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ORIGINAL SCIENTIFIC PAPER

Understanding Injury Dynamics in Youth Soccer: A Six-Season Study of Traumatic and Overuse Injuries

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Abstract

Despite extensive research on adolescent and late-pubertal soccer players, there is limited longitudinal data on injury incidence in prepubertal and early pubertal soccer players. This study aimed to analyze the incidence and distribution of traumatic and overuse injuries in youth soccer players aged 8 to 15 years over six competitive seasons. A prospective cohort study was conducted on 811 youth soccer players from a professional soccer academy, tracking injuries across six seasons (2016/17–2021/22). Injury data were extracted from medical records and classified based on the FIFA consensus statement. Injuries were categorized as traumatic or overuse, with incidence expressed per 1000 hours of exposure. While the distribution of traumatic and overuse injuries remained consistent across age categories, younger players exhibited a higher proportion of overuse injuries, whereas older players sustained more traumatic injuries. Additionally, injury incidence increased with age, with the highest number recorded in U15 players. The overall traumatic-to-overuse injury ratio was approximately 50:50, differing from patterns seen in senior-level players. Injury incidence in youth soccer players follows an age-related trend, with overuse injuries being more prevalent in younger players and traumatic injuries increasing with age. These findings highlight the need for age-specific injury prevention programs, emphasizing proper workload management for younger players and injury mitigation strategies for older athletes. Future research should investigate long-term injury trends and predictors across multiple clubs to optimize player development and safety.

Keywords: *youth soccer, injury incidence, traumatic injuries, overuse injuries, player development, injury prevention*

Introduction

Youth soccer (football) participation expands worldwide, with more and more children being registered in domestic clubs and associations every year. Due to the growing interest and related intensified competition, the training and selection process in youth soccer has gotten more challenging, with stronger, faster, and more agile children being selected (Fortin-Guichard et al., 2022; Mikić, Marasović, Rađa, Erceg, & Sivrić, 2024). Studies have shown that the intensity of play in youth soccer, primarily observed through an increase in the number of explosive actions, progressively increases with the age of the players (Di Giminiani & Visca, 2017; Ergun, Denerel, Mehmet, & Ertat, 2013; Sermaxhaj et al., 2024; Wagner et al., 2023). Related to this, an increased load is necessary for the development of players' skills and capacities, as well as for their preparation and adaptation to the demands of the senior level (Rabbani, Wong, Clemente, & Kargarfard, 2021). Due to this increased training and game load, injuries are an inevitable part of the overall process (Bourogiannis, Hatzimanouil, Semanltianou, Georgiadis, & Sykaras, 2023; Eckard, Padua, Hearn, Pexa, & Frank, 2018). Despite advancements in knowledge, technology, and the growing number of professionals involved in training, the continuous rise in injury rates remains a serious issue in this population of athletes (Bourdon et al., 2017; Price, Hawkins, Hulse, & Hodson, 2004). Injuries disrupt the development of young athletes by negatively affecting their future performances and keeping them away from sports training for a period of time, thereby slowing down the development of relevant abilities (Jones et al., 2019).

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Given the growing interest in soccer, a comprehensive investigation into injury occurrence in this vulnerable population is essential to create a safer environment for young participants.

Due to the importance of this topic and the sensitivity of the observed population, the issue of injuries in young soccer players has been extensively studied (Jones et al., 2019; Nilsson, Östenberg, & Alricsson, 2016; Read, Oliver, Croix, Myer, & Lloyd, 2015; Rössler, Junge, Chomiak, Dvorak, & Faude, 2016). Studies conducted on soccer players from the U9 to U21 categories indicate an injury rate ranging from 1.3 to 21.1 per 1000 hours of exposure, with a mean of 5.8 injuries per 1000 hours (Weishorn et al., 2023). Notably, as players age, both the absolute number of injuries and the proportion of injured players within a team increase (e.g., 22% in older players (U18 to U21) versus 10% in younger players (U9 to U16) (Jones et al., 2019). The injury rate is higher in older players (U17 to U21), reaching 7.9 injuries per 1000 hours, compared to younger categories (U9 to U16), which record 3.7 injuries per 1000 hours (Jones et al., 2019). Interestingly, authors suggest that soccer players over the age of 14 exhibit injury characteristics similar to adult players in terms of injury type, location, mechanism, and even frequency (Hägglund, Waldén, & Ekstrand, 2009; Junge & Dvorak, 2004). Chronologically older and more physically developed players tend to play more aggressively, take greater risks, and engage in a significantly higher number of physical duels, much like senior players, which directly correlates with an increased risk of injury (Le Gall et al., 2006).

While numerous studies focus on soccer players in late puberty and adolescence, there is a significant lack of research on prepubertal children (Faude, Rößler, & Junge, 2013). The available data indicate an overall injury incidence of 0.1 to 1.6 injuries per 1000 hours for children under 12 years old (Faude et al., 2013; Rinaldo, Gualdi-Russo, & Zaccagni, 2021). The lower number of injuries in this age group can be attributed to several factors, including the lower intensity of play and generally fewer training hours (Rinaldo et al., 2021; Rommers et al., 2020). Due to inter-individual differences in the growth and maturation process, it is crucial to examine injury characteristics in the youngest age categories, as their physical development presents unique challenges. Between the ages of 11 and 13 in female children and 13 and 15 in male children, rapid skeletal growth occurs—a phase known as peak height velocity (PHV). Research suggests that during this period, as well as one year before and after PHV, young athletes are at an increased risk of both traumatic and overuse injuries. This heightened susceptibility is likely due to increased physical load, reduced load resistance caused by adolescent "clumsiness," and pre-existing growth-related pain syndromes (Bult, Barendrecht, & Tak, 2018; Maternea, Farooqb, Johnsona, Greigc, & McNaughtonc, 2016; Van der Sluis, Elferink-Gemser, Brink, & Visscher, 2015).

