The absence of unified FMS criteria complicates synthesis and generalization of findings.

Conclusions

The development of fundamental movement skills in children aged 5–12 is a critically important task in early sport training. The strongest evidence relates to game-based learning models, sensory integration, and structured repetition modes. It is essential to standardize FMS assessment criteria and consider sensitive periods of motor development.

Practical Recommendations

- Use game-based models (GEL, active games with martial-arts elements).
- Plan training loads according to optimal repetition modes.
- Apply a multisensory approach (visual, auditory, tactile stimuli).
- Develop manipulative skills from age 5 using a "simple → complex" progression.
- Provide regular monitoring of motor competence.

Future Research

- Development of unified criteria for FMS assessment.
- Examination of long-term effects of different learning models.
- Identification of sensitive periods for various FMS categories.
- Comparison of the effectiveness of game-based vs. technique-oriented methods.

AI Transparency Statement

AI-assisted software (ChatGPT, OpenAI, USA) was used solely as a technical tool during manuscript preparation—for language editing, stylistic improvement, and structuring of text based on material provided by the authors. No AI tools were used for data collection, statistical analysis, interpretation of results, or generation of original scientific findings. All aspects of the study, including problem formulation, study design, data analysis, and conclusions, were fully developed and critically evaluated by the authors.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

Barnett, L. M., Stodden, D., Cohen, K. E., Smith, J. J., Lubans, D. R., Lenoir, M., Iivonen, S., Miller, A. D., Laukkanen, A., Dudley, D., Lander, N. J., Brown, H., & Morgan, P. J. (2016). Fundamental movement skills: An important focus. *Journal of Teaching in Physical Education, 35*(3), 219-225. https://doi.org/10.1123/jtpe.2014-0209

Hulteen, R. M., Morgan, P. J., Barnett, L. M., Stodden, D. F., & Lubans, D. R. (2018). Development of Foundational Movement Skills: A Conceptual Model for Physical Activity Across the Lifespan. *Sports Medicine, 48*(7), 1533-1540. https://doi.org/10.1007/s40279-018-0892-6

Cools, W., de Kristine, M., Samaey, C., & Andries, C. (2011). Fundamental movement skill performance of preschool children in relation to family context. *Journal of Sports Sciences, 29*(7), 649-660. https://doi.org/10.1080/02640414.2010.551540

Huang, C., & Choosakul, C. (2025). Children's Fundamental Movement Skills, Social Emotional Development and Physical Activity Development Based on Kids' Athletics Intervention: SEM Modelling and Analysis. *Physical Education Theory and Methodology, 25*(2), 382-390. Scopus. https://doi.org/10.17309/tmfv.2025.2.20

Yunak, I., Ivashchenko, O., Nosko, M., & Nosko, Y. (2022). Pattern Recognition: Age-Specific Features Of Fundamental Movement Skills Formation In Elementary School Students. *Physical Education Theory and Methodology, 22*(3), 430-436. Scopus. https://doi.org/10.17309/tmfv.2022.3.19

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents: Review of associated health benefits. *Sports Medicine, 40*(12), 1019-1035. https://doi.org/10.2165/11536850-000000000-00000

Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychology of Sport and Exercise, 15*(4), 382-391. Scopus.

Barnett, L. M., Verswijveren, S. J. J. M., Ridgers, N. D., Tietjens, M., Lander, N. J., & Abbott, G. (2025). Children with high actual and perceived motor skill competence are more physically active: A pooled latent profile analysis of cross-sectional data. *Journal of Sports Sciences, 43*(9), 821-832. Scopus. https://doi.org/10.1080/02640414.2025.2477419

Komaini, A., Kiram, Y., Mario, D. T., Handayani, S. G., & Erianjoni, n. (2023). Fundamental Movement Skills In Children In Mentawai Islands: Indigenous Tribes In Indonesia. *Physical Education Theory and Methodology, 23*(4), 520-530. Scopus. https://doi.org/10.17309/tmfv.2023.4.05

Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2009). Childhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity. *Journal of Adolescent Health, 44*(3), 252-259. https://doi.org/10.1016/j.jadohealth.2008.07.004

Mathisen, G. E. (2016). Motor competence and implications in primary school. *Journal of Physical Education and Sport, 16*(1), 206-209.

Fernández-Valero, P., Soto-Sánchez, J., Páez, J., Leyton-Dinamarca, B., Kain, J., Hurtado, J., & Reyes-Amigo, T. (2021). Fundamental movement skills and physical activity recommendations for preschool children. *Journal of Physical Education and Sport,* 21, 3286-3293. https://doi.org/10.7752/jpes.2021.s6436

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306. https://doi.org/10.1080/00336297.2008.10483582

Samsudin, S., Gani, R. A., Setiawan, E., Németh, Z., Kardiyanto, D. W., & Wınarno, M. E. (2022). Increasing Physical Activity and Fundamental Movement Skills of Primary School Students During the Covid-19 Through Exergame. *Physical Education Theory and Methodology, 22*(4), 459-465. Scopus. https://doi.org/10.17309/tmfv.2022.4.01

Mosston, M., & Ashworth, S. (2008). *Teaching physical education.* Spectrum Institute.

Logan, S. W., Robinson, L. E., Wilson, A. E., & Lucas, W. A. (2012). Getting the fundamentals of movement: A meta-analysis of the effectiveness of motor skill interventions in children. *Child: Care, Health and Development, 38*(3), 305-315. Scopus.

Lander, N., Barnett, L. M., Brown, H., & Telford, A. (2017). Physical education teacher training improves student fundamental movement skills: A cluster randomized controlled trial. *Journal of Science and Medicine in Sport, 20*(8), 709-714. https://doi.org/10.1016/j.jsams.2017.02.002

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273-1284. https://doi.org/10.1007/s40279-015-0351-6

Basman, A. J. (2019). Assessment criteria of fundamental movement skills for various age groups: A systematic review. *Journal of Physical Education and Sport, 19*(1), 722–732. https://doi.org/10.7752/jpes.2019.01104

Lai, S. K., Costigan, S. A., Morgan, P. J., Lubans, D. R., Stodden, D. F., Salmon, J., & Barnett, L. M. (2014). Do school-based interventions focusing on physical activity, fitness, or fundamental movement skill competency produce a sustained impact in these outcomes in children and adolescents? A systematic review of follow-up studies. *Sports Medicine, 44*(1), 67-79. https://doi.org/10.1007/s40279-013-0099-9

Sulistiyono, S., Akhiruyanto, A., Primasoni, N., Arjuna, F., Santoso, N., & Yudhistira, D. (2021). The Effect of 10 Weeks Game Experience Learning (Gel) Based Training on Teamwork, Respect Attitude, Skill and Physical Ability in Young Football Players. *Physical Education Theory and Methodology, 21*(2), 173-179. https://doi.org/10.17309/tmfv.2021.2.11

Samsudin, S., Setiawan, I., Taufik, M., & Solahuddin, S. (2021). Volleyball Fundamental Movement Learning Model in Primary School. *Physical Education Theory and Methodology, 21*(3), 194-199. https://doi.org/10.17309/tmfv.2021.3.02

Akbar, Z., Awalludin, & Tohar, K. (2021). Fundamental movement skills and sensory movement strategies to support online learning in early childhood. *Journal of Physical Education and Sport,* 21, 2364-2371. https://doi.org/10.7752/jpes.2021.s4317

Ivashchenko, O., Khudolii, O., Iermakov, S., Chernenko, S., & Honcharenko, O. (2018). Full factorial experiment and discriminant analysis in determining peculiarities of motor skills development in boys aged 9. *Journal of Physical Education and Sport,* 18, 1958-1965. https://doi.org/10.7752/jpes.2018.s4289

Kruglov, V., & Khudolii, O. (2022). Discriminant Analysis: Age-Specific Features of Motor Fitness of Girls Aged 7 to 9. *Physical Education Theory and Methodology, 22*(3s), S142-S147. https://doi.org/10.17309/tmfv.2022.3s.20

Iermakov, S., Ivashchenko, O., Khudolii, O., Chernenko, S., Veremeenko, V., & Zelenskyi, B. (2021). Pattern Recognition: Impact of Exercises Modes on Developing a Small Ball Throwing Skill in Boys Aged 8. *Physical Education Theory and Methodology, 21*(1), 77-83. https://doi.org/10.17309/tmfv.2021.1.10

Dudley, D., Okely, A., Pearson, P., & Cotton, W. (2011). A systematic review of the effectiveness of physical education and school sport interventions targeting physical activity, movement skills and enjoyment of physical activity. *European Physical Education Review, 17*(3), 353-378. https://doi.org/10.1177/1356336X11416734

Marchenko, S. (2025). Study of the Factor Structure of Motor Fitness in 8-Year-Old Boys During the Process of Mastering the "Kin Geri" Kick Technique. *Physical Education Theory and Methodology, 25*(3), 675-683. https://doi.org/10.17309/tmfv.2025.3.25

Marchenko, S., & Fedotov, B. (2024). Age Differences in the Manifestation of Endurance Ability of Boys Karate Athletes. *Journal of Learning Theory and Methodology, 5*(3), 89–97. https://doi.org/10.17309/jltm.2024.5.3.01

Hardy, L. L., King, L., Farrell, L., Macniven, R., & Howlett, S. (2010). Fundamental movement skills among Australian preschool children. *Journal of Science and Medicine in Sport, 13*(5), 503-508. Scopus.

Hardy, L. L., Reinten-Reynolds, T., Espinel, P., Zask, A., & Okely, A. D. (2012). Prevalence and correlates of low fundamental movement skill competency in children. *Pediatrics, 130*(2), e390–e398. Scopus.

Foweather, L., Knowles, Z., Ridgers, N. D., O'Dwyer, M. V., Foulkes, J. D., & Stratton, G. (2015). Fundamental movement skills in relation to weekday and weekend physical activity in preschool children. *Journal of Science and Medicine in Sport, 18*(6), 691-696. Scopus.

Barnett, L. M., Hardy, L. L., Lubans, D. R., Cliff, D. P., Okely, A. D., Hills, A. P., & Morgan, P. J. (2013). Australian children lack the basic movement skills to be active and healthy. *Health Promotion Journal of Australia, 24*(2), 82-84. https://doi.org/10.1071/HE12920

Morgan, P. J., Barnett, L. M., Cliff, D. P., Okely, A. D., Scott, H. A., Cohen, K. E., & Lubans, D. R. (2013). Fundamental movement skill interventions in youth: A systematic review and meta-analysis. *Pediatrics, 132*(5), e1361–e1383. Scopus.

Rukavytsia, V., Ivashchenko, O., Khudolii, O., Yermakova, T., & Iermakov, S. (2022). Pattern recognition: The effect of exercise performance modes on the effectiveness of teaching the vault to 8-year-old boys. *Pedagogy of Physical Culture and Sports, 26*(6), 426-431. Scopus. https://doi.org/10.15561/26649837.2022.0609

Marchenko, S., Ivashchenko, O., Jagiełło, W., Iermakov, S., Khudolii, O., & Yermakova, T. (2022). Discriminant analysis: Features of training 10-year-old boys in the technique of kicks in kyokushin karate. *Archives of Budo,* 18, 1–11. Scopus.

Marchenko, S., Khudolii, O., Ivashchenko, O., & Musliumova, S. (2023). Didactics: Peculiarities of planning and managing the process of teaching the Mae hiza geri chudan technique in 8-year-old boys. *Slobozhanskyi Herald of Science and Sport, 27*(2), 92-98. Scopus. https://doi.org/10.15391/snsv.2023-2.005

Marchenko, S., Ivashchenko, O., Jagiełło, W., Iermakov, S., & Khudolii, O. (2024). Motor skills in the structure of motor fitness of 9-year-old boys engaged in kyokushinkai karate. *Archives of Budo,* 20, 208–221. Scopus.

Bruininks, R. H., & Bruininks, B. D. (2005). *Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOT-2)*. Pearson Assessments.

Формування фундаментальних рухових навичок у дітей 5–12 років: теорія, емпіричні дані та педагогічні моделі

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 15 с., 10 табл., 39 джерел.

Історія питання. Фундаментальні рухові навички (FMS) є базовою основою моторного розвитку дітей і визначають здатність ефективно виконувати складніші спортивні рухи. FMS пов'язані з рівнем фізичної активності, здоров'ям, спортивною успішністю та довгостроковою траєкторією рухового розвитку. Водночас спостерігається значна різнорідність у визначеннях, педагогічних підходах та критеріях оцінювання FMS, що ускладнює стандартизацію навчальних програм.

Мета. Узагальнити сучасні теоретичні, емпіричні та педагогічні підходи до формування фундаментальних рухових навичок у дітей 5–12 років та систематизувати доказові моделі навчання у фізичному вихованні та початковій спортивній підготовці.

Матеріали і методи. Пошук літератури здійснено у базах Scopus, Web of Science, PubMed, ERIC, Google Scholar (2000–2025). Застосовано комбінації ключових слів "fundamental movement skills", "motor learning", "physical education", "instructional model", "manipulative skills", "early sport training". Додатково проведено сніжковий пошук за працями Barnett, Ivashchenko, Khudolii, Marchenko. До аналізу включено емпіричні дослідження, огляди, концептуальні моделі та програмні звіти; виключено клінічні вибірки та роботи без даних щодо FMS. Синтез виконано за доменами.

Результати. Виявлено чотири ключові напрями сучасних досліджень: (1) Теоретичні засади FMS. Виділено три категорії навичок (локомоторні, маніпулятивні, стабілізаційні), їх координаційну основу та контекстуальну залежність від умов навчання. (2) Зв'язок FMS із фізичною активністю та здоров'ям. Високий рівень FMS асоціюється з вищою руховою активністю, кращою фізичною підготовленістю та нижчим ризиком ожиріння; маніпулятивні навички є найсильнішим предиктором спортивної участі. (3) Педагогічні моделі навчання. Ефективними є ігрові інтервенції (GEL-підхід), сенсорно-інтегративні методи, структуровані режими повторень і програмоване навчання складних рухів. (4) Маніпулятивні та складні рухові дії. Формування кидків, ловіння, ударів і ведення м'яча є центральною умовою включення дітей у спортивні ігри; оптимізація навантаження (6 повторень, паузи 45–60 с) забезпечує максимальний приріст навченості.

Висновки. Формування FMS у віці 5–12 років є ключовим компонентом фізичного виховання та початкової підготовки в спорті. Найефективнішими виявились комбіновані педагогічні моделі, що поєднують ігровий контекст, сенсорно-інтегративні стимули та структуровані режими повторення. Існує нагальна потреба у стандартизації критеріїв оцінювання FMS, уніфікації тестових інструментів та подальшому впровадженні цифрових методів аналізу рухів.

Ключові слова: фундаментальні рухові навички; моторна компетентність; фізичне виховання; педагогічні моделі; початкова спортивна підготовка.

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Review Article

Cold-Water Immersion and Athletic Recovery: A Systematic Review of Randomized Controlled Trials (2000–2024)

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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. Cold-water immersion (CWI) is a commonly used recovery strategy among athletes, but evidence of its effectiveness remains inconsistent due to variations in protocols and outcome measures.

Objectives. This systematic review aimed to evaluate the effects of CWI on post-exercise recovery in athletes, focusing on physiological, performance, and perceptual outcomes.

Materials and Methods. Following PRISMA guidelines and PROSPERO registration (CRD420251068097), four electronic databases (PubMed, Web of Science, Scopus, and ProQuest) were searched for randomized controlled trials (RCTs) published between 2000 and 2024. Studies were included if they achieved a PEDro score ≥6. Twelve RCTs met the inclusion criteria. Data were synthesized narratively, supported by vote-counting and harvest plots, as heterogeneity prevented meta-analysis.

Results. CWI consistently reduced delayed-onset muscle soreness (DOMS) and muscle damage biomarkers (e.g., creatine kinase, lactate dehydrogenase) within 24–48 hours post-exercise. Several trials also reported improvements in subjective recovery. The effects on neuromuscular performance (e.g., sprinting, countermovement jump) were mixed and appeared context-dependent. Evidence regarding inflammatory markers (e.g., IL-6, CRP) was limited and inconclusive. Variability in water temperature, immersion duration, and timing contributed to inconsistent outcomes across studies.

Conclusions. The findings indicate that moderate-to-strong evidence supports the short-term use of CWI to reduce muscle soreness and damage, as well as to enhance perceptual recovery. The effects on performance and inflammation remain unclear, emphasizing the need for protocol standardization. CWI remains a practical tool for athletes, especially in high-load or congested schedules, but its application should be individualized.

Keywords: cold-water immersion, athletic recovery, muscle soreness, randomized controlled trials, exercise-induced muscle damage.

Introduction

Muscle recovery is a critical component of athletic training and performance maintenance. Intense or prolonged physical activity induces structural and metabolic stress in skeletal muscle, resulting in exercise-induced muscle damage (EIMD) (Mielgo-Ayuso & Fernández-Lázaro, 2021). Common symptoms of EIMD include reduced muscular strength, stiffness, swelling, and delayed onset muscle soreness (DOMS), all of which can negatively impact subsequent performance if not adequately addressed (Peake et al., 2017). Efficient recovery is particularly essential in competitive sports settings, where athletes are often required to perform multiple bouts of high-intensity effort within limited recovery windows. Inadequate recovery has been associated with increased fatigue, elevated risk of injury, and impaired long-term performance adaptations

(Doherty et al., 2021; Kellmann et al., 2018). In contrast, the application of effective recovery strategies promotes the restoration of muscle function, reduces inflammation, replenishes energy stores, and enhances psychological readiness (Edholm et al., 2024a). Recovery is now widely recognized as an active phase of the training cycle, involving integrated physiological, biochemical, and psychological processes that aim to restore homeostasis and prepare the athlete for subsequent workloads (Rebelo et al., 2025). Among the various recovery strategies studied in recent decades, cold-water immersion (CWI) has garnered substantial attention for its potential to alleviate DOMS and accelerate muscle recovery. CWI typically involves submerging the body or limbs in cold water (10°C–15°C) for 10–15 minutes following exercise. The proposed benefits of CWI include reduced muscle soreness, attenuated inflammation, and expedited return to baseline performance levels. Mechanistically, CWI is believed to act via peripheral vasoconstriction, reduced metabolic activity, hydrostatic pressure effects, and altered neuromuscular signalling, though these mechanisms remain incompletely understood (Algafly & George, 2007; Peake et al., 2017). Several randomized controlled trials (RCTs) and meta-analyses have evaluated the efficacy of CWI for enhancing post-exercise recovery. A 2025 network meta-analysis concluded that medium-duration CWI at moderate temperatures (11°C–15°C) significantly reduced DOMS and improved markers of muscle function, such as jump performance (Wang et al., 2025). Similarly, Xiao et al. reported that immediate application of CWI following strenuous exercise resulted in reduced subjective fatigue and enhanced perceptual recovery (Xiao et al., 2023). Despite such findings, the literature remains inconclusive due to inconsistencies in CWI protocol parameters (e.g., temperature, immersion depth, duration), variation in study populations, and heterogeneity in outcome measures.

These methodological discrepancies hinder direct comparisons between studies and limit the generalizability of findings. Therefore, a systematic synthesis of high-quality evidence is warranted to clarify the role of CWI in post-exercise recovery. This systematic review aims to critically evaluate randomized controlled trials published between 2000 and 2024 that investigated the effects of cold-water immersion on post-exercise recovery outcomes. The review focuses on key domains such as muscle soreness, muscle function, biochemical markers of muscle damage, inflammation, fatigue, and overall athletic performance. The findings will help establish the current state of evidence, identify optimal CWI protocols, and provide evidence-based recommendations for practitioners in sports science and athletic rehabilitation.

Materials and Methods

Registration

The present systematic review was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021) and registered in an international database of systematic reviews in health and social care (PROSPERO CRD420251068097).

Literature Search: Administration and Update

A systematic literature search was performed, and updated up to May 2025, in the electronic databases PubMed, Web of Science, SCOPUS and ProQuest using the Boolean operators AND/OR, in combinations with the keywords: "muscle damage", "muscle soreness", "cold-water immersion", "cooling intervention", "cold exposure", "rct", "random", "sport", "athlete", "player", "muscle recovery", "post-exercise recovery". One author (RD) conducted the initial search and removed duplicates. Two authors (AS and SP) independently screened the titles, abstracts, and full-texts of the retrieved studies. The search results were then analysed according to the eligibility criteria (Table 1). A third author (RS) resolved potential disagreements between AS and SP.

Inclusion and Exclusion Criteria

Studies were selected based on predefined eligibility criteria using the PICOS framework (Participants, Interventions, Comparators, Outcomes, and Study Design) (Liberati et al., 2009). Only original, peer-reviewed, full-text articles published in English were considered for inclusion. Additional exclusion criteria are detailed in Supplementary File 1.

Table 1 Inclusion criteria according to the PICOS conditions

Items	Details Inclusion Criteria
Population	Athletes
Intervention	effects of recovery strategies, specifically cold-water immersion, Contrast water immersion on post-exercise recovery and performance.
Comparison	Two or more groups
Outcome	muscle recovery (e.g., markers of muscle damage, inflammation) and/or performance indicators (e.g., strength, power, endurance)
Study Design	randomised controlled trials (RCT)

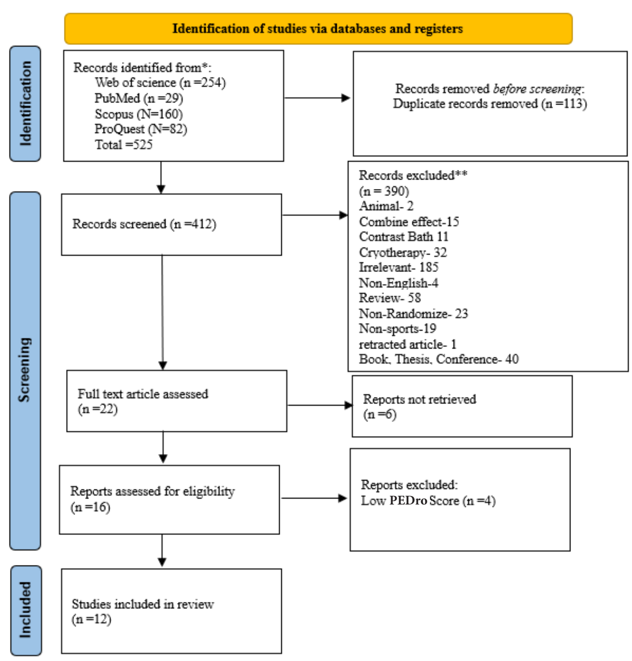

Fig. 1 PRISMA flow chart of the study selection process

Table 2. Characteristics of the studies examined in the present review

Author (Year)	Design	Participants	Intervention	Comparator	Outcomes Measured	Main Findings
(Micheletti et al., 2019)	RCT	64 male youth footballers (13–17 yrs)	CWI (13°C, 15 min)	Passive rest	Lactate, HRV, DOMS, MVIC, agility, sprint, recovery score	CWI improved lactate clearance and HRV; no significant effect on performance outcomes
(Leeder et al., 2019)	RCT	16 male athletes (rugby, hockey, football)	CWI post-tournament	Control	Sprint performance, soreness	CWI maintained sprint speed and reduced soreness at 24–48h
(Chow et al., 2018)	RCT	24 amateur rugby players	CWI (ice bath) vs room temp water	Room temp immersion (25°C)	Jump height, agility, pain threshold	Mixed results: improved jump recovery, no significant effect on agility
(Halson et al., 2014)	RCT	24 cyclists	CWI (15°C, 15 min) after training blocks	Control	Power output, CMJ, adaptation markers	No significant long-term benefit; acute power unchanged
(Parouty et al., 2010)	RCT	14 competitive swimmers	CWI (10°C, 15 min) post-sprint	Passive rest	100m freestyle time, HR, lactate, RPE	CWI improved 100m performance and reduced RPE/lactate
(Roonkiani et al., 2020)	RCT	20 young male soccer players	CWI (10°C, 15 min post-match)	Control	CK, LDH, muscle soreness	CWI reduced CK, LDH and soreness significantly at 24–48h
(Elias et al., 2013)	RCT	21 elite male footballers	CWI post-match (10°C for 10 min)	Passive recovery	CMJ, MVC, soreness, fatigue	CWI improved CMJ and soreness at 24–48h; faster neuromuscular recovery
(Ascensão et al., 2011)	RCT	20 junior soccer players (18.2 ± 1.3 yrs)	CWI at 10°C for 10 min post-match	Thermoneutral water immersion (35°C, 10 min)	CK, Myoglobin, CRP, DOMS (quad, calf, adductors), Strength, Jump, Sprint (0–20m)	CWI reduced CK and CRP at 24–48h; improved strength and reduced quadriceps and calf soreness at 24h
(Duñabeitia et al., 2022)	RCT	34 recreational runners	Massage + CWI	Control	Running economy, lower-limb biomechanics	CWI + massage preserved running economy; limited effects on biomechanics
(Leeder et al., 2015)	RCT	15 trained athletes	Seated vs standing CWI (10°C, 10 min)	Passive control	Sprint recovery, DOMS	Standing CWI more effective in reducing DOMS and improving sprint performance
(Barber et al., 2020)	RCT	20 male rugby players	Repeated CWI at 14°C for 15 min	Passive rest	CMJ, strength, RPE, DOMS, fatigue	Improved strength and power at 24–48h; reduced perceived fatigue
(Tavares et al., 2020)	RCT	12 highly trained volleyball athletes (age: 20.7 ± 2.6 years; all male)	12 min cold-water immersion (10°C) after each training session for 5 days	Passive recovery (rest in seated position)	CMJ height, muscle soreness, perceived recovery, muscle damage markers (CK), fatigue ratings, training loads	No significant group × time interaction for performance. CWI group had significantly lower soreness and fatigue during training week; no effect on CMJ or CK.
(Janusiak et al., 2025)	RCT	48 basketball players	Recovery including CWI	Active recovery	Pressure pain threshold	Significant improvement in pressure pain threshold post-intervention
(Stearns et al., 2018)	RCT	33 elite triathletes (22 males, 11 females); mean age 40 ± 11 years; participated in Ironman WC	10 min cold-water immersion (CWI) at 10°C immediately post-race	Passive rest (no CWI)	DOMS, CK, myoglobin, IL-6, CRP, cortisol, hydration (Usg, BML), Tgi	No significant group × time effects for any outcome. CWI did not enhance recovery of muscle damage or inflammation markers within 40 hrs post-race.
(Guo et al., 2022)	RCT	30 elite male race walkers (3 groups, n=10 each)	CWI: 10°C for 10 min daily post-training over 15 days	CWT and Control (stretching only)	IL-6, PGE2, RPE, Muscle soreness (VAS)	CWI reduced IL-6 and PGE2 vs CWT; no significant change in RPE or soreness
(Sánchez-Ureña et al., 2017)	RCT	10 male adolescent basketball players (14 ± 0.4 yrs)	Continuous CWI: 12 min at 12°C; Intermittent: 4×2 min + 1 min rest	Passive seated recovery (12 min)	Muscle soreness (VAS), CMJ, thigh muscle volume	Both CWI protocols reduced soreness and preserved CMJ; no volume change

Data Extraction

After the final inclusion, the following data were extracted from the articles: a) First author name and publication year; b) Study design; c) Types of athletes; d) Participants' characteristics age, sex, height, weight and sample size by group; e) Session; f) Duration; g) Type of exercise training; h) Characteristics of WCI (water temperature) ; i) Characteristics of control group intervention, and j) The main findings are related to predefined outcomes from the experimental and control groups, comparing each other. Data from the included studies were extracted independently by one reviewer (RD), who consulted with another reviewer (SP), and any discrepancies were resolved by a consensus by the third reviewer (RS). Then, the data were transferred to an Excel spreadsheet. This process follows Cochrane Consumer and Communication Review Group's standardised data extraction protocol (Prictor & Hill, 2013).

Study Selection

The study selection process was conducted in multiple stages. Initially, one reviewer (S.P.) performed the preliminary screening, during which duplicate records were removed using Zotero reference management software (Ivey & Crum, 2018). Titles and abstracts were then reviewed to identify studies that potentially met the predefined inclusion criteria focusing on cold water immersion and post-exercise recovery in athletes. In the next stage, the full texts of the shortlisted studies were independently assessed by two reviewers (S.P. and A.S.) to confirm eligibility. Any disagreements regarding study inclusion were resolved through discussion or consultation with a third reviewer (R.D.). Ultimately, twelve randomized controlled trials evaluating the effects of CWI on recovery outcomes in athletic populations were included in this systematic review.