Among the youngest soccer players, the most common traumatic injuries are bone fractures, particularly of the tibia and forearm bones. These injuries are often attributed to the immaturity of the skeletal system and insufficiently developed falling techniques. Since training intensity increases with age, excessively intense training sessions introduced too early can lead to overuse injuries and even burnout syndrome, especially when combined with inadequate rest and recovery protocols (Brenner, Medicine, & Fitness, 2007; Brink et al., 2010). Additionally, growth-related injuries, such as Osgood-Schlatter disease (which peaks in the U14 category) and Sever's disease (which peaks in the U11 category), are common issues in youth soccer and affect approximately 17% of pre-adolescent players (Schultz, 2022). Due to their more developed bodies and higher levels of strength and power, older players are more prone to traumatic injuries, which predominantly include knee and ankle sprains, muscle lesions, and contusions (Wik et al., 2021).

A review of the literature highlights a lack of systematic longitudinal studies examining injury frequencies by type in prepubertal and early pubertal youth soccer players. Tracking the distribution of injuries over the years of growth and development is essential for assessing the adaptation of young athletes to soccer-specific training. Therefore, the present study aims to determine the frequency of both traumatic and overuse injuries in soccer players aged 8 to 15 years. By identifying injury patterns in this population, these findings can contribute to developing appropriate training strategies and optimizing training loads, ensuring that young soccer players are trained safely and effectively. A deeper understanding of injury risks in younger athletes is crucial for fostering long-term athletic development while minimizing injury-related setbacks.

Methods

Study design

This prospective cohort study examined the frequency and characteristics of traumatic and overuse injuries in youth soccer players aged 8 to 15 years. The study was conducted over a multi-season period, tracking injury incidence and distribution across different age categories. Injury data were extracted from the internal medical database of a professional soccer academy. Before participation, all players and their legal guardians were

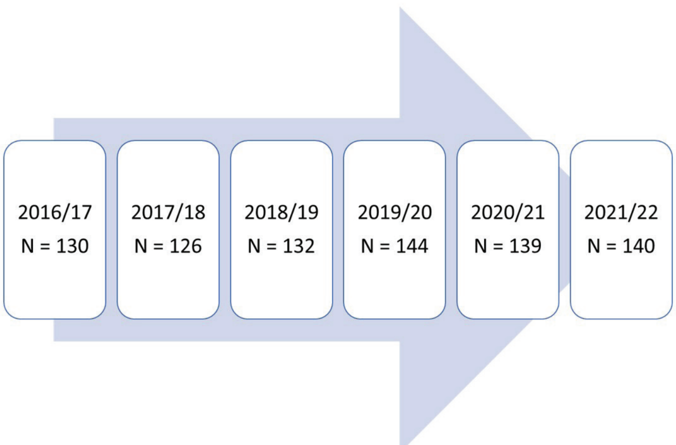

FIGURE 1. Time line of the study protocol with number of subjects tested in each competitive season

informed about the purpose and methodology of the study, and written informed consent was obtained. The study was conducted in accordance with the Declaration of Helsinki and received approval from the Ethics Committee of the Faculty of Kinesiology (Ethical Approval Number: 2181-205-02-05-23-0007). The study protocol is presented in Figure 1.

Participants

A total of 811 youth soccer players (age range 8–15 years) were included in this study. All participants were registered players of a professional youth soccer academy, competing in their respective age categories (U9, U11, U13, U15). Players were included from the moment of their registration and were excluded immediately upon leaving the academy. In order to ensure data consistency, only players who completed a full competitive season were included in the final analysis. Confidentiality of the extracted injury data was maintained by assigning anonymous identification codes to each participant, known only to the research team.

Variables and data collection

All injuries were systematically recorded and classified by medical professionals of the academy during daily medical check-ups before or after training sessions and matches. Injury classification was based on the consensus statement of the FIFA Medical Assessment and Research Centre (Fuller et al., 2006). Injuries were classified as either acute (traumatic) injuries or overuse injuries based on their mechanism of occurrence. Acute injuries were defined as those resulting from a specific, identifiable event, such as fractures, sprains, or contusions, whereas overuse injuries were attributed to repetitive microtrauma without a clear incident, including conditions like tendinopathies, Osgood-Schlatter disease, and Sever's disease. Injury severity was assessed based on time lost from training and competition, and soccer exposure was calculated for each season by summing the total training and match hours per player. Adjustments were made for the 2019/2020 season to account for training interruptions caused by the COVID-19 pandemic. Injury incidence was expressed as the number of injuries per 1000 hours of exposure, with injuries further categorized by type, anatomical location, and severity. Additionally, the proportion of traumatic vs. overuse injuries was analyzed across age groups, while reinjury was defined as an injury occurring at the same location and of the same type after the player had returned to full participation.

Statistics

Descriptive data were presented as arithmetic means and standard deviations. The muscle injury incidence was calculated as the number of injuries sustained per 1000 hours of exposure, while the injury incidence rate ratio (IRR) and 95% confidence intervals were computed to compare injury rates between the first and last observed seasons. To examine differences between acute and overuse injuries, a chi-square test was performed using an online statistical calculator. The level of statistical significance was set at $p<0.05$. Statistical analyses were conducted using MedCalc Statistical Software (ver-

Table 1. Injury incidence /1000 h of exposure

SEASON	CATEGORY	TRAUMA	OVERUSE	OVERALL	TRAUMA/OVERUSE RATIO
2016/17	U9	0.87	0.87	1.74	1.00
	U11	1.72	4.17	5.88	0.41
	U13	3.27	4.12	7.39	0.79
	U15	6.98	4.93	11.92	1.41
2017/18	U9	0.00	1.45	1.45	0.00
	U11	3.04	2.03	5.06	1.50
	U13	4.66	3.73	8.39	1.25
	U15	3.22	3.10	6.33	1.04
2018/19	U9	1.38	0.69	2.07	2.00
	U11	4.17	2.45	6.62	1.70
	U13	3.66	3.18	6.84	1.15
	U15	3.35	3.48	6.83	0.96
2019/20	U9	0.42	1.25	1.66	0.33
	U11	1.04	1.82	2.85	0.57
	U13	3.02	3.96	6.98	0.76
	U15	2.39	2.67	5.06	0.89
2020/21	U9	1.08	0.36	1.44	3.00
	U11	0.87	0.87	1.74	1.00
	U13	1.34	1.78	3.12	0.75
	U15	2.41	2.90	5.31	0.83
2021/22	U9	0.35	0.35	0.69	1.00
	U11	1.60	1.20	2.80	1.33
	U13	2.91	2.32	5.23	1.25
	U15	3.86	2.79	6.65	1.38

sion 19.2.6), Microsoft Excel 2019 (Microsoft, Redmond, WA, USA), and SPSS (IBM, Armonk, NY, USA, version 25.0).