Risk of Bias Assessment

The methodological quality and risk of bias of the included studies were independently assessed by two reviewers (R.D. and A.C.) using the Physiotherapy Evidence Database (PEDro) scale, a valid and reliable tool (De Morton, 2009; Maher et al., 2003; Yamato et al., 2017), widely used in CWI research (Cain et al., 2025; Malta et al., 2021; Nye et al., 2016). Although referred to as a «methodological quality» scale, the PEDro scale primarily evaluates elements associated with the potential for bias in clinical trials. The overall risk of bias of studies was interpreted using the following convention (Cashin & McAuley, 2020) ≤ 3 points was considered as "poor" quality (i.e., high risk of bias), 4–5 points was considered as "moderate" quality, while 6–7 points and 8–10 points was considered as "good" and "excellent" quality, respectively. For practical purposes and given the nature of the research field, we considered studies with ≥ 6 points to have low risk of bias. Two authors (R.D. and A.C.) independently assessed risk of bias, and a third author (R.S.) helped to resolve discrepancies.

Results

A comprehensive search strategy was developed and tailored for each database to optimize both sensitivity and specificity. A total of 525 references were identified through the search. After the removal of 113 duplicate records, 412 unique articles remained. Titles and abstracts were screened, resulting in the exclusion of 383 records due to irrelevance, conference proceedings, or review articles. The remaining 24 full-text articles were assessed for eligibility.

Risk of Bias of the Included Studies

According to the PEDro checklist results (Table 3), the median (i.e., non-parametric) score was 6.0 (low risk of bias – good quality), with four studies (Guo et al., 2022; Janusiak et al., 2025; Micheletti et al., 2019; Sánchez-Ureña et al., 2017) attaining 4–5points (some risk of bias – moderate quality), and 12 studies attaining 6 points (low risk of bias – good quality).

Table 3 Rating of studies according to the Physiotherapy Evidence Database (PEDro) scale

	Study	1	2	3	4	5	6	7	8	9	10	11	Score
1	(Micheletti et al., 2019)	✓	✓	×	×	×	×	×	✓	✓	✓	✓	5
2	(Leeder et al., 2019)	×	✓	×	✓	×	×	×	✓	✓	✓	✓	6
3	(Chow et al., 2018)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
4	(Halson et al., 2014)	×	✓	×	✓	×	×	×	✓	✓	✓	✓	6
5	(Parouty et al., 2010)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
6	(Roonkiani et al., 2020)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
7	(Elias et al., 2013)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
8	(Ascensão et al., 2011)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
9	(Duñabeitia et al., 2022)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
10	(Leeder et al., 2015)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
11	(Barber et al., 2020)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
12	(Tavares et al., 2020)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
13	(Janusiak et al., 2025)	✓	✓	×	✓	×	×	×	✓	×	✓	✓	5
14	(Stearns et al., 2018)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
15	(Guo et al., 2022)	×	✓	×	×	×	×	×	✓	×	✓	✓	4
16	(Sánchez-Ureña et al., 2017)	✓	✓	×	✓	×	×	×	✓	×	✓	✓	5

Participant Characteristics and Intervention Overview

The characteristics of the participants and the cold-water immersion (CWI) interventions from the included studies are summarised in Table 3. A total of 12 studies involving 301 competitive athletes (261 males and 40 females) were analysed. Participants were drawn from a variety of sports disciplines, including football n = 3; (Ascensão et al., 2011; Elias et al., 2013; Roonkiani et al., 2020), team sports combining rugby, football, and hockey n = 2; (Leeder et al., 2015, 2019), swimming n = 1; (Parouty et al., 2010), cycling n = 1; (Halson et al., 2014), rugby n = 3; (Barber et al., 2020; Chow et al., 2018), running n = 1; (Duñabeitia et al., 2022), triathlon n = 1; (Stearns et al., 2018), and volleyball n = 1; (Tavares et al., 2020). Participant ages ranged from approximately 18 to 41 years, with most studies focusing on young adult athletes (18–22 years). Endurance-based cohorts such as triathletes and runners included older individuals (mean ages ~36–41 years). Anthropometric characteristics were generally homogenous within studies, with reported body mass spanning 62–86 kg and height between 168–188 cm. Female athletes were underrepresented and were included in studies involving rugby, swimming, and triathlon. All included participants were reported as well-trained or elite-level athletes. Cold-water immersion was the primary intervention across all studies, with variations in protocol duration, frequency, and water temperature. Control groups typically received either passive rest or alternative recovery modalities such as massage or contrast water therapy. The consistent application of structured recovery interventions across diverse athletic populations enhances the comparability and relevance of findings for performance recovery research.

Interventions Characteristics

The CWI protocols employed across the 12 included studies demonstrated considerable consistency in certain parameters while also exhibiting methodological diversity reflective of practical applications in sport recovery. Water temperatures used for CWI ranged from as low as 5 °C to approximately 15 °C, with the majority of studies utilizing temperatures between 10 °C and 14 °C to induce the intended physiological cooling effects. Immersion durations typically spanned 10 to 15 minutes, although shorter exposure (e.g., 1-minute immersion at 5 °C) and intermittent protocols (e.g., two 5-minute immersions separated by rest) were also reported. The depth of immersion was generally standardized to include the lower limbs up to the level of the iliac crest or hips, and athletes were commonly positioned in a seated posture within temperature-controlled water baths. One study directly compared seated versus standing CWI and reported significantly different hydrostatic pressures at the ankle, highlighting the influence of posture on immersion efficacy. Timing of the intervention was also a critical parameter, with all studies initiating CWI either immediately or within 30 minutes following physical exertion, aligning with recommendations for post-exercise recovery. Control conditions varied across studies and included passive rest at ambient room temperature (approximately 20–28 °C), thermoneutral water immersion (25–35 °C), or no treatment. Additionally, some studies included alternative recovery modalities for comparison, such as contrast water therapy – where participants alternated between hot (38 °C) and cold (12 °C) immersion cycles—and therapeutic massage involving standard friction and pressure techniques applied by trained professionals. These variations reflect the comparative interest in evaluating the relative benefits of CWI versus other commonly used post-exercise recovery strategies. Overall, while the core features of CWI – cold temperature, post-exercise timing, and immersion of the lower limbs – were consistently applied, the specific designs, durations, and supplementary interventions differed across studies. Such heterogeneity in protocols should be carefully considered when interpreting pooled outcomes or assessing the generalizability of findings within athletic populations.

Outcome Measures

The results of the included studies were categorized based on the effects of CWI on various components of physical performance and recovery in athletes. Outcome measures were grouped according to specific fitness or physiological parameters assessed across the studies, such as muscle soreness, strength recovery, inflammatory markers, and performance metrics. All included articles were independently classified by the review authors based on their primary outcome domains. Any discrepancies in classification were resolved through discussion until consensus was achieved. A summary of the studies along with their predefined outcome measures is presented in Table 4.

Effects of Cold-Water Immersion on Recovery Outcomes

Muscle soreness: Several studies have reported significant reductions in delayed-onset muscle soreness (DOMS) following cold-water immersion (CWI) compared to passive recovery or alternative modalities. For example, one trial found that a 14-min immersion in \~14°C water immediately after match-play significantly attenuated perceived soreness at 48 h relative to contrast-water therapy or passive rest (ES ≈ 0.59). Similarly, a soccer study reported that a single 10-min CWI at 10°C after a competitive match significantly lowered soreness in the quadriceps and calf at 24 h, a reduction interpreted by the authors as reflecting accelerated neuromuscular recovery. In a simulated rugby match protocol, two 5-min immersions at 10°C (with a short intermission) likewise yielded markedly lower soreness scores at 24 and 48 h (large effect sizes) compared to a non-immersed control, indicating a pronounced analgesic effect. By contrast, another investigation found no overall soreness difference between CWI and control, but observed that DOMS at 48 h was significantly lower when immersion was performed in a seated versus standing posture ($p = .001$, ES = 1.86), suggesting that hydrostatic pressure may influence recovery. Collectively, these findings support the efficacy of post-exercise CWI in attenuating DOMS, especially during the 24–48 h window following high-intensity or competitive exercise(Ascensão et al., 2011; Barber et al., 2020; Elias et al., 2013; Leeder et al., 2015).

Muscle damage markers: Several studies have evaluated the effect of cold-water immersion (CWI) on markers of muscle damage following simulated sports protocols. Across

Table 4 Research Output

Study	N	Sport	MS	MD	IM	STR	PERF	SUBJ	POW
(Leeder et al., 2019)	21	Team sports	0	+	+	0	+	0	0
(Chow et al., 2018)	18	Rugby	0	0	0	-	0	0	0
(Halson et al., 2014)	21	Cycling	0	0	0	0	+	-	+
(Parouty et al., 2010)	10	Swimming	0	0	0	0	-	0	0
(Roonkiani et al., 2020)	20	Athletes	0	+	0	0	0	0	0
(Elias et al., 2013)	16	Soccer	+	0	0	0	+	+	+
(Ascensão et al., 2011)	21	Team sports	+	0	0	0	0	+	0
(Duñabeitia et al., 2022)	20	Running	0	0	0	0	0	+	0
(Leeder et al., 2015)	21	Team sports	+	0	0	0	0	+	0
(Barber et al., 2020)	16	Rugby	+	+	0	+	0	0	+
(Tavares et al., 2020)	13	Volleyball	0	0	0	0	0	0	0
(Stearns et al., 2018)	33	Triathlon	0	0	0	0	0	0	0

MS = Muscle Soreness, MD = Muscle Damage Markers, IM = Inflammatory Markers, STR = Strength, PERF = Performance, SUBJ = Subjective Recovery or Fatigue, POW = Jump or Power Performance. '+' indicates a significant beneficial effect of CWI, '–' indicates a significant detrimental effect, '0' indicates no significant difference.

these investigations, creatine kinase (CK) consistently emerged as a key biomarker of muscle membrane disruption. In a simulated tournament scenario, CK levels significantly increased following each bout of exercise, with progressive accumulation across three sessions ($p < .001$). However, participants in the CWI group demonstrated significantly lower CK concentrations before ($p = .004$) and after ($p = .001$) the final bout compared to controls, though this effect did not persist at 24 hours post-exercise, suggesting transient protective effects. Interleukin-6 (IL-6) levels were acutely elevated post-exercise ($p < .001$) but were significantly lower in the CWI group after the first ($p = .003$) and third bouts ($p = .038$), indicating an acute anti-inflammatory effect, while C-reactive protein (CRP) also increased over time ($p < .05$), yet no between-group differences were observed at 24 hours, suggesting minimal influence of CWI on prolonged systemic inflammation (Leeder et al., 2019). Similarly, in a soccer-specific study, significant group × time interactions were found for CK ($F(4,64) = 6.64$, $p = .0012$, $\eta^2 = 0.293$) and lactate dehydrogenase (LDH) ($F(4,64) = 2.86$, $p = .0471$, $\eta^2 = 0.152$), with the CWI group exhibiting significantly lower levels of CK at 24 ($p = .031$) and 48 hours ($p = .045$), and reduced LDH at 24 hours ($p = .015$), confirming the muscle-protective effects of CWI in prolonged intermittent exercise (Roonkiani et al., 2020). In another investigation involving a simulated rugby protocol, repeated CWI (2 × 5 min at 10°C) led to large reductions in CK concentrations at 24 hours ($d = –2.63$) and 48 hours ($d = –2.20$), compared to the control group, indicating substantial attenuation of muscle damage(Barber et al., 2020). Collectively, these findings suggest that CWI is effective in blunting post-exercise elevations in CK and IL-6, with more modest or inconsistent effects on systemic inflammatory markers such as CRP and LDH, particularly within the initial 48-hour recovery window.

Inflammatory Markers: Among the twelve studies included in this review, only one study Leeder and his colleagues evaluated the effect of CWI on inflammatory markers. This study assessed interleukin-6 (IL-6) and C-reactive protein (CRP) as indicators of systemic inflammation following repeated sprint exercise. While both IL-6 and CRP levels increased post-exercise, reflecting a typical inflammatory response to high-intensity physical exertion, the application of CWI did not significantly attenuate these elevations compared to the control condition. These findings suggest that, within the context of repeated sprint activity, CWI may have a limited influence on modulating acute inflammatory responses. Therefore, evidence for the anti-inflammatory effects of CWI remains inconclusive and warrants further investigation in future research (Leeder et al., 2019).

Performance outcomes: Performance outcomes across the included studies were assessed through various metrics such as sprint speed, countermovement jump (CMJ), maximal voluntary contraction (MVC), repeated time-trial efforts, and agility-based tasks. The findings revealed mixed effects of CWI on performance, with variations depending on the type of activity, measurement timing, and athletic context. Leeder et al. reported a significant group × time interaction in sprint speed at 24 hours following repeated intermittent running (LIST protocol), with the CWI group maintaining sprint performance while the control group exhibited a decline ($p = .034$; ES = 0.83 ± 0.59). In contrast, CMJ and MVC demonstrated only trivial, non-significant reductions in both groups, suggesting that CWI did not substantially influence neuromuscular recovery in terms of power or strength capacity (Leeder et al., 2019). In a longitudinal training context, researcher found that CWI during a simulated cycling Grand Tour enhanced performance in short, high-intensity efforts. The CWI group showed likely beneficial improvements in 1-second peak power (+4.4% ± 4.2%) and repeat maximal 4-minute cycling bouts (+3.0% ± 3.8%), without hindering adaptation to longer-duration efforts such as the 10-minute time trial. These findings support the role of CWI in preserving or enhancing repeated power output under heavy training loads (Halson et al., 2014). Conversely, a group of authors observed a performance decrement in well-trained swimmers following CWI. Athletes recorded significantly slower 100-meter sprint times after CWI (65.6 ± 3.4 s) compared to passive recovery (64.2 ± 3.5 s; $p < .05$), despite perceiving better recovery. This suggests that CWI may impair short-term explosive performance, potentially due to residual cooling effects affecting neuromuscular contractility (Parouty et al., 2010). A team of researchers investigated performance in elite footballer's post-match and found no statistically significant benefits of CWI on sprint (10 m and 20 m), agility (505 test), or CMJ. However, CMJ height was better maintained in the CWI group relative to the control group, implying a possible neuromuscular preservation effect, although between-group differences were not significant (Elias et al., 2013). Overall, the evidence indicates that CWI may offer selective benefits for performance recovery, particularly for short-duration, high-intensity efforts. However, its effects on explosive or agility-based performance are less consistent, and in some cases, may even be detrimental if applied prior to competition. These variations likely reflect differences in protocol, sport specificity, and physiological demands.

Strength recovery: Two randomized controlled trials investigated the effects of cold-water immersion (CWI) on strength recovery following exercise-induced muscle damage, with contrasting outcomes influenced by differences in protocol. Chow et al. examined the acute effects of a single brief immersion at 5°C and found a significant reduction in isokinetic peak torque of the knee extensors (−8.15%, $p = .018$) and countermovement jump (CMJ) height (−3.23%, $p = .030$) post-intervention, indicating impaired muscular strength and explosive power(Chow et al., 2018). In contrast, researchers employed a repeated immersion protocol (2 × 5 min at 10°C) and reported enhanced recovery of maximal voluntary isometric contraction (MVIC), with strength returning to baseline by 48 hours post-exercise (100.4% in the CWI group vs. 85.8% in control) (Barber et al., 2020). These findings suggest that while very cold, short-duration CWI may negatively affect immediate strength performance, repeated immersion at moderate temperatures is more effective in promoting strength recovery during the post-exercise period.

Subjective recovery/fatigue: Cold-water immersion (CWI) appears to be an effective strategy for improving subjective recovery and reducing fatigue in athletes following intense training or competition. Multiple studies have reported that CWI significantly enhances perceived recovery and reduces fatigue-related symptoms. Athletes who underwent CWI interventions (typically 10 minutes at 10°C) consistently reported better recovery perceptions at 24–48 hours post-exercise compared to control groups, as evidenced in studies involving footballers (Ascensão et al., 2011; Elias et al., 2013), endurance runners (Duñabeitia et al., 2022), and team sport athletes (Leeder et al., 2015). These benefits were reflected through higher perceived recovery scores, lower ratings of fatigue, and reduced delayed onset muscle soreness (DOMS) using tools such as Likert scales, visual analogue scales, and RPE. However, findings by Halson et al. suggest that while CWI may offer short-term perceptual benefits during periods of intensified training, it might have detrimental effects on recovery perception during taper phases (Halson et al., 2014). Overall, the evidence supports CWI as a beneficial recovery modality for improving subjective outcomes in the short term, particularly during high training loads or competitive periods.

Power Performance: Cold-water immersion (CWI) has shown mixed effects on power performance outcomes, with evidence suggesting that its efficacy may depend on the training context and recovery timeline. Several studies report positive effects of CWI on restoring lower-limb power, particularly as measured by countermovement jump (CMJ) height and maximal voluntary isometric contraction (MVIC). In elite footballers and rugby athletes, CWI was effective in attenuating post-exercise declines in CMJ performance and promoting faster recovery of muscle strength within 24–48 hours (Barber et al., 2020; Elias et al., 2013). Barber et al. further demonstrated that repeated CWI sessions significantly restored both CMJ and MVIC values to baseline levels, with large effect sizes supporting its utility in high-impact team sports. Conversely, Halson et al. found no significant benefit of CWI in preserving CMJ performance during prolonged intensified training or taper phases in competitive cyclists, indicating that CWI may be less effective in mitigating chronic training-induced power loss (Halson et al., 2014). Overall, CWI appears to be beneficial for short-term recovery of explosive power following acute bouts of strenuous activity, especially in collision-based or intermittent sports.

Summary of inconsistencies: Across domains, findings were not uniform. Variability likely reflects differing protocols and exercise types. Notably, one study using very cold water (5°C) found some negative outcomes (Chow et al.), whereas studies with milder temperatures (~10–12°C) more often saw benefits. The frequency and timing of immersion (single post-event vs repeated daily exposures) and the nature of the exercise (contact sports vs endurance events) also varied widely among trials. These factors may explain why some studies observed no effect or even slight impairments with CWI, despite a general pattern of reduced soreness, lower damage markers, and faster subjective recovery. Overall, while most evidence favors a beneficial role of CWI for soreness, muscle damage, and some performance and strength outcomes, the magnitude of benefit appears context-dependent.

Discussion

Summary of Key Findings: This systematic review examined the effects of CWI on post-exercise recovery in athletes, synthesizing evidence from 12 randomized controlled trials involving 301 participants from various sporting disciplines. The analysis revealed that CWI consistently reduces delayed-onset muscle soreness (DOMS) within the first 24–48 hours following intense exercise. Reductions in muscle damage biomarkers, particularly CK and lactate dehydrogenase (LDH), were also frequently reported, suggesting CWI's protective effects on muscle integrity. Improvements in subjective recovery metrics such as perceived fatigue and recovery ratings were observed across multiple trials. However, the effects of CWI on neuromuscular performance outcomes, including sprinting, jumping, and maximal voluntary contraction, were heterogeneous and context-dependent. Limited evidence was available on systemic inflammatory markers, restricting conclusions in this domain.

Comparison with Existing Literature: The findings of the present review align with existing literature that highlights the short-term benefits of CWI in attenuating post-exercise soreness and muscle damage. Meta-analyses by (Dupuy et al., 2018; Machado et al., 2016; Wang et al., 2025) support the analgesic and biochemical benefits of CWI, particularly when immersion is conducted shortly after exercise using water temperatures between 10–15 °C for 10–15 minutes. Similarly, recent systematic reviews have indicated moderate-to-large effect sizes for CWI in reducing DOMS and CK concentrations (Hohenauer et al., 2015; Poppendieck et al., 2013). However, the literature presents divergent findings on performance outcomes. While some trials have reported improved or preserved sprint performance and explosive power following CWI (Elias et al., 2013; Leeder et al., 2019), others have documented either no change or performance decrements, especially with very cold immersion (<6°C) or when applied before competition (Halson et al., 2014; Parouty et al., 2010). These inconsistencies are also reflected in prior reviews (Croft et al., 2012; White et al., 2014), emphasizing the importance of protocol specificity, sport context, and timing relative to the performance task.

Mechanistic Explanations: The observed effects of CWI can be explained by several interrelated physiological mechanisms. Cold exposure leads to peripheral vasoconstriction, which reduces local blood flow, limiting edema formation and the infiltration of inflammatory cells (Peake et al., 2016; Wilcock et al., 2006). Hydrostatic pressure exerted during immersion enhances venous return and lymphatic drainage, contributing to the clearance of metabolic byproducts (Xiao et al., 2023). Additionally, reduced tissue temperature slows metabolic activity, decreases nerve conduction velocity, and dampens nociceptor sensitivity—thereby producing analgesic effects and improving perceived recovery (Algafly & George, 2007; White et al., 2014). On the molecular level, CWI may modulate the expression of heat shock proteins, pro-inflammatory cytokines (e.g., IL-6), and oxidative stress markers, although these effects appear to be transient and vary across individuals and exercise types (Howatson & Van Someren, 2008). Conversely, the application of CWI at excessively low temperatures or for prolonged durations may impair muscle contractility by decreasing excitation-contraction coupling efficiency and enzymatic function, potentially explaining the short-term performance decrements observed in some trials (Pointon & Duffield, 2012; Vaile et al., 2008).

Clinical and Practical Implications: These findings carry significant implications for coaches, athletes, and sports medicine professionals. CWI appears to be a valuable recovery tool for mitigating muscle soreness, minimizing muscle damage, and improving perceptual recovery following high-intensity or collision-based sports. It is particularly useful during congested competition schedules, where rapid recovery is essential. However, CWI should be applied with caution prior to performance tasks requiring maximal neuromuscular output due to potential residual cooling effects. Protocols should be tailored to individual needs, considering sport type, recovery window, and immersion parameters. Integrating CWI with other modalities—such as sleep hygiene, nutrition, and compression—may optimize recovery outcomes (Edholm et al., 2024b; Kellmann et al., 2018).

Strengths and Limitations: This review presents several methodological strengths. A comprehensive search strategy, use of standardized data extraction (Cochrane protocol), and rigorous quality assessment using the PEDro scale (with most studies scoring ≥6) enhance the internal validity of the findings. The focus on randomized controlled trials strengthens causal inference. However, limitations should be noted. Considerable heterogeneity in CWI protocols—such as immersion temperature, duration, and timing—complicates cross-study comparisons. Most participants were young, male, well-trained athletes, limiting generalizability to other populations such as females, adolescents, or recreational athletes. Furthermore, small sample sizes, lack of blinding, and limited long-term follow-up in most trials restrict the external validity and clinical applicability of findings. Publication bias could not be ruled out due to the absence of formal funnel plot analysis.

Recommendations for Future Research: Future studies should aim to standardize CWI protocols by systematically varying immersion parameters to determine optimal dosing strategies for different sports and recovery timelines. Research involving female athletes, older populations, and underrepresented sports (e.g., endurance disciplines) is warranted to enhance generalizability. Further exploration of the molecular and systemic effects of CWI—particularly its influence on cytokine profiles, oxidative stress markers, and long-term adaptations—would clarify the underlying mechanisms. High-powered, multi-centre trials with adequate follow-up are needed to evaluate the chronic effects of CWI on performance, recovery kinetics, injury risk, and training adaptation.

Conclusion

This systematic review provides moderate-to-strong evidence supporting the short-term efficacy of cold-water immersion (CWI) as a post-exercise recovery strategy. CWI was consistently effective in attenuating delayed-onset muscle soreness and reducing biochemical markers of muscle damage, particularly creatine kinase, within 24 to 48 hours post-exercise. Improvements in subjective recovery ratings further reinforce its practical utility in high-performance and competitive sport settings. However, the effects on neuromuscular performance outcomes such as sprint speed, countermovement jump, and maximal strength were variable and context-dependent. Similarly, evidence on inflammatory markers remains limited and inconclusive. The therapeutic benefit of CWI appears to be influenced by protocol characteristics, including water temperature, immersion duration, and timing of application. Therefore, individualized application based on sport demands, athlete characteristics, and recovery objectives is recommended. Given the heterogeneity in study designs and underrepresentation of female and recreational athletes, further high-quality randomized controlled trials with standardized protocols are warranted. Long-term studies investigating the chronic effects of CWI on training adaptation, performance, and injury prevention are also necessary to optimize its role in sports recovery frameworks.

Key Points

- Cold-water immersion (CWI) consistently reduces delayed-onset muscle soreness (DOMS) and muscle damage markers (e.g., creatine kinase, LDH) within 24–48 hours post-exercise.

- Subjective recovery (fatigue, perceived recovery) is frequently improved with CWI, supporting its practical use in competitive and high-load athletic contexts.
- Effects on neuromuscular performance (sprint, jump, strength) are variable, showing benefits in some settings but neutral or even negative outcomes in others.
- Evidence on inflammatory markers remains limited and inconclusive, highlighting the need for further research.
- Protocol standardization (temperature, duration, timing) is crucial, as heterogeneous methods contribute to inconsistent findings.

Conflict of Interest

The authors declare that there is no conflict of interest

References

Mielgo-Ayuso, J., & Fernández-Lázaro, D. (2021). Nutrition and Muscle Recovery. *Nutrients, 13*(2), 294. https://doi.org/10.3390/nu13020294

Peake, J.M., Neubauer, O., Della Gatta, P.A., & Nosaka, K. (2017). Muscle damage and inflammation during recovery from exercise. *Journal of Applied Physiology, 122*(3), 559-570. https://doi.org/10.1152/japplphysiol.00971.2016

Doherty, R., Madigan, S.M., Nevill, A., Warrington, G., & Ellis, J.G. (2021). The Sleep and Recovery Practices of Athletes. *Nutrients, 13*(4), 1330. https://doi.org/10.3390/nu13041330

Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts, A.J., Duffield, R., Erlacher, D., Halson, S.L., Hecksteden, A., Heidari, J., Kallus, K.W., Meeusen, R., Mujika, I., Robazza, C., Skorski, S., Venter, R., & Beckmann, J. (2018). Recovery and Performance in Sport: Consensus Statement. *International Journal of Sports Physiology and Performance, 13*(2), 240-245. https://doi.org/10.1123/ijspp.2017-0759

Edholm, P., Ørtenblad, N., Holmberg, H.-C., & Sperlich, B. (2024a). Optimizing recovery strategies for winter athletes: Insights for Milano-Cortina 2026 Olympic Games. *Sport Sciences for Health, 20*(4), 1169-1182. https://doi.org/10.1007/s11332-024-01245-1

Rebelo, A., Pereira, J.R., Broek, G.V., Coelho-e-Silva, M.J., Elferink-Gemser, M.T., & Valente-dos-Santos, J. (2025). Optimizing recovery: The impact of training load in elite volleyball players. *International Journal of Sports Medicine, 46*(05), 356-365. https://doi.org/10.1055/a-2519-9330

Algafly, A.A., & George, K.P. (2007). The effect of cryotherapy on nerve conduction velocity, pain threshold and pain tolerance. *British Journal of Sports Medicine, 41*(6), 365-369. https://doi.org/10.1136/bjsm.2006.031237

Wang, H., Wang, L., & Pan, Y. (2025). Impact of different doses of cold water immersion (duration and temperature variations) on recovery from acute exercise-induced muscle damage: A network meta-analysis. *Frontiers in Physiology,* 16, 1525726. https://doi.org/10.3389/fphys.2025.1525726

Xiao, F., Kabachkova, A.V., Jiao, L., Zhao, H., & Kapilevich, L.V. (2023). Effects of cold water immersion after exercise on fatigue recovery and exercise performance-Meta analysis. *Frontiers in Physiology,* 14. https://doi.org/10.3389/fphys.2023.1006512

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ,* n71. https://doi.org/10.1136/bmj.n71

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gotzsche, P.C., Ioannidis, J.P. A., Clarke, M., Devereaux, P.J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *BMJ,* 339(jul21 1), b2700-b2700. https://doi.org/10.1136/bmj.b2700