Results

Injury incidence for all age categories, expressed as the number of injuries per 1000 hours of exposure is presented in Table 1, separately for traumatic, overuse and overall injuries. Additionally, the ratio between traumatic and overuse injuries is presented with values above 1 indicating more traumatic injuries for specific categories and seasons, and vice versa.

The injury incidence rate ratios (IRR) (Table 2) were calculated for the overall sample and individual age categories between 2016/17 and 2021/22, showing a general decrease in injury incidence across all groups (IRR =1.73, 95% CI: 1.35–2.22). The most significant decline was observed in the U9 category (IRR =2.25, 95% CI: 0.92–5.49).

Table 2. Injury incidence rate ratio (IRR), comparison between year 1 and year 6 with 95% confidence intervals

	IRR 1-6	95% CI	
ALL	1.73	1.35	2.23
U9	2.25	0.92	5.49
U11	2.10	1.34	3.13
U13	1.41	1.05	1.86
U15	1.79	1.45	2.18

Figure 2 presents the total number of both traumatic and overuse injuries for each category in the observed period. Results suggest a higher number of overuse injuries in all categories except the oldest, U15 (126 traumatic vs 106 overuse).

The results of the chi-square test are presented in Table 3 and show no significant differences between the number of players suffering traumatic compared to players with overuse injuries. For the U9 category in the second season, no traumatic injuries were recorded so the calculations were conducted for the remaining three categories.

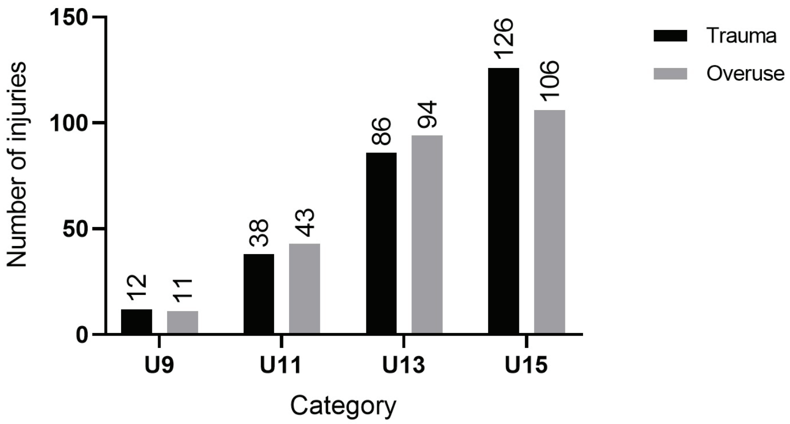

FIGURE 2. Total number of traumatic and overuse injuries per category

Table 3. Differences between the number of players with traumatic and overuse injuries (Chi-square test - χ2)

SEASON	CATEGORY	TRAUMA		OVERUSE		χ2 (p)
		N	%	N	%	
16/17	U9	3	20%	2	13.3%	6.47 (0.09)
	U11	5	17.9%	14	50.0%	
	U13	14	32.6%	22	51.2%	
	U15	31	68.9%	24	53.3%	
17/18	U9	0	0%	3	21.4%	0.22 (0.89)
	U11	8	29.6%	7	25.9%	
	U13	21	52.6%	16	42.1%	
	U15	19	42.3%	18	38.5%	
18/19	U9	4	17.4%	2	8.7%	0.97 (0.81)
	U11	10	36.7%	7	26.7%	
	U13	14	35.7%	15	40.5%	
	U15	17	40.4%	16	38.3%	

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Table 3. Differences between the number of players with traumatic and overuse injuries (Chi-square test - χ2)

SEASON	CATEGORY	TRAUMA		OVERUSE		χ2 (p)
		N	%	N	%	
19/20	U9	1	4.2%	2	8.3%	1.05 (0.79)
	U11	4	11.4%	5	14.3%	
	U13	12	30.0%	15	37.5%	
	U15	15	32.6%	12	26.1%	
20/21	U9	3	13.6%	1	4.5%	1.35 (0.72)
	U11	3	9.1%	4	12.1%	
	U13	8	19.5%	10	24.4%	
	U15	17	37.8%	17	37.8%	
21/22	U9	1	4.5%	1	4.5%	0.13 (0.98)
	U11	7	20.0%	5	14.3%	
	U13	16	38.6%	13	31.8%	
	U15	20	51.2%	14	34.9%	
OVERALL	U9	12	9.9%	11	9.1%	2.26 (0.52)
	U11	37	20.1%	42	22.9%	
	U13	84	34.7%	92	37.9%	
	U15	120	45.4%	101	38.1%	

Discussion

This study aimed to analyze the incidence of traumatic and overuse injuries in soccer players aged 8 to 15 years, revealing several key findings. The most notable result is that there were no significant differences in the types of injuries across individual age categories, indicating a consistent injury distribution throughout development. However, younger players exhibited a slightly higher incidence of overuse injuries, whereas older players sustained more traumatic injuries. Moreover, the findings confirm that injury incidence increases with age, as older players experienced more injuries than younger age groups. Finally, the overall number of acute and overuse injuries was similar across all age groups, suggesting a balanced occurrence of both injury types.

The absence of significant differences in the distribution of traumatic and overuse injuries across individual age categories suggests a consistent injury pattern throughout player development. This finding indicates that, despite physiological and biomechanical changes associated with growth, young soccer players experience similar proportions of acute and overuse injuries at different stages of development. Such results align with previous research emphasizing that both traumatic and overuse injuries remain prevalent across youth age groups (Pulici, 2024). A similar distribution of injury types may reflect the structured training methodologies and injury prevention programs implemented at the academy, ensuring balanced workloads across different age categories. Additionally, the lack of significant variation in injury type suggests that injury mechanisms remain relatively unchanged during early soccer development, reinforcing the need for generalized prevention strategies applicable to all age groups.