Prictor, M., & Hill, S. (2013). Cochrane Consumers and Communication Review Group: Leading the field on health communication evidence. *Journal of Evidence-Based Medicine, 6*(4), 216-220. https://doi.org/10.1111/jebm.12066

Ivey, C., & Crum, J. (2018). Choosing the right citation management tool: EndNote, Mendeley, RefWorks, or Zotero. *Journal of the Medical Library Association, 106*(3). https://doi.org/10.5195/jmla.2018.468

Micheletti, J., Vanderlei, F., Machado, A., de Almeida, A., Nakamura, F., Netto, J., & Pastre, C. (2019). A New Mathematical Approach to Explore the Post-exercise Recovery Process and Its Applicability in a Cold Water Immersion Protocol. *Journal Of Strength And Conditioning Research, 33*(5), 1266-1275. https://doi.org/10.1519/JSC.0000000000003041

Leeder, J., Godfrey, M., Gibbon, D., Gaze, D., Davison, G., van Someren, K., & Howatson, G. (2019). Cold water immersion improves recovery of sprint speed following a simulated tournament. *European Journal Of Sport Science, 19*(9), 1166-1174. https://doi.org/10.1080/17461391.2019.1585478

Chow, G., Chung, J., & Fong, S. (2018). Differential effects of post-exercise ice water immersion and room temperature water immersion on muscular performance, vertical jump, and agility in amateur rugby players: A randomized controlled trial. *Science & Sports, 33*(6), E271-E279. https://doi.org/10.1016/j.scispo.2018.04.005

Halson, S., Bartram, J., West, N., Stephens, J., Argus, C., Driller, M., Sargent, C., Lastella, M., Hopkins, W., & Martin, D. (2014). Does Hydrotherapy Help or Hinder Adaptation to Training in Competitive Cyclists? *Medicine And Science In Sports And Exercise, 46*(8), 1631-1639. https://doi.org/10.1249/MSS.0000000000000268

Parouty, J., Al Haddad, H., Quod, M., Leprêtre, P., Ahmaidi, S., & Buchheit, M. (2010). Effect of cold water immersion on 100-m sprint performance in well-trained swimmers. *European Journal Of Applied Physiology, 109*(3), 483-490. https://doi.org/10.1007/s00421-010-1381-2

Roonkiani, S., Ebrahimi, M., & Majelan, A. (2020). Effect of cold water immersion on muscle damage indexes after simulated soccer training in young soccer players. *Biomedical Human Kinetics, 12*(1), 236-241. https://doi.org/10.2478/bhk-2020-0030

Elias, G.P., Wyckelsma, V.L., Varley, M.C., McKenna, M.J., & Aughey, R.J. (2013). Effectiveness of water immersion on postmatch recovery in elite professional footballers. *International Journal of Sports Physiology and Performance, 8*(3), 243-253. Scopus. https://doi.org/10.1123/ijspp.8.3.243

Ascensão, A., Leite, M., Rebelo, A.N., Magalhäes, S., & Magalhäes, J. (2011). Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. *Journal of Sports Sciences, 29*(3), 217-225. https://doi.org/10.1080/02640414.2010.526132

Duñabeitia, I., Arrieta, H., Rodriguez-Larrad, A., Gil, J., Esain, I., Gil, S., Irazusta, J., & Bidaurrazaga-Letona, I. (2022). Effects of Massage and Cold Water Immersion After an Exhaustive Run on Running Economy and Biomechanics: A Randomized Controlled Trial. *Journal Of Strength And Conditioning Research, 36*(1), 149-155. https://doi.org/10.1519/JSC.0000000000003395

Leeder, J., Van Someren, K., Bell, P., Spence, J., Jewell, A., Gaze, D., & Howatson, G. (2015). Effects of seated and standing cold water immersion on recovery from repeated sprinting. *Journal Of Sports Sciences, 33*(15), 1544-1552. https://doi.org/10.1080/02640414.2014.996914

Barber, S., Pattison, J., Brown, F., & Hill, J. (2020). Efficacy Of Repeated Cold Water Immersion On Recovery After A Simulated Rugby Union Protocol. *Journal Of Strength And Conditioning Research, 34*(12), 3523-3529. https://doi.org/10.1519/JSC.0000000000002239

Tavares, F., Simoes, M., Matos, B., Smith, T., & Driller, M. (2020). The Acute and Longer-Term Effects of Cold Water Immersion in Highly-Trained Volleyball Athletes During an Intense Training Block. *Frontiers In Sports And Active Living,* 2. https://doi.org/10.3389/fspor.2020.568420

Janusiak, M., Rui Miguel da Silva, Francisco Tomás González Fernández, Smoter, M., Kisilewicz, A., & Klich, S. (2025). Eficacia de estrategias de recuperación en umbrales de presión del dolor en jugadores de baloncesto. *Retos,* 65, 569-578. https://doi.org/10.47197/retos.v65.110201

Stearns, R., Nolan, J., Huggins, R., Maresh, C., Munoz, C., Pagnotta, K., Volk, B., & Casa, D. (2018). Influence of cold-water immersion on recovery of elite triathletes following the ironman world championship. *Journal Of Science And Medicine In Sport, 21*(8), 846-851. https://doi.org/10.1016/j.jsams.2017.12.011

Guo, C., Fan, Y., Kong, X., & Zhao, C. (2022). The effect of different water immersion strategies on delayed onset muscle soreness and inflammation in elite race walker. *Journal Of Mens Health, 18*(3). https://doi.org/10.31083/j.jomh1803064

Sánchez-Ureña, B., Martínez-Guardado, I., Crespo, C., Timón, R., Calleja-González, J., Ibañez, S., & Olcina, G. (2017). The use of continuous vs. Intermittent cold water immersion as a recovery method in basketball players after training: A randomized controlled trial. *Physician And Sportsmedicine, 45*(2), 134-139. https://doi.org/10.1080/00913847.2017.1292832

De Morton, N.A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: A demographic study. *Australian Journal of Physiotherapy, 55*(2), 129-133. https://doi.org/10.1016/S0004-9514(09)70043-1

Maher, C.G., Sherrington, C., Herbert, R.D., Moseley, A.M., & Elkins, M. (2003). Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy, 83*(8), 713-721.

Yamato, T.P., Maher, C., Koes, B., & Moseley, A. (2017). The PEDro scale had acceptably high convergent validity, construct validity, and interrater reliability in evaluating methodological quality of pharmaceutical trials. *Journal of Clinical Epidemiology,* 86, 176-181. https://doi.org/10.1016/j.jclinepi.2017.03.002

Cain, T., Brinsley, J., Bennett, H., Nelson, M., Maher, C., & Singh, B. (2025). Effects of cold-water immersion on health and wellbeing: A systematic review and meta-analysis. *PLOS ONE, 20*(1), e0317615. https://doi.org/10.1371/journal.pone.0317615

Malta, E.S., Dutra, Y.M., Broatch, J.R., Bishop, D.J., & Zagatto, A.M. (2021). The Effects of Regular Cold-Water Immersion Use on Training-Induced Changes in Strength and Endurance Performance: A Systematic Review with Meta-Analysis. *Sports Medicine, 51*(1), 161-174. https://doi.org/10.1007/s40279-020-01362-0

Nye, E.A., Edler, J.R., Eberman, L.E., & Games, K.E. (2016). Optimizing Cold-Water Immersion for Exercise-Induced Hyperthermia: An Evidence-Based Paper. *Journal of Athletic Training, 51*(6), 500-501. https://doi.org/10.4085/1062-6050-51.9.04

Cashin, A.G., & McAuley, J.H. (2020). Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. *Journal of Physiotherapy, 66*(1), 59. https://doi.org/10.1016/j.jphys.2019.08.005

Dupuy, O., Douzi, W., Theurot, D., Bosquet, L., & Dugué, B. (2018). An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review With Meta-Analysis. *Frontiers in Physiology,* 9, 403. https://doi.org/10.3389/fphys.2018.00403

Machado, A.F., Ferreira, P.H., Micheletti, J.K., De Almeida, A.C., Lemes, Í.R., Vanderlei, F.M., Netto Junior, J., & Pastre, C.M. (2016). Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis. *Sports Medicine, 46*(4), 503-514. https://doi.org/10.1007/s40279-015-0431-7

Hohenauer, E., Taeymans, J., Baeyens, J.-P., Clarys, P., & Clijsen, R. (2015). The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. *PLOS ONE, 10*(9), e0139028. https://doi.org/10.1371/journal.pone.0139028

Poppendieck, W., Faude, O., Wegmann, M., & Meyer, T. (2013). Cooling and Performance Recovery of Trained Athletes: A Meta-Analytical Review. *International Journal Of Sports Physiology And Performance, 8*(3), 227-242. https://doi.org/10.1123/ijspp.8.3.227

Croft, M., Keely, B., Morris, I., Tann, L., & Lappin, G. (2012). Predicting Drug Candidate Victims of Drug-Drug Interactions, using Microdosing. *Clinical Pharmacokinetics, 51*(4), 237-246. https://doi.org/10.2165/11597070-000000000-00000

White, G.E., Rhind, S.G., & Wells, G.D. (2014). The effect of various cold-water immersion protocols on exercise-induced inflammatory response and functional recovery from high-intensity sprint exercise. *European Journal of Applied Physiology, 114*(11), 2353-2367. https://doi.org/10.1007/s00421-014-2954-2

Peake, J., Roberts, L., Raastad, T., Figueiredo, V., Cameron-Smith, D., Coombes, J., & Markworth, J. (2016). The effects of cold water immersion on inflammation, growth and neurotrophic factors in skeletal muscle after resistance exercise. *The FASEB Journal, 30*(S1). https://doi.org/10.1096/fasebj.30.1_supplement.1291.4

Wilcock, I.M., Cronin, J.B., & Hing, W.A. (2006). Physiological Response to Water Immersion: A Method for Sport Recovery? *Sports Medicine, 36*(9), 747-765. https://doi.org/10.2165/00007256-200636090-00003

Howatson, G., & Van Someren, K.A. (2008). The Prevention and Treatment of Exercise-Induced Muscle Damage. *Sports Medicine, 38*(6), 483-503. https://doi.org/10.2165/00007256-200838060-00004

Pointon, M., & Duffield, R. (2012). Cold Water Immersion Recovery after Simulated Collision Sport Exercise. *Medicine & Science in Sports & Exercise, 44*(2), 206-216. https://doi.org/10.1249/mss.0b013e31822b0977

Vaile, J., Halson, S., Gill, N., & Dawson, B. (2008). Effect of Hydrotherapy on Recovery from Fatigue. *International Journal of Sports Medicine, 29*(7), 539-544. https://doi.org/10.1055/s-2007-989267

Edholm, P., Ørtenblad, N., Holmberg, H.-C., & Sperlich, B. (2024b). Optimizing recovery strategies for winter athletes: Insights for Milano-Cortina 2026 Olympic Games. *Sport Sciences for Health, 20*(4), 1169-1182. https://doi.org/10.1007/s11332-024-01245-1

Занурення у холодну воду та спортивне відновлення: Систематичний огляд рандомізованих контрольованих досліджень (2000–2024)

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 4 табл., 1 рис., 48 джерел.

Історія питання. Занурення у холодну воду (ЗХВ) є поширеною стратегією відновлення серед спортсменів, проте докази її ефективності залишаються суперечливими через розбіжності в протоколах та методах оцінки результатів.

Мета дослідження. Цей систематичний огляд мав на меті оцінити вплив методики ЗХВ на відновлення спортсменів після тренувань, зосередившись на фізіологічних, продуктивних та перцептивних показниках.

Матеріали та методи. Згідно з рекомендаціями переважних елементів звітності для систематичних оглядів і метааналізів (PRISMA) та міжнародного проспективного реєстру систематичних оглядів (PROSPERO) (CRD420251068097), проведено пошук у чотирьох електронних наукометричних базах даних (PubMed, Web of Science, Scopus та ProQuest) щодо рандомізованих контрольованих досліджень (РКД), опублікованих у період з 2000 по 2024 рік. До аналізу включено дослідження, які отримали показник PEDro ≥6. Критеріям включення відповідало 12 РКД. Синтез даних здійснено у формі опису, підкріпленого підрахунком голосів та графіками збору інформації, оскільки гетерогенність перешкоджала проведенню метааналізу.

Результати. Застосування методики занурення у холодну воду сприяло послідовному зменшенню синдрому відстроченого м’язового болю (СВМБ) та біомаркерів пошкодження м’язів (наприклад, креатинкінази, лактатдегідрогенази) протягом 24–48 годин після тренування. У кількох дослідженнях також повідомлялося про поліпшення суб’єктивного відновлення. Вплив на нервово-м’язову продуктивність (наприклад, спринт, стрибок із контррухом) був неоднозначним і, як виявилося, залежав від контексту. Доказові дані щодо маркерів запалення (наприклад, IL-6, CRP) були обмеженими і непереконливими. Варіабельність температури води, тривалості занурення та часових рамок сприяла неоднорідності результатів у різних дослідженнях.

Висновки. Результати дослідження свідчать про наявність помірних та переконливих доказів доцільності короткострокового застосування методики ЗХВ з метою зменшення м’язового болю та пошкодження, а також поліпшення перцептивного відновлення. Вплив на продуктивність та запалення залишається нез’ясованим, що підкреслює необхідність стандартизації протоколу. ЗХВ залишається практичним інструментом для спортсменів, зокрема при високих навантаженнях або напруженому графіку, однак застосування цієї методики має бути індивідуалізовано.

Ключові слова: занурення у холодну воду, спортивне відновлення, м’язовий біль, рандомізовані контрольовані дослідження, пошкодження м’язів, спричинене фізичними навантаженнями.

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Review Article

The Effectiveness of Mental Toughness Training in Athletes: A Systematic Review and Meta-analysis

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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 effectiveness of interventions targeting mental toughness (MT) in sport.

Materials and Methods. Eligibility criteria encompassed quantitative controlled experimental studies of MT interventions in athletes. Information sources comprised studies indexed in Web of Science, PubMed, Scopus, Embase, and SPORTDiscus from inception to April 13, 2025. Reference lists of included studies were also screened. Risk of bias was considered as follows: Two authors independently assessed the reporting quality and risk of bias of included studies using a modified Downs and Black index. Regarding the synthesis of results, the standardized mean difference (SMD) was calculated to evaluate the effects of interventions using the random effect model.