However, results suggest a slightly higher incidence of overuse injuries in younger players and a greater incidence of traumatic injuries in older players with also general increase in injury incidence in older age. The observed differences in injury patterns across age groups can be explained by the changing demands of training and competition as players develop. Younger players tend to sustain more overuse injuries, likely due to repetitive movements involved in learning new techniques, a high volume of training repetitions, and insufficient mastery of movement patterns (Zwolski, Quatman-Yates, & Paterno, 2017). While increased training loads generally have a protective effect by enhancing strength and neuromuscular control, excessive training exposure can lead to overuse injuries, overtraining, and even illness (Serfaty & Palmer, 2025).

In contrast, older players experience a higher proportion of traumatic injuries, reflecting the increased physical intensity of matches, greater competitiveness, and more aggressive style of play. With stronger, faster, and larger players engaging in frequent duels and physical contact, the likelihood of trauma-induced injuries such as sprains, contusions, and fractures increases. The overall rise in injury incidence with age is consistent with previous studies, which attribute this trend to greater training and match exposure, as well as the higher physical and tactical demands of the game (Karabin, Pupiš, & Švantner, 2024; Rabie, Arafa, Bahloul, & Abdelbadie, 2025; Serfaty & Palmer, 2025).

Our study found that the total traumatic-to-overuse injury ratio over six seasons was approximately 50:50, which is in line with previous studies on youth soccer (Błażkiewicz, Grygorowicz, Białostocki, & Czaprowski, 2018; Rommers et al., 2020). However, this distribution differs from patterns seen in senior players, where traumatic injuries tend to be more prevalent (Leppänen et al., 2019; Rommers et al., 2020). The shift toward more acute injuries in older players is likely due to increased match intensity, greater physical contact, higher training loads, and more competitive play at the senior level.

Additionally, mature athletes may have better neuromuscular control and movement efficiency, reducing the likelihood of overuse injuries while being more exposed to high-impact trauma (Mandorino, Figueiredo, Gjaka, & Tessitore, 2023). These findings emphasize the importance of tailoring injury prevention strategies to different age groups, considering the evolving injury risks as players transition from youth to senior-level competition.

Conclusion

This study examined the incidence and distribution of traumatic and overuse injuries in youth soccer players aged 8 to 15 years over a six-season period, revealing several key findings. The results showed that injury types were consistently distributed across all age categories, with younger players experiencing slightly more overuse injuries, while older players sustained more traumatic injuries and more injuries overall. The number of traumatic and overuse injuries was unexpectedly equal, suggesting that training methodologies and injury prevention strategies may influence injury patterns.

From a practical perspective, these findings highlight the importance of age-specific injury prevention programs that account for the unique physiological and biomechanical demands of young athletes. Coaches and medical staff should closely monitor training loads, ensuring a gradual progression in intensity to minimize overuse injuries in younger players while implementing techniques to reduce the risk of traumatic injuries in older age groups. Future research should focus on longitudinal studies with larger number of clubs to examine the long-term effects of injury trends on player development and to identify age-specific injury predictors.

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Conflict of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Cognitive and Physical Development in Childhood: A Study of Visual-Motor Coordination and Fitness in Kyrgyzstan

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Abstract

This study examines the relationship between cognitive performance, particularly visual-motor coordination, and physical fitness among 3345 children aged 8 to 10 from Kyrgyzstan's Bishkek and Chüy regions. The primary objective was to explore how visual-motor coordination and decision-making skills relate to physical performance in middle childhood. Physical fitness was assessed using the Eurofit test battery, which evaluates general physical competence across multiple components such as strength, balance, and flexibility, and is widely used in developmental and educational settings. The Kohs Block Design Test (KOHS) evaluated cognitive performance, particularly visual-motor coordination. Correlation analysis was performed to examine the relationship between physical performance and visual-motor coordination. Data analysis also involved the Shapiro–Wilk test for normality, one-way ANOVA and Tukey's post hoc tests for age group comparisons, and independent t-tests for gender differences. All statistical analyses were performed using SPSS Version 21, with significance set at $p<0.05$. Eight-year-olds demonstrated significantly better visual-motor coordination compared to 9- and 10-year-olds ($p<0.01$), and 8-year-old girls outperformed boys ($p<0.05$). A strong negative correlation was found, indicating that faster completion times in visual-motor tasks were associated with better physical performance. Additionally, physical performance scores generally improved with age. The findings highlight a strong association between visual-motor coordination and physical performance. The findings highlight a strong association between visual-motor coordination and physical performance, supporting the notion that these abilities develop in parallel during early childhood. This underscores the importance of early interventions that target both cognitive-perceptual and motor domains to foster well-rounded developmental progress.

Keywords: *visual-motor coordination, physical performance, physical fitness, cognitive performance*

Introduction

Middle childhood, encompassing ages 8 to 10, is a period marked by a rapid transition through specific developmental sequences and stages (Aral & Baran, 2011; Bacanlı, 2001). The shift from concrete to abstract thinking typically begins around the age of 6 or 7 and continues until approximately 11 or 12 years of age (Yazgan et al., 2004). During this phase, children's cognitive development advances, enabling them to perform more complex tasks, use language more effectively, extend their attention spans, and enhance their memory utilization (Gander & Gardiner, 2001). They begin to focus less on the superficial features of objects and pay greater attention to underlying causes, emphasizing the realities beneath appearances (Shaffer, 1996). This cognitive development becomes evident not only

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in their understanding of objects but also in their perceptions of others, relationships, and themselves (Aral & Baran, 2011).

In addition to cognitive development, self-perception and self-concept evolve as children assume new roles beyond the family, particularly with the introduction of school life (Bayhan & Artan, 2009). This period also marks early pubertal changes in girls and significant advancements in motor skills, including increased muscle strength and coordination, enhancing abilities such as running, jumping, and throwing (Yazgan et al., 2004).

In line with the focus of this study, only cognitive development aspects closely related to physical performance are emphasized. Rather than detailing general intelligence theories or broad psychometric approaches, this introduction concentrates on functional cognitive skills such as visual-motor coordination.

Cognitive development arises from the interaction between biological maturation and environmental experiences (Carey et al., 2015). According to Piaget, this development is a dynamic process characterized by a continual cycle of equilibrium, disequilibrium, and re-equilibration, in which individuals adapt to new stimuli to function effectively. His theory describes a progression through four developmental stages: in the sensorimotor stage, which spans from birth to approximately two years of age, infants learn about the world through sensory and motor interactions. This is followed by the preoperational stage, from ages two to seven, during which symbolic thinking begins to emerge, although logical reasoning remains limited. Between the ages of seven and eleven, children enter the concrete operational stage, where logical thinking becomes more pronounced but is still grounded in tangible, concrete experiences. Finally, in the formal operational stage, beginning around age eleven, individuals acquire the ability to think abstractly and reason about hypothetical situations (Lourenço, 2016).

The study group in this research corresponds to the concrete operational stage, during which children begin to overcome egocentrism and consider others' perspectives, even though their reasoning remains bound to observable and tangible situations (Oesterdiekhoff, 2016). At this stage, thinking becomes more flexible; children develop the ability to understand cause-effect relationships, classify and arrange objects according to certain attributes, and comprehend fundamental logical principles such as conservation and reversibility. While cognitive differences between boys and girls are generally minimal, girls tend to exhibit faster physical development up to approximately age 11, after which boys demonstrate accelerated growth (Yazgan et al., 2004).

In the context of this research, visual-motor coordination is particularly significant due to its role in both cognitive functioning and physical performance. Skills such as spatial orientation, motor planning, and sensorimotor integration are directly relevant to children's ability to perform physically demanding tasks. This provides a scientifically grounded framework for understanding how cognitive and motor domains interact in middle childhood.

Recent research supports the critical role of visual-motor coordination in academic success, daily functioning, and sport performance. For instance, visual-motor integration is strongly linked with early literacy and numeracy skills (Cameron et al., 2012). Additionally, studies show that motor coordination enhances attention and memory, and that sensorimotor interventions can improve cognitive and social skills in children (Roebers & Kauer, 2009). These findings reinforce the value of integrating visual-motor skill development in both educational and sport-related practices.

Considering this information, the aim of this study is to examine cognitive development in children aged 8 to 10 in relation to physical performance and to identify age and gender related cognitive differences.

Methods

Research design

This study was conducted under the protocol signed between Kyrgyz-Turkish Manas University, the Ministry of Education and Science of the Kyrgyz Republic, and the Ministry of Sports of the Kyrgyz Republic. It involved the assessment of physical performance in a total of 3,345 children attending 17 public schools in the Bishkek and Chüy regions of Kyrgyzstan. The children were divided into three age groups: 8 years old (girls: 616, boys: 612), 9 years old (girls: 631, boys: 586), and 10 years old (girls: 419, boys: 481). In this study, children who showed superior results in standardized physical fitness tests were noted. Additionally, their cognitive performance in quick and accurate decision-making was measured, and the relationship between physical and cognitive performance was examined.

The study protocol was approved by the Ethics Committee of the Kyrgyz State University of Physical Education (Approval No.1382018) and conducted in full compliance with the principles outlined in the Declaration of Helsinki.

Determination of physical performance

To evaluate students' physical performance, the Eurofit Test Battery was used. The Eurofit Test Battery assesses balance, flexibility, upper body strength, explosive leg power, reaction speed, abdominal endurance, aerobic capacity, and agility with coordination. This test battery has been endorsed by the Committee of Ministers of the Council of Europe as a standardized tool for assessing the physical fitness of children aged 6–18 years (Adam et al., 1988). Before the tests, all children in the study were informed about the test procedures and measurement tools in both Kyrgyz and Russian. Practical demonstrations were also provided to familiarize participants with the process. Each student underwent a health evaluation by medical professionals before testing, and only those who received medical clearance were allowed to participate. Doctors and nurses remained on-site throughout the measurement process to ensure the safety of the participants.

Visual-Motor Coordination Test

This timed assessment comprises 17 cards and patterned blocks. Participants were seated at a table and shown the completed version of the test for 20 seconds. Subsequently, they were instructed to replicate the displayed pattern by rearranging the scattered blocks within a 2-minute time limit. The time taken to complete the task was recorded as the score. Participants who were unable to complete the task within the allotted time were assigned a score of zero.

In addition to the tests administered to evaluate physical performance, the Kohs Block Design Test (KOHS) was used to assess children's visual-motor coordination. This non-verbal test is validated for children aged six and above and is widely applied in linguistically diverse populations due to its language-free structure (Kaufman & Lichtenberger, 2006; Sattler, 2001). Incorporated into standard intelligence batteries, KOHS is supported by studies reporting strong internal consistency and test–retest reliability (Lezak et al., 2012).

In this study, participants were shown a model pattern and asked to reconstruct it using colored blocks within a two-minute time limit. The completion time was recorded as a measure of visual-motor coordination, with shorter durations indicating better performance. KOHS results were then analyzed in relation to the children's physical performance scores to explore cognitive–motor interaction.

Statistical analysis

The data were analyzed using an index method, where the test scores of the children were equally weighted and calculated through a specially designed program in Excel. The Visual-Motor Coordination Test (Kohs Block Design Test - KOHS) was used to assess visual-motor coordination and quick, accurate decision-making skills. The scores from this test were combined with the physical measurements obtained through the Eurofit test battery to create a comprehensive performance index. Each parameter was weighted and normalized to ensure equitable comparisons among participants.

Data analysis was conducted using IBM SPSS Statistics 21. The Shapiro-Wilk test assessed normality. One-way ANOVA with Tukey post-hoc compared age groups (8, 9, 10 years), and independent t-tests analyzed gender differences. Pearson's or Spearman's correlation evaluated relationships between Visual-Motor Coordination and physical test scores. A 95% confidence interval was used, with $p<0.05$ considered statistically significant.

Results

The demographic characteristics of the participants, including height and body weight, categorized by age groups for both boys and girls, are presented in Table 1.

Table 1. Descriptive Statistics of Participants by Age Groups

Gender	Age	n	Height (cm)	Weight (kg)
Girls (n:1666)	8	616	127.26±5.65	26.88±4.85
	9	631	132.80±5.94	29.88±5.73
	10	419	137.94±6.60	32.85±6.84
Boys (n:1679)	8	612	128.17±6.78	27.85±5.39
	9	586	133.49±6.14	30.72±6.53
	10	481	138.25±6.00	33.69±6.72

As illustrated in Table 2, a reduction in the completion time of the intelligence test was associated with an increase in the performance scores from the physical performance tests. A strong negative correlation was observed between intelligence test completion times and physical test performance scores.