Results. This review included a total of 10 studies involving 465 participants, with sports primarily including soccer (24.7%), basketball (19.7%), and table tennis (17.5%). Seven studies (67.3%) employed a combination of psychological skills training interventions. The meta-analysis incorporated all 10 studies and their respective experimental groups to elucidate the overall efficacy of MT training programs. The pooled effect size was statistically and practically significant, yielding a large standardized mean difference of $g = 0.81$ (95% CI 0.57–1.05, $p < 0.001$), indicating a substantial advantage of MT training interventions over control conditions.

Conclusions. This meta-analysis provides strong empirical evidence supporting the effectiveness of psychological interventions — particularly multicomponent Psychological Skills Training (PST) — in enhancing mental toughness among athletes across different sports. However, due to the lack of long-term follow-up assessments, reliance on quasi-experimental designs, and diversity in measurement approaches, the findings should be interpreted with caution. To advance the field, further research should adopt more rigorous methodologies, including large-scale randomized controlled trials and longitudinal designs, to identify the most effective components and delivery methods for developing mental toughness. These efforts will ultimately inform evidence-based practices for coaches, psychologists, and practitioners aiming to cultivate high-performing athletes.

Keywords: mental toughness, psychological skills training, athletes, intervention.

Introduction

Over the past few decades, sports researchers have been dedicated to exploring the concept of mental toughness, aiming to gain a deeper understanding of individuals who can consistently deliver high – level performances in challenges, stress, or adversity (Konter et al., 2019). To enhance comprehension of mental toughness, studies employing quantitative or qualitative methods have been conducted across various sports categories. These efforts have led to updates and more empirical advances in the conceptual construction (e.g., Jones et al., 2002; Clough et al., 2002; Gucciardi et al., 2008), assessment tools (e.g., Clough et al., 2002; Sheard et al., 2009), and effectiveness of mental toughness (e.g., Clough & Strycharczyk, 2012; Mahoney et al., 2014). Since the millennium, the growing research interest, driven by the potential link between mental toughness and successful performance, has clearly reflected the value placed on this concept by sport psychologists, coaches, and athletes.

Mental toughness training is crucial for enhancing athletes' psychological qualities. Research indicates that the cultivation of mental toughness a nonlinear, long-term process driven by a continuous interaction between individuals (training, experiential learning), society, and the environment (support systems) (Connaughton et al., 2008). Studies based on interviews and analyses have shown that factors such as the sporting process, interpersonal relationships within and beyond sports, and the broader family and social environment all contribute to the development of mental toughness, through the navigation of both positive and adverse experiences (Thewell et al., 2010). In addition, coaches play a key role in psychological resilience training. They can boost athletes' mental toughness by creating a positive training environment and teaching mental strategies such as goal – setting, visualization, positive self – talk, and mental rehearsal (Butt et al., 2010). Prior research has underscored the importance of cultivating independence and adaptability in young athletes within an environment that is both supportive and challenging (Cook et al., 2014). Through a systematic review focusing on studies in athletic and competitive contexts, an integrated framework was proposed, positing that mental toughness arises from the dynamic interactions among individual attributes, contextual systems, and participation in progressively challenging activities as a long-term process (Anthony et al., 2016). Building on this, subsequent studies proposed coach-targeted educational programs that integrate mental toughness theory with the GROW model to facilitate the development of mental toughness among elite athletes (Anthony et al., 2018). From the perspective of sport psychology, it has been suggested that coaches can effectively enhance athletes' mental toughness by exposing them to challenging situations and teaching relevant psychological skills (Weinberg et al., 2016). Furthermore, research emphasizes the need for coaches to adopt intentional strategies in fostering mental toughness—taking into account individual athlete differences, promoting autonomy, and creating environments that are simultaneously supportive and demanding (Weinberg et al., 2018).

However, most studies are limited to qualitative interviews or quantitative cross – sectional designs. The lack of evidence – based information on effective developing and sustaining mental toughness training strategies has hindered the progress of mental toughness training practices (Stamatis et al., 2020). Therefore, a systematic summary and evaluation of the effectiveness of empirically – tested mental toughness interventions in sports is necessary.

There is no denying that some narrative and systematic reviews have been published to explore various strategies for developing mental toughness (MT) and offering insights and support for relevant practices. However, these reviews predominantly focus on qualitative research, cross-sectional studies, or the integration of mixed-methods observational research with quantitative experimental studies (e.g., Crust & Clough, 2011; Anthony et al., 2016; Stamatis et al., 2020). Guided by PRISMA standards, this review centers on quantitative experimental research concerning mental toughness interventions. It aims to conduct a systematic review and meta-analysis of all available empirical evidence regarding the effectiveness of MT training. By doing so, it seeks to provide guidance for potential recommendations that can help practitioners and researchers design and evaluate evidence-based MT training programs. Thus, this study intends to systematically review and meta – analyze existing evidence to address the research question of whether there are valid and empirical interventions for sport MT training.

Materials and methods

Eligibility criteria

After an initial search for relevant literature, the author team drafted and revised the eligibility criteria. Following the Population, Intervention, Comparison, Outcome, and Study design (PICOS) principles, the study selection criteria were as follows:

Population: Participants included athletes of any age or gender involved in a sport who received varying levels of mental toughness (MT) interventions. These athletes originated from two types of studies: those that specifically employed psychological and/or physical methods to enhance athletes' MT levels, and those that assessed MT changes as a byproduct of athletic training protocols not necessarily targeting MT.

Intervention: MT interventions broadly encompassed any psychological and/or physical strategies prescribed to athletes to influence their MT levels. There were no restrictions on the type, components, frequency, or duration of the training.

Comparison: The comparison focused on the differences between a control group and an experimental group in outcome variables resulting from the interventions.

Outcome: Studies were required to include outcome measures related to MT. These outcome measures were obtained through pre – and post – tests (including self – report tools specifically designed to measure MT and other tools used by researchers to infer athletes' MT levels).

Study design: This protocol involved quantitative pre- and post – test experimental studies aimed at investigating the effects of MT interventions on athletes' MT levels. Both randomized controlled trials and non – randomised studies (e.g., quasi – experimental designs) were considered, while Case studies and single-arm studies were excluded. There was no publication date limitation, but the studies were restricted to English – language papers.

Information Sources

The authors searched the following five electronic databases to identify relevant studies: Web of Science, PubMed, Scopus, Embase, and SPORTDiscus. Additionally, the reference lists of included studies, related reviews, and books were screened to identify other potentially relevant sources. The search was not restricted by publication year but was limited to articles published in English. The final search was conducted on April 13, 2025.

Search Strategy

This systematic review and meta-analysis were conducted in accordance with the PRISMA reporting guideline (PRISMA 2020 statement). The review protocol was prospectively registered in PROSPERO (registration number: CRD420251036604). The above five electronic databases were searched using a Boolean logic-based multi-field search strategy without restrictions on the date range. Specifically, (1) Web of Science: mental toughness (Title) AND sport* OR athlete* OR player* OR athletic* OR exercise* OR training* OR developing (All Fields); (2) PubMed: (mental toughness[Title/Abstract]) AND (sport* OR athlete* OR player* OR athletic* OR exercise* OR training* OR developing)) AND (English[Language]; (3) Scopus: TITLE (mental AND toughness) AND TITLE-ABS-KEY (sport* OR athlete* OR player* OR athletic* OR exercise* OR training* OR developing)) AND (LIMIT-TO (LANGUAGE, "English"); (4) Embase: ('mental toughness'/exp OR 'mental toughness' OR (mental AND ('toughness'/exp OR toughness))) AND 'mental toughness':ti AND (sport*:ti,ab,kw OR athlete*:ti,ab,kw OR player*:ti,ab,kw OR athletic*:ti,ab,kw OR exercise*:ti,ab,kw OR training*:ti,ab,kw OR developing:ti,ab,kw) AND [english]/lim; (5) SPORTDiscus: TI mental toughness AND (sport* OR athlete* OR player* OR athletic* OR exercise* OR training* OR developing).

Selection Process

Two reviewers were involved in the study selection process and independently screened titles and abstracts to assess their relevance. Studies that fell outside the scope of this systematic review were excluded. All eligible articles were then subjected to full-text screening, with two researchers independently evaluating the eligibility of the identified articles based on the inclusion criteria. Any disagreements between reviewers were resolved by consensus or confirmation of a third investigator.

Data Collection Process

Data extraction was conducted by one researcher using a standardized form from the full texts of eligible articles, with a second researcher verifying the accuracy and completeness of the extracted data. Discrepancies regarding the extracted data were resolved by consensus or confirmation of a third investigator.

Data Items

The authors extracted the following information from each of the included studies: (1) publication details (authors, year); (2) participant characteristics (number of participants, country, age, gender, role); (3) research design, number of experimental groups and number of participants per group; (4) intervention strategies, including training tools/techniques implemented intervention duration and frequency; (5) measurement tools and types of outcome metrics used; and (6) effect sizes.

Study Risk of Bias Assessment

To assess the reporting quality and risk of bias of the studies included in our review, two authors independently utilized a modified Downs and Black index (Downs & Black, 1998) to evaluate the studies. This method is suitable for assessing the reporting quality of both randomized and non – randomized intervention studies and is widely used in systematic reviews related to sports science (Toth et al., 2020; Thurlow et al., 2024; Kittel et al., 2025). A score of 0 was assigned for any item that lacked explicit information for accurate assessment. The study quality was evaluated by two investigators independently and any discrepancies were resolved by consensus or confirmation of a third investigator.

Effect Measures

The primary outcome of interest is self-reported and other-reported MT ratings, with MT scores translated into standardised variables to address heterogeneity in measurement tools. The intended summary effect measures are standardised mean differences (SMDs), applicable to between-subjects design. SMDs were estimated according to each study's design. The meta-analyses were implemented using RevMan 5.4 (Cochrane Collaboration, Oxford, UK) in this review for the effect size estimates. The standardized mean difference (SMD) with 95% confidence intervals (CI) was extracted from the pre- and post-intervention.

Synthesis Methods

Pooled effect sizes were estimated using a random effects model and were presented in forest plots. The heterogeneity was assessed using the I^2, with I^2 values of 25%, 50%, and 75% indicating low, medium, and high heterogeneity, respectively (Higgins & Thompson, 2002). The random-effects model assumes that each observed effect size is a random draw from a distribution of true effects, so between-study variability reflects both sampling error and genuine heterogeneity (Wang et al., 2023). Sensitivity analyses were conducted to assess the robustness of the pooled effect across study designs by comparing randomised controlled trials with quasi-experimental studies. A leave-one-out procedure was employed to determine whether any single investigation materially altered the overall estimate.

Reporting Bias Assessment

Reporting bias and small-study effects were examined via funnel-plot inspection and Egger's test (Egger et al., 1997). Asymmetry was considered present when the funnel plot showed visual distortion and the Egger intercept yielded $p < 0.10$.

Results

Study Selection

The initial search yielded 1297 studies. Following the removal of duplicates (n=465) and retraction(n=1), 831 underwent title and abstract screening, 29 articles were subject to full text review and 21 studies were excluded for not meeting the eligibility criteria. In addition, 7 relevant studies were identified through citation searching, 2 studies were included after full-text review. This process resulted in a total of 10 studies included in the review (see Figure 1).

Study Characteristics

The combined participant count across all included studies was 465, with an average sample size of 47 participants

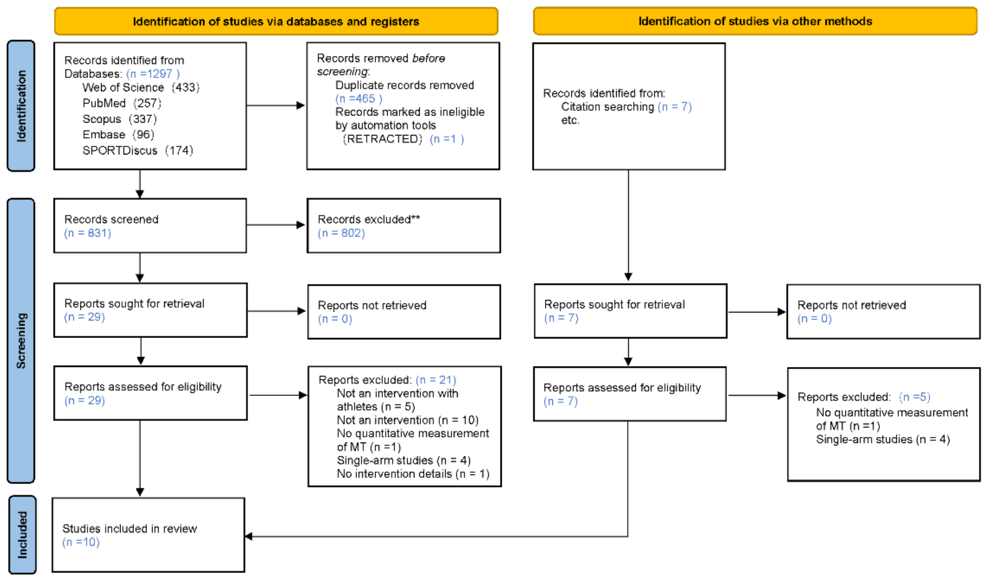

Fig. 1. PRISMA flow chart of search process

Table 1. Summary of included studies in this review.