Table 3 presents a combined evaluation of test results for boys and girls, showing that as age increased, average test scores decreased while completion times improved.

Table 2. Relationship Between Visual-Motor Coordination Test Scores and Physical Test Scores

	All participants	Girls	Boys	Age 8	Age 9	Age 10
N	3345	1666	1679	1228	1217	900
Correlations	-0.258	-0.273	-0.285	-0.267	-0.254	-0.222
P	0.001	0.001	0.001	0.001	0.001	0.001

Note (0-0.10- Weak), (0.10-0.20 - moderate), (0.20 and above - strong or powerful); A negative (-) sign indicates that as one value increases, the other decreases, demonstrating an inverse relationship.

Table 3. Visual-Motor Coordination and Physical Test Results by Age Groups

Tests	Age 8	Age 9	Age 10	Total
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Flamingo Balance Test	13.83±0.58 †	12.11±0.49 ‡	11.05±0.45 ‡	12.46±0.3
Plate Tapping Test	18.95±0.09 †	17.35±0.08 ‡	16.18±0.09 §	17.62±0.06
Standing Broad Jump	116.59±0.50 §	125.54±0.54 ‡	133.39±0.6 †	124.37±0.33
10x5 Meter Shuttle Run	24.32±0.07 †	23.45±0.07 ‡	22.78±0.11 ‡	23.59±0.05
Handgrip Strength Test (Right)	13.94±0.09 §	15.69±0.1 ‡	17.49±0.13 †	15.53±0.07
Handgrip Strength Test (Left)	13.46±0.09 §	15.01±0.09 ‡	16.75±0.12 †	14.91±0.06
Sit-Up Test	15.58±0.25 †	15.80±0.2 †	16.00±0.22 ‡	15.77±0.13
Bent Arm Hang	12.39±0.42 †	12.18±0.4 †	11.18±0.41 ‡	11.99±0.24
Sprint (20 m)	4.87±0.01 †	4.67±0.01 ‡	4.49±0.01 §	4.70±0.01
Sit and Reach Test	27.21±0.17 †	2.81±0.17 †	27.74±0.19 †‡	27.68±0.1
Visual-Motor Coordination Test	1.74±0.03 †	1.59±0.03†	1.56±0.03†	1.64±0.02
N	1228	1217	900	3345

Note † ‡ §: Different symbols given in the same row indicate statistical significance.

The scores of 9- and 10-year-olds were statistically similar but significantly lower than those of 8-year-olds, indicating faster test completion among older children. In physical tests, the advancement in age was found to result in a statistically significant improvement in physical performance. Notably, 10-year-olds demonstrated the best scores across all parameters.

Table 4 examines the intelligence test results of boys and girls within the same age group. It was observed that 8-year-old girls scored significantly lower than boys on the intelligence test assessing fast and accurate decision-making. However, no statistically significant differences were detected between the intelligence test scores of boys and girls aged 9 and 10.

Table 4. Comparison of Visual-Motor Coordination Test Results Between Same-Age Girls and Boy

Variable	Age 8 Mean±SD	t	p	Age 9 Mean±SD	t	p	Age 10 Mean±SD	t	p
Girls	(1.70±0.04)	-1.449	0.031*	(1.51±0.04)	-3.137	0.527	(1.58±0.05)	0.744	0.793
Boys	(1.78±0.03)			(1.67±0.04)			(1.54±0.04)		
Total n=3345	Girls (n:616)			Girls (n:631)			Girls (n:419)		
	Boys (n:612)			Boys (n:586)			Boys (n:481)		

Note *p<0.05; **p<0.01

Discussion

This study investigates the relationship between physical performance and cognitive abilities, particularly visual-motor coordination, and it focuses on developmental characteristics that influence both motor and cognitive skills. The KOHS blocks were selected to assess both concrete and abstract thinking skills. The literature highlights the strong link between visual-motor coordination and cognitive abilities such as decision-making, attention, and hand-eye coordination. In this context, understanding the interaction between physical performance and visual-motor skills contributes to clarifying developmental dynamics during middle childhood.

The analysis of Table 3 indicates that the time-based performance of the 8-year-old group, assessed using KOHS blocks, was recorded as 1.74, decreasing by 15 seconds to 1.59 in the 9-year-old group. Although the time continued to decrease in the 10-year-old group, the difference between the 9- and 10-year-olds was only three seconds. Statistical analysis revealed a significant difference between the 8-year-old group and both the 9- and 10-year-old groups, whereas the difference between the 9- and 10-year-old groups was not statistically significant. These findings are consistent with the developmental psychology literature.

The period between 8 and 11 years is a crucial stage in human development, often termed 'early adolescence' (Shaffer, 1996) or 'pre-adolescence' (Çapri & Çelikkaleli, 2005). During this phase, physical, emotional, cognitive, and sexual development accelerate, with girls typically entering earlier than boys (Gander & Gardiner, 2001). The timing of this stage is influenced by climate, culture, nutrition, and environmental factors (Bertan et al., 2009), alongside significant individual differences in development.

From age 8, girls, followed by boys a year or two later, show significant improvements in hand-eye coordination, enhancing tool-handling skills (Boyd & Bee, 2009). This period also marks increased cognitive development, enabling children to establish cause-and-effect relationships (Kandemir, 2007; Wood, 1998) and engage in tasks beyond their physical capacity (Bingham, 1983; Özer & Özer, 2005). While concrete operational thinking remains dominant, abstract reasoning improves, allowing them to recognize connections between geometric shapes, events, and objects (Wadsworth, 2015). The use of KOHS blocks in this study aligns with these cognitive developments.

Children in this age group exhibit a highly developed imagination, a strong sense of autonomy, and a tendency to act independently (Nicolopovlov, 1993). Additionally, a significant increase in self-confidence is observed during this developmental stage (Gallahue & Ozmun, 1998).

The acceleration in cognitive development typically becomes evident around the age of 8 and maintains similar characteristics until the age of 12; however, the initial pace does not continue at the same rate in the following years (Charlesworth, 2004). While 8-year-old children are at a beginner level in discovering numerical concepts, relationships, and processes, there is a notable improvement in these skills as they approach the age of 9 (Charlesworth, 2004; Gander & Gardiner, 2001). As shown in Table 4, the significant time difference between the 8 and 9-10 age groups supports this observation. By the age of 9, children's problem-solving skills have significantly improved; however, it cannot be said that they have fully reached the stage of abstract thinking (Nicolopoulou, 2004). The 8-year-old group mainly exhibits characteristics of concrete cognitive development, showing a tendency to reason based on tangible objects. However, as they approach the age of 9, this process gradually evolves towards abstract thinking.

KOHS blocks were chosen as an effective tool for assessing both concrete and abstract thinking skills and distinguishing the performance of the 8-10 age group sample (Boake, 2002). The significant difference observed between the 8 and 9-10 age groups indicates that the method possesses sufficient discriminative power. Children's ability to perceive the whole, understand how its parts can be interchanged, and integrate them to solve a problem reflects both concrete and abstract intelligence (Kunda et al., 2016).

The correlation values presented in Table 2 further support this finding. In the measurements conducted on 3,345 children using KOHS blocks, it was observed that as the allotted time decreased, performance scores in physical performance tests increased (r=-0.258, p<0.001). This indicates a moderate negative correlation between time and performance. Spending less time on comprehension, understanding, discovery, decision-making, and execution is an indicator of higher cognitive functioning (Burggraaf et al., 2018). The consistency of results across all age groups confirms the reliability of these measurements.

Although research on the interaction between cognitive and motor development remains limited, the present study contributes to the field by examining how cognitive skills, particularly visual-motor coordination, relate to age-related developmental changes in physical performance. These findings should be interpreted within a developmental context. The observed relationship supports the idea that enhancing cognitive functions may indirectly contribute to improved physical skills in educational and developmental programs.

These findings have practical implications beyond research. Integrating visual-motor coordination assessments into early childhood education programs can support both cognitive and physical development. Additionally, such tools can be employed in school-based screening to identify children who may benefit from early interventions aimed at improving attention, decision-making, and motor planning. This developmental approach could enhance the effectiveness of curricula in physical education and general cognitive readiness (Brian et al., 2017; Robinson et al., 2015).

Gender differences align with cognitive development theories. As shown in Tables 1 and 4, the average performance time for 8-year-old girls is 1.7 seconds, compared to 1.78 seconds for boys. This difference can be attributed to girls entering puberty earlier, allowing them to transition to abstract thinking 1–2 years before boys (Özer & Özer, 2005). This advantage in KOHS block performance persists at ages 9 and 10. While the 0.08-second gap between boys and girls at age 8 is minimal, it increases to 0.16 seconds by age 9, doubling in size. This progression highlights the differing cognitive development rates between genders.

Another indication of the alignment between measurements and cognitive development theories is the decreasing difference between boys and girls at age 10 compared to age 9. As shown in Table 4, the performance time for 10-year-old girls (1.58 seconds) closely matches that of boys (1.54 seconds). This suggests that while boys enter puberty later, their accelerated development narrows the gap over time (Gander & Gardiner, 2001; Kandemir, 2007). Across the 8-10 age range, the difference remains in favor of girls by 0.07 seconds, and it is expected to diminish beyond age 10.

Our findings highlight visual-motor coordination as a key predictor of physical performance, particularly at younger ages, though varying by age and gender. Table 2 shows a significant inverse relationship between visual-motor coordination and physical performance ($r=-0.258$, $p<0.001$), indicating that better coordination (lower completion time) correlates with higher performance. Literature supports the critical role of visual-motor skills in cognitive and physical performance. Robinson et al. (2015) emphasize their role in motor competence development, especially in early childhood, where this relationship is strongest. They also suggest that the strength of motor-cognitive links may decrease with age, as developmental systems become more specialized.

Gender-specific analysis in this study shows a slightly stronger relationship in boys ($r=-0.285$) than in girls ($r=-0.273$), suggesting that cognitive skills may play a greater role in boys' motor performance development. Similar trends were reported in previous studies, indicating that gender may moderate the strength of motor-cognitive associations (Cameron et al., 2012; Robinson et al., 2015).

Age-group analysis indicates the strongest relationship in 8-year-olds ($r=-0.267$), followed by 9-year-olds ($r=-0.254$) and 10-year-olds ($r=-0.222$), showing that visual-motor coordination has a greater impact on physical performance at younger ages, gradually decreasing with age. According to Piaget (1964), concrete operational thinking dominates during this stage, supporting visual-motor coordination, but reliance on these skills may decline as abstract thinking develops. These findings align with the literature, highlighting the importance of early interventions to enhance both cognitive and physical abilities.

Conclusion

The findings of this study underscore the strong connection between cognitive performance, particularly visual-motor coordination and decision-making speed, and physical performance. The results are fully consistent with the principles of developmental psychology and cognitive development theories. The emphasis should be placed on their relevance to cognitive and motor development in educational and health contexts. These findings can inform early interventions and educational practices aimed at improving children's cognitive and physical functioning in tandem.

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Conflicts of Interest

All authors declare that there is no conflict of interests regarding the paper and its publication.

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ORIGINAL SCIENTIFIC PAPER

Analysis of the Associations between Physical Literacy and Health Literacy in Older Females; Cross Sectional Study

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Abstract

Physical literacy (PL) and health literacy (HL) are important concepts known to be related to health behavior in all age groups, but studies rarely have examined the possible associations between them in older persons. This study aimed to evaluate the associations between HL and PL in older females, emphasizing the associations between specific facets of studied concepts. The participants were females from urban center in southern Croatia (n=45, 60-80 years of age). They were tested on HL (via the European Health Literacy Survey Questionnaire), and PL (via the Perceived Physical Literacy Questionnaire) in controlled and supervised settings. In addition to total scores (PL-total and HL-total), five subdomains of PL (PL-physical competence, PL-understanding, PL-motivation, PL-confidence, and PL-knowledge) and 12 HL-subscores were observed as variables. There was no correlation between HL-total and PL-total (Pearson's R =0.16, p>0.05). Canonical analysis calculated between PL-subdomains and HL-subscores indicated a nonsignificant multivariate association between concepts (Can R =0.67, p>0.05). However, specific domain-level analysis revealed that PL-understanding subdomain was a significant correlate of HL across several subscores, and the HL total. The results suggest that understanding the PL concept may serve as a bridge between PL and HL, potentially being important for promoting autonomy and informed health behavior in older females.