Study	Population	Study Design	Intervention		Measures
Authors, Year	**Characters**	**Type/ Arm**	**Strategies**	**Duration /Frequency**	**Tools**
Abdelbaky, 2012	Race walking Romania Gender missing	QED EG CG	Mental Toughness Program	8 weeks, 3 days per week	PPI
Ajilchi et al., 2019	Basketball Iran male	RCT EG CG	Mindful Sport Performance Enhancement	6 weeks, 1 session(90-min) per week	MTQ48
Ajilchi et al., 2022	Type missing Iran Female	RCT EG CG	Mindfulness–Acceptance–Commitment programme	7 weeks, 1 session(45-min) per week	SMTQ
Bell et al., 2013	Cricket UK male	QED EG CG	Mental toughness training program	2 years, 5 events, 46 days in total	MTI
Bhambri et al., 2005	Table –tennis India Male & female	QED EG-COM EG-IM EG-RE CG	Imagery training; Relaxation training; Combination	2 weeks	PPI
Gucciardi et al., 2009	Football Australia male	QED EG-PST EG-MTT CG	Psychological Skills Training program	6 weeks, 1 session(120-min) per week	AfMTI
Pociusi et al., 2024	Basketball Lithuania male	QED EG CG	mental toughness skills training program	6 weeks, 1 session(60-min) per week	MTQ48
Putra et al., 2025	Type missing Indonesia Male & female	QED EG CG	MTTC model	11 weeks, 3 session(75-100-min) per week	MTI-G
Sharma et al., 2023	Table tennis India male	QED EG CG	Visual Motor Behaviour Rehearsal Training	6 weeks, 3 session(40-min) per week	SMTQ
Singh et al., 2020	Football India Gender missing	QED EG CG	Visuo Motor Behavioral Rehearsal	6 weeks, 5 session(30-min) per week	PPI

Note: RCT, Randomized Controlled Trial; QED, Quasi-experimental Design; EG, Experimental Group; CG, Control Group; COM, Combination Group; IM, Imagery Group; RE, Relaxation Group; MTT, Mental Toughness Training Group; PST, Psychological Skills Training Group; PPI, Psychological Performance Inventory; MTQ48, Mental Toughness Questionnaire (48 Items); SMTQ, The Sports Mental Toughness Questionnaire; MTI, Mental Toughness Inventory; AfMTI, Australian football Mental Toughness Inventory; MTI-G, Mental Toughness Index (Gucciardi).

per study. The studies encompassed a diverse range of sports and athletic skill levels. In terms of sports, the primary ones were football (n=24.7%), basketball (n=19.7%), and table tennis (n=17.5%), with other sports such as cricket, race walking also represented. Two studies did not specify the particular sport (n=11.1%). Regarding skill levels, three studies featured national-level athletes (n=18.8%), while others included athletes from sports academies, state-level, student-athletes, sport science students, and amateurs.

Seven studies shared the most popular intervention strategy, which was a combination of multiple psychological skill trainings (n=67.3%), including techniques like self-talk, imagery, mental rehearsal, arousal regulation, attention control, active games, relaxation, breathing, progressive muscle relaxation, and goal-setting. Mindfulness training was the focus of two studies (n=16%), and Visual Motor Behaviour was examined in two others (n=19.2%), though the main techniques were linked to psychological skill training. One study looked into the role of stressful environments with multidisciplinary team support (n=8.8%). One experimental group in a study focused on developing key mental toughness traits(7.9%), while the other experimental group used PST combination strategy.. Table 1 presents a summary of the participants and study characteristics of the included studies. For more details, please see Supplementary Information.

Risk of Bias in Studies

Table 2 summarises the outcomes of the modified Downs and Black scale for the assessment of reporting quality and risk of bias. Results ranged from 7 to 11, with a mean score of 9.5 ± 1.03.

Results of Individual Studies

Details of the training strategies and study outcomes of individual studies were provided in Table 1. Figure 2 displays the forest plot of individual-study standard mean difference (SMD) and the pooled effect estimate for MT training outcomes. The analysis is restricted to published data only.

Results of Syntheses

The estimated standardized mean differences (SMDs) ranged from 0.05 (Sharma & Prasad, 2023) to 2.30 (Ajilchi

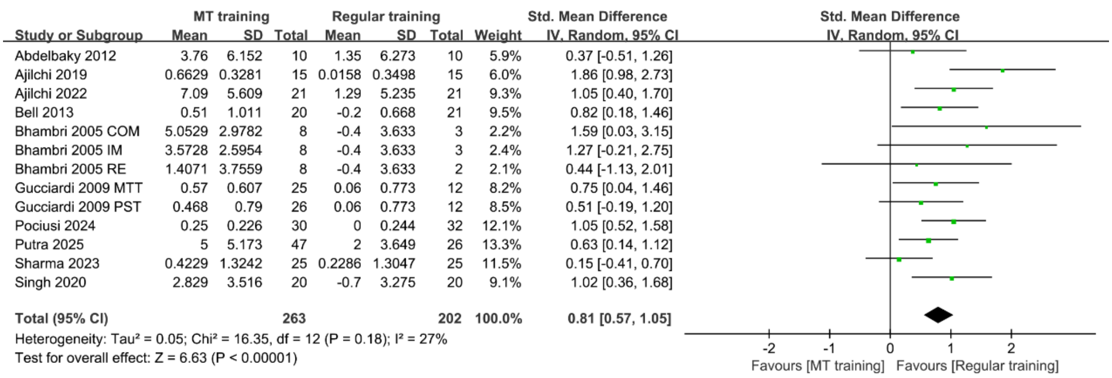

Fig. 2. Forest plot for meta-analyses. COM, Combination Group; IM, Imagery Group; RE, Relaxation Group; MTT, Mental Toughness Training Group; PST, Psychological Skills Training Group

Table 2. Modified Downs and Black scale outcomes for the assessment of reporting quality and risk of bias.

Study	Quality Assessment Domains														Total/14
	1	2	3	6	7	10	12	15	18	20	22	23	25	27	
Abdelbaky, 2012	1	1	1	1	1	1	0	0	1	1	1	1	1	0	11
Ajilchi et al., 2019	1	1	1	1	1	1	0	0	1	1	0	1	1	0	10
Ajilchi et al., 2022	1	1	1	1	1	1	0	0	1	1	0	1	1	0	10
Bell et al., 2013	1	1	1	1	1	1	0	0	1	1	0	0	1	0	9
Bhambri et al., 2005	1	1	1	1	1	1	0	0	1	1	1	0	0	0	9
Gucciardi et al., 2009	1	1	1	1	1	1	0	0	1	1	0	1	1	0	10
Pociusi et al., 2024	1	1	1	1	1	1	0	0	1	1	0	1	1	0	10
Putra et al., 2025	1	1	1	1	1	1	0	0	1	1	0	1	0	0	9
Sharma et al., 2023	1	1	1	1	1	1	0	0	1	1	1	1	0	0	10
Singh et al., 2020	1	1	1	1	1	0	0	0	1	0	1	0	0	0	7

Note: 0 = no; 1 = yes; U = unable to determine. Item 1: clear aim/hypothesis; Item 2: outcome measures clearly described; Item 3: patient characteristics clearly described; Item 6: main findings clearly described; Item 7: measures of random variability provided; Item 10: actual probability values reported; Item 12: participants prepared to participate representative of the entire population; Item 15: blinding of outcome measures; Item 18: appropriate statistics; Item 20: valid and reliable outcome measures; Item 22: participants recruited over the same period; Item 23: randomised; Item 25: adjustment made for confounding variables; Item 27: a power to detect a clinically important effect.

Table 3. Sensitivity Analyses Results

Study omitted	Estimate			Heterogeneity:		
	SMD	95% Conf. Interval	P	Q	P	I^2
ALL trials include	0.81	[0.57, 1.05]	P < 0.0001	16.35	0.18	27%
Nonrandomized controlled trials	0.79	[0.40, 1.18]	P < 0.0001	13.86	0.03	57%
Abdelbaky, 2012	0.84	[0.59, 1.08]	P < 0.0001	15.46	0.16	29%
Ajilchi et al., 2019	0.73	[0.53, 0.93]	P < 0.0001	10.33	0.50	0%
Ajilchi et al., 2022	0.78	[0.53, 1.04	P < 0.0001	15.67	0.15	30%
Bell et al., 2013	0.81	[0.55, 1.08]	P < 0.0001	16.34	0.13	33%
Bhambri et al., 2005 COM	0.79	[0.55, 1.03]	P < 0.0001	15.33	0.17	28%
Bhambri et al., 2005 IM	0.80	[0.55, 1.04]	P < 0.0001	15.94	0.14	31%
Bhambri et al., 2005 RE	0.82	[0.57, 1.07]	P < 0.0001	16.15	0.14	32%
Gucciardi et al., 2009 MTT	0.82	[0.55, 1.08]	P < 0.0001	16.34	0.13	33%
Gucciardi et al., 2009 PST	0.84	[0.58, 1.09]	P < 0.0001	15.67	0.15	30%
Pociusi et al., 2024	0.78	[0.52, 1.04]	P < 0.0001	15.30	0.17	28%
Putra et al., 2025	0.84	[0.57, 1.11]	P < 0.0001	15.89	0.15	31%
Sharma et al., 2023	0.88	[0.67, 1.09]	P < 0.0001	10.46	0.49	0%
Singh et al., 2020	0.79	[0.53, 1.05]	P < 0.0001	15.85	0.15	31%

Note: Nonrandomized controlled trials included: Bell et al., 2013, Bhambri et al., 2005 (CON, IM, RE), Putra et al., 2025, Singh et al., 2020.

et al., 2019), reflecting intervention-specific effects spanning the continuum from negligible to highly substantial. Bhambri et al. (2005) included three intervention arms—two single-strategy PST conditions (Relaxation and Imagery) and one combined-strategy condition, whereas Gucciardi et al. (2009) provided two arms consisting of a composite PST protocol and a key mental toughness traits protocol (MTT). Together, these five arms were retained in this meta-analysis to elucidate the overall efficacy of mental toughness training programmes. The pooled effect size was both statistically and practically significant, yielding a large standardized mean difference of $g = 0.81$ (95 % CI 0.57–1.05, $p < .001$), indicating a robust advantage for mental-training interventions over control conditions. The entire confidence interval(CI 0.57–1.05) lies above Cohen's threshold for a medium effect, providing compelling evidence of the efficacy of mental-training interventions. The 95 % CI's width reflects modest imprecision attributable to the limited study pool, yet its entirety lies in the large-effect range. Thus, the evidence robustly affirms the efficacy of mental-training interventions for heightening mental toughness across varied athletic populations. The heterogeneity among studies was low (Q=16.35) $I^2 = 27\%$, $p = 0.18$), indicating acceptable consistency across included trials and supporting the use of a random-effects model in the meta-analysis. Sensitivity analysis was conducted by removing nonrandomized controlled trials; the remaining trials (n = 7) continued to demonstrate a statistically significant effect ($g = 0.79$, 95% CI 0.40–1.18, $p < .001$). Heterogeneity was significant and moderate ($Q = 13.86$, $I^2 = 57\%$, $p = 0.03$). A sensitivity analysis using the leave-one-out method was conducted to examine the influence of individual studies on the overall pooled effect size and heterogeneity. Excluding the study with the highest standardized mean difference (Ajilchi et al., 2019) reduced the pooled SMD from 0.79 to 0.73 (95% CI: 0.53–0.93, $p < .001$), with heterogeneity decreasing from $I^2 = 27\%$ to 0%. Conversely, removing the study with the lowest effect size (Sharma & Prasad, 2023) increased the pooled SMD to 0.88 (95% CI: 0.67–1.09, $p < .001$), again resulting in $I^2 = 0\%$. These changes suggest that methodological differences or potential bias in individual studies may account for the observed heterogeneity. However, across all iterations of the leave-one-out procedure in Table 3, the pooled effect estimates remained within a narrow range (0.73–0.88), indicating that no single study unduly influenced the overall findings. This supports the robustness and reliability of the meta-analytic results.

Reporting Biases

As shown in Figure 3, the funnel plot appears visually symmetrical, with an approximately equal distribution of studies on both sides of the mean effect size. Given the inclusion of only 10 studies, it is difficult to reliably detect

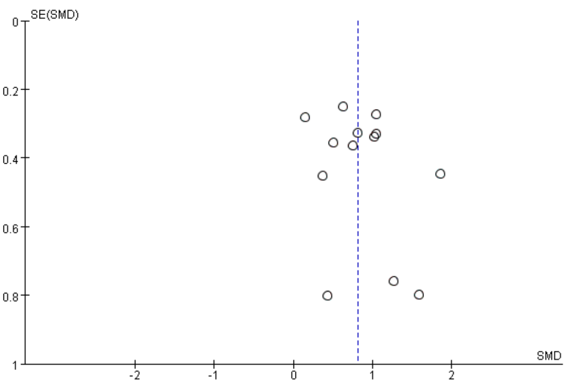

Fig. 3. Funnel plot

deviations from the ideal distribution. Furthermore, Egger's regression test yielded a bias coefficient of 1.05 (SE = 1.01, t = 1.04, p = 0.321), indicating no statistically significant asymmetry in the funnel plot. Therefore, there is no evidence of publication bias in this analysis.

Discussion

Compared to previously published narrative and systematic reviews, the present study provides more empirical support for the development of mental toughness by strictly limiting the inclusion criteria to quantitative controlled experimental studies. This meta-analysis synthesized evidence from 10 studies, demonstrating that interventions aimed at enhancing mental toughness are significantly effective across various sporting contexts and levels of competition. Despite differences in sample characteristics, intervention modalities, and types of sport, the low level of between-study heterogeneity suggests a high degree of robustness in the overall findings. Sensitivity analyses further reinforced this conclusion, indicating that while differences in study design or methodological quality may account for some heterogeneity, no single study disproportionately influenced the overall effect size.

Mental toughness can be developed through various approaches (Bull et al., 2005), yet no research has determined the superiority of any single method (Clough & Strycharczyk, 2012). Although this meta-analysis integrated the effects of diverse interventions, it remains difficult to identify a single best strategy for cultivating mental toughness due to differences in study designs, intervention components, and participant populations. Psychological skills training (PST) is widely regarded as one of the most commonly used programs for fostering positive psychological development (Park & Jeon, 2023; Williams & Krane, 2001). Most of the included studies (n = 7) adopted multi-component PST strategies – such as goal setting, imagery, self-talk, arousal regulation, relaxation, and attentional control. Bhambri et al. (2005), for instance, empirically suggested that combined strategies may be more effective than single techniques. However, due to the wide variability in intervention efficacy and the presence of potential bias in some studies (e.g., non-randomized quasi-experiments), the actual effectiveness and applicability of the interventions reported in the included studies should be viewed with caution. More rigorous empirical research will help identify intervention strategies that should be prioritized for improving athletes' Mental toughness.