Keywords: *physical competence, physical activity, health behavior, adults, correlations*

Introduction

Physical literacy (PL) encompasses the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engaging in physical activities for life (Gilic, Sekulic, Munoz, Jaunig, & Carl, 2025). In older adults, PL assumes heightened significance, as it directly impacts their ability to maintain independence, quality of life, and overall well-being (Galan-Arroyo et al., 2023). By fostering a diverse range of movement skills, promoting active lifestyles, and enhancing awareness of the benefits of physical activity, PL acts as a protective factor against age-related decline. Improved balance, strength, and coordination resulting from enhanced PL can significantly reduce the risk of falls, a leading cause of morbidity in older populations. Furthermore, consistent engagement in physical activity, driven by PL, contributes to better cardiovascular health, muscle mass preservation, and cognitive function, all of which are crucial for healthy aging (Ding et al., 2024).

Health literacy (HL), defined as the degree to which individuals have the capacity to obtain, process, and understand basic health information and the services needed to make appropriate health decisions, is paramount for older adults (Kulakci-Altintas & Ayaz-Alkaya, 2025). As individuals age, they often face increasingly complex health challenges, including chronic disease management, medication adherence, and the ability to navigate healthcare systems. Adequate HL empowers older adults to effectively manage these challenges, enabling them to make informed choices about their health. For example, understanding medication instructions, interpreting health-related infor-

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mation from various sources, and communicating effectively with healthcare providers are all essential components of HL. Furthermore, strong HL promotes preventive behaviors, such as engaging in recommended screenings and adopting healthy lifestyle habits, which can significantly reduce the burden of age-related illnesses. Ultimately, HL is a critical determinant of health outcomes and quality of life in older populations, facilitating proactive self-management and informed decision-making (Kulakci-Altintas & Ayaz-Alkaya, 2025; Pigazzini, Wieczorek, Meier, & Maurer, 2024).

Both PL and HL are essential for promoting healthy aging and improving the overall well-being of older adults. Not surprisingly, it is theorized that these concepts are correlated and, in some cases, are observed as the same concept, but the results more often do not confirm such observations. For example, in studies dealing with older adolescents, the authors reported a weak relationship between PL and HL (Blažević, Blazevic, & Sekulic, 2024; Kesic, Peric, et al., 2022). Research examining the associations between HL and PL in adults has focused primarily on the relationship between HL and physical activity (as one of the PL facets), and some studies have reported a positive association between higher HL and increased physical activity levels in older adults, but others reported no significant associations (Buja et al., 2020; Lim, van Schooten, Radford, & Delbaere, 2021). However, physical activity, although being an important determinant of overall PL, is only one of the PL domains and, more importantly, is strongly influenced by different contextual factors (i.e., health status, mobility, gender, cultural background, and living environment). On the other hand, the associations between HL and other domains of PL (physical competence, understanding, motivation, and knowledge) have rarely been investigated for older adults.

Understanding the association between PL and HL is crucial for promoting overall well-being, especially in older adults. First, both PL and HL contribute to a holistic view of health. The PL focuses on the ability, confidence, and motivation to engage in physical activity, whereas the HL focuses on the ability to understand and utilize health information (Geets-Kesić, Maras, & Gilić, 2023; Kesic, Peric, et al., 2022). Second, both PL and HL are important from the perspective of preventive health since both literacies play a vital role in preventing chronic diseases (Kesic, Savicevic, Peric, Gilic, & Zenic, 2022). For example, by understanding health information (facet of HL) and engaging in regular physical activity (facet of PL), individuals can reduce their risk of conditions such as heart disease, diabetes, and obesity. Therefore, developing both PL and HL empowers individuals to take control of their health. This leads to better decision-making, improved self-management of health conditions, and increased overall well-being.

Despite growing recognition of the importance of both HL and PL in promoting well-being, their relationship remains underexplored—particularly in older adults. While some theoretical frameworks suggest that these constructs are closely interconnected or even overlapping, empirical evidence supporting this linkage is generally in disagreement with such hypotheses, while studies dealing with this issue in older adults are lacking. Understanding how these literacies interact later in life is essential, as both are critical to maintaining autonomy, health behavior, and quality of life in aging populations. The purpose of this study was to address this research gap by examining the associations between PL and HL in older females, offering insight into how integrated approaches to health promotion might be developed. Therefore, the aim of this study was to evaluate the associations that may exist between different facets of PL and different domains of HL in older females from Croatia. It was hypothesized that HL and PL would be significantly positively correlated but with a moderate magnitude of this association, indicating a limited level of shared variance between the constructs in older females (<30% of the shared variance).

Materials and methods

Participants

The sample of participants in this study included 45 females, 60-80 years of age, from the city of Split in southern Croatia. Given the significant influence of sociocultural factors on both HL and PL, we intentionally targeted only one geographical region and sampled participants accordingly in order to reduce sociocultural differences between them. The participants varied in health conditions, and the sample included those with no health problems, as well as those with serious health issues (diabetes, cardiovascular issues, arthritis, etc.). However, all of them were physically capable of visiting the testing center individually (please see later for variables and testing), meaning that they were independent and motorically functional, whereas more than 60% of them were involved in certain types of recreational physical exercise. They were personally invited to participate in the study, which was organized as a part of the research project at the Faculty of Kinesiology, University of Split. Prior to testing, they were informed that their participation was voluntary, that they could refuse to participate. The investigators explained the benefits and risks of their participation, and the participants provided informed consent for study participation. The inclusion criteria included being female older than 60 years, being a resident of the city of Split in southeastern Croatia, having the necessary level of independence and movement/motor functionality to visit the testing center individually, and having an appropriate level of cognitive functionality to clearly understand and respond to questionnaire items evaluating HL and PL. The exclusion criteria were being younger than 60 years, lacking the cognitive ability to respond to questionnaires, and having insufficient motor functionality and independence in visiting the testing center. The study was approved by the Ethical Committee of the Faculty of Kinesiology.

Variables

The sample of variables in this study included participants' age (self-reported, in years), HL status, and PL status. The HL and PL were gathered over a single testing session via a digital platform under the supervision and instruction of the first author of the study.

The PL was evaluated via the Perceived Physical Literacy Questionnaire for South Eastern Europe (PPLQ-SEE) (Gilic et al., 