Although this review strictly followed the PRISMA reporting guidelines, this systematic review and meta-analysis also have some limitations. First, the total number of included studies (n = 10) limits the generalizability and power of the analyses. Although publication bias was not detected using Egger's regression test (bias = 1.05, p = .321), the small number of included studies limits the sensitivity of funnel plot-based diagnostics. Second, intervention heterogeneity and varied measurements of MT may have introduced unaccounted biases. Third, the sustainability of outcomes remains uncertain, as the enduring impacts of these interventions cannot be ascertained without longer-term assessment. A final notable consideration is that the meta-analytic findings, derived from a synthesis of RCTs and quasi-experimental studies, are constrained by the limited number of RCTs, thereby affecting the certainty of the evidence.

The findings of this study offer clear practical value for sport psychologists, coaches, and practitioners. Implementing structured Psychological Skills Training (PST) programs – particularly those using multicomponent strategies –can significantly enhance athletes' Mental Toughness (MT). PST is a process closely tied to daily activities and skill development in sport and exercise contexts (Weinberg & Gould, 2023). Beyond the studies included in this review, numerous other investigations have explored the effects of specific PST techniques or their combinations on MT in particular settings. While the methodological rigor and quality of these studies warrant cautious interpretation, they nonetheless provide broader perspectives and valuable reference points. Therefore, when attempting to develop a mental toughness training program tailored to specific needs, it is essential to carefully select PST techniques and strategies based on factors such as sport type and population characteristics.

Future research should prioritize larger-scale RCTs with consistent intervention protocols and standardized MT outcome measures. Longitudinal designs assessing retention of MT gains post-intervention would address current gaps. Further, dismantling studies comparing single versus multicomponent strategies could clarify which techniques yield the greatest impact. Exploration of mediators and moderators, such as motivation, coping style, and sport type, would provide deeper theoretical and practical insights into how and for whom PST is most effective.

Conclusions

This meta-analysis provides strong empirical evidence supporting the effectiveness of psychological interventions—particularly multicomponent Psychological Skills Training (PST) —in enhancing mental toughness among athletes across different sports. However, due to the lack of long-term follow-up assessments, reliance on quasi-experimental designs, and diversity in measurement approaches, the findings should be interpreted with caution. To advance the field, future research should adopt more rigorous methodologies, including large-scale randomized controlled trials and longitudinal designs, to identify the most effective components and delivery methods for developing mental toughness. These efforts will ultimately inform evidence-based practices for coaches, psychologists, and practitioners aiming to cultivate high-performing athletes.

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Conflict of Interest

The authors declare that there is no conflict of interest.

References

Konter, E., Beckmann, J., & Loughead, T. M. (Eds.). (2019). *Football psychology: from theory to practice.* Routledge, 23-37.

Jones, G., Hanton, S., & Connaughton, D. (2002). What is this thing called mental toughness? An investigation of elite sport performers. *Journal of applied sport psychology, 14*(3), 205-218. https://doi.org/10.1080/10413200290103509

Clough, P., Earle, K., & Sewell, D. (2002). Mental toughness: The concept and its measurement. *Solutions in sport psychology, 1*(1), 32-46.

Gucciardi, D. F., Gordon, S., & Dimmock, J. A. (2008). Towards an understanding of mental toughness in Australian football. *Journal of applied sport psychology, 20*(3), 261-281. https://doi.org/10.1080/10413200801998556

Sheard, M., Golby, J., & Van Wersch, A. (2009). Progress toward construct validation of the Sports Mental Toughness Questionnaire (SMTQ). *European Journal of Psychological Assessment, 25*(3), 186-193. https://doi.org/10.1027/1015-5759.25.3.186

Clough, P., & Strycharczyk, D. (2012). *Developing mental toughness: Improving performance, wellbeing and positive behaviour in others.* Kogan Page Publishers.

Mahoney, J. W., Gucciardi, D. F., Ntoumanis, N., & Mallet, C. J. (2014). Mental toughness in sport: Motivational antecedents and associations with performance and psychological health. *Journal of Sport and Exercise Psychology, 36*(3), 281-292. https://doi.org/10.1123/jsep.2013-0260

Connaughton, D., Wadey, R., Hanton, S., & Jones, G. (2008). The development and maintenance of mental toughness: Perceptions of elite performers. *Journal of sports sciences, 26*(1), 83-95. https://doi.org/10.1080/02640410701310958

Thelwell, R. C., Such, B. A., Weston, N. J., Such, J. D., & Greenlees, I. A. (2010). Developing mental toughness: Perceptions of elite female gymnasts. *International Journal of Sport and Exercise Psychology, 8*(2), 170-188. https://doi.org/10.1080/1612197X.2010.9671941

Butt, J., Weinberg, R., & Culp, B. (2010). Exploring mental toughness in NCAA athletes. *Journal of intercollegiate sport, 3*(2), 316-332. https://doi.org/10.1123/jis.3.2.316

Cook, C., Crust, L., Littlewood, M., Nesti, M., & Allen-Collinson, J. (2014). 'What it takes': perceptions of mental toughness and its development in an English Premier League Soccer Academy. *Qualitative research in sport, exercise and health, 6*(3), 329-347. https://doi.org/10.1080/2159676X.2013.857708

Anthony, D. R., Gucciardi, D. F., & Gordon, S. (2016). A meta-study of qualitative research on mental toughness development. *International Review of Sport and Exercise Psychology, 9*(1), 160-190. https://doi.org/10.1080/1750984X.2016.1146787

Anthony, D. R., Gordon, S., Gucciardi, D. F., & Dawson, B. (2018). Adapting a behavioral coaching framework for mental toughness development. *Journal of Sport Psychology in Action, 9*(1), 32-50. https://doi.org/10.1080/21520704.2017.1323058

Weinberg, R., Freysinger, V., Mellano, K., & Brookhouse, E. (2016). Building mental toughness: Perceptions of sport psychologists. *The Sport Psychologist, 30*(3), 231-241. https://doi.org/10.1123/tsp.2015-0090

Weinberg, R., Freysinger, V., & Mellano, K. (2018). How can coaches build mental toughness? Views from sport psychologists. *Journal of Sport Psychology in Action, 9*(1), 1-10. https://doi.org/10.1080/21520704.2016.1263981

Stamatis, A., Grandjean, P., Morgan, G., Padgett, R. N., Cowden, R., & Koutakis, P. (2020). Developing and training mental toughness in sport: A systematic review and meta-analysis of observational studies and pre-test and post-test experiments. *BMJ open sport & exercise medicine, 6*(1). https://doi.org/10.1136/bmjsem-2020-000747

Crust, L., & Clough, P. J. (2011). Developing mental toughness: From research to practice. *Journal of Sport Psychology in Action, 2*(1), 21-32. https://doi.org/10.1080/21520704.2011.563436

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of epidemiology & community health, 52*(6), 377-384. https://doi.org/10.1136/jech.52.6.377

Toth, A. J., McNeill, E., Hayes, K., Moran, A. P., & Campbell, M. (2020). Does mental practice still enhance performance? A 24 Year follow-up and meta-analytic replication and extension. *Psychology of Sport and Exercise,* 48, 101672. https://doi.org/10.1016/j.psychsport.2020.101672

Thurlow, F., Huynh, M., Townshend, A., McLaren, S. J., James, L. P., Taylor, J. M., & Weakley, J. (2024). The effects of repeated-sprint training on physical fitness and physiological adaptation in athletes: a systematic review and meta-analysis. *Sports Medicine, 54*(4), 953-974. https://doi.org/10.17605/OSF.IO/RVNDW

Kittel, A., Lindsay, R., Larkin, P., Spittle, M., & Cunningham, I. (2025). The effectiveness of decision-making training in team-sport officials: A systematic review and meta-analysis. *Psychology of Sport and Exercise,* 102841. https://doi.org/10.1016/j.psychsport.2025.102841

Cochrane Handbook for Systematic Reviews of Interventions. (2024). Version 6.5, https://training.cochrane.org/handbook/current.

Higgins, J. P., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in medicine, 21*(11), 1539-1558. https://doi.org/10.1002/sim.1186

Wang, Y., Lei, S. M., & Fan, J. (2023). Effects of mindfulness-based interventions on promoting athletic performance and related factors among athletes: A systematic review and meta-analysis of randomized controlled trial. *International journal of environmental research and public health, 20*(3), 2038. https://doi.org/10.3390/ijerph20032038

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ, 315*(7109), 629-634. https://doi.org/10.1136/bmj.315.7109.629

Abdelbaky, F. M. (2012). Impacts of mental toughness program on 20 km race walking. *Science, movement and health, 12*(1), 67-71.

Ajilchi, B., Amini, H. R., Ardakani, Z. P., Zadeh, M. M., & Kisely, S. (2019). Applying mindfulness training to enhance the mental toughness and emotional intelligence of amateur basketball players. *Australasian Psychiatry, 27*(3), 291-296. https://doi.org/10.1177/1039856219828119

Ajilchi, B., Mohebi, M., Zarei, S., & Kisely, S. (2022). Effect of a mindfulness programme training on mental toughness and psychological well-being of female athletes. *Australasian Psychiatry, 30*(3), 352-356. https://doi.org/10.1177/10398562211057075

Bell, J. J., Hardy, L., & Beattie, S. (2013). Enhancing mental toughness and performance under pressure in elite young cricketers: A 2-year longitudinal intervention. *Sport, Exercise, and Performance Psychology, 2*(4), 281. https://doi.org/10.1037/spy0000010

Bhambri, E., Dhillon, P. K., & Sahni, S. P. (2005). Effect of psychological interventions in enhancing mental toughness dimensions of sports persons. *Journal of the Indian academy of applied psychology, 31*(1-2), 65-70.

Gucciardi, D. F., Gordon, S., & Dimmock, J. A. (2009). Evaluation of a mental toughness training program for youth-aged Australian footballers: I. A quantitative analysis. *Journal of applied sport psychology, 21*(3), 307-323. https://doi.org/10.1080/10413200903026066

Pocius, E., & Malinauskas, R. (2024). Development of mental toughness among basketball sports school students. *Behavioral Sciences, 14*(4), 314. https://doi.org/10.3390/bs14040314

Putra, M. F. P., Sutoro, S., Zainuri, A., Numberi, G. K. I., Nurhidayah, D., & Kadir, A. (2025). Mental toughness training circle (MTTC): what is its impact on the mental toughness, anxiety, and academic performance of college-level athletes and non-athletes? *Retos,* 64, 866-876. https://doi.org/10.47197/retos.v64.109694

Sharma, A., & Prasad, B. K. (2023). Effect of VMBR Training on Psychological Dimensions of Anxiety and Mental Toughness of Table Tennis Players. *Physical Education Theory and Methodology, 23*(1), 28-34. https://doi.org/10.17309/tmfv.2023.1.04

Singh, S. P., & Bhowmik, S. K. (2020). Effect of Visuo-Motor Behavior Rehearsal on enhancing Mental Toughness of Soccer Players. *Rupkatha Journal on Interdisciplinary Studies in Humanities, 12*(5), 1-11. https://doi.org/10.21659/rupkatha.v12n5.rioc1s19n3

Bull, S. J., Shambrook, C. J., James, W., & Brooks, J. E. (2005). Towards an understanding of mental toughness in elite English cricketers. *Journal of applied sport psychology, 17*(3), 209-227. https://doi.org/10.1080/10413200591010085

Park, I., & Jeon, J. (2023, January). Psychological skills training for athletes in sports: web of science bibliometric analysis. *In Healthcare, 11*(2), p. 259. MDPI. https://doi.org/10.3390/healthcare11020259

Williams, J. M., & Krane, V. (2001). Psychological characteristics of peak performance. *Applied sport psychology: Personal growth to peak performance,* 4, 137-147.

Weinberg, R. S., & Gould, D. (2023). *Foundations of sport and exercise psychology.* Human kinetics. 514-61

Ефективність тренування психічної стійкості у спортсменів: Систематичний огляд та метааналіз

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 3 табл., 3 рис., 39 джерел.

Мета дослідження. Мета цього дослідження полягала у вивченні ефективності інтервенцій, спрямованих на розвиток психічної стійкості (ПС) у спорті.

Матеріали та методи. Критерії прийнятності охоплювали кількісні контрольовані експериментальні дослідження інтервенцій з розвитку ПС у спортсменів. До інформаційних джерел належали дослідження, індексовані в Web of Science, PubMed, Scopus, Embase та SPORTDiscus з моменту створення до 13 квітня 2025 року. Також проведено аналіз списків використаних джерел включених досліджень. Ризик упередженості розглядали у такий спосіб: Двоє авторів незалежно оцінили якість звітності та ризик упередженості включених досліджень, використовуючи модифікований індекс Даунса і Блека. Щодо узагальнення результатів, з метою оцінки впливу інтервенцій із використанням моделі випадкового ефекту було розраховано стандартизовану середню різницю (ССР).

Результати. Представлений огляд включав загалом 10 досліджень за участю 465 учасників, які займалися переважно футболом (24.7%), баскетболом (19.7%) та настільним тенісом (17.5%). У семи дослідженнях (67.3%) застосовано комбінацію інтервенцій із тренування психологічних навичок. Метааналіз охоплював усі 10 досліджень та відповідні експериментальні групи з метою з'ясування загальної ефективності програм із тренування ПС. Сукупний розмір ефекту був статистично та практично значущим, надаючи велику стандартизовану середню різницю $g = 0.81$ (95% ДІ 0.57–1.05, $p < 0.001$), що вказує на істотну перевагу інтервенцій із тренування ПС над контрольними умовами.

Висновки. Цей метааналіз надає переконливі емпіричні докази ефективності психологічних інтервенцій, зокрема багатокомпонентного тренування психологічних навичок (ТПН), у підвищенні психічної стійкості серед спортсменів різних видів спорту. Однак через відсутність довгострокових обсерваційних оцінок, використання квазіекспериментальних моделей та різноманітність підходів до вимірювання, слід з обережністю інтерпретувати отримані результати. Задля досягнення прогресу в цій галузі у подальших дослідженнях слід застосовувати ретельніші методології, включаючи великомасштабні рандомізовані контрольовані випробування та лонгітюдні проєкти, щоб визначити найефективніші компоненти та методи щодо реалізації розвитку психічної стійкості. Зазначені дослідницькі зусилля в кінцевому підсумку слугуватимуть основою для науково обґрунтованих практик тренерів, психологів та фахівців-практиків, які прагнуть виховати спортсменів високого рівня.

Ключові слова: психічна стійкість, тренування психологічних навичок, спортсмени, інтервенція.

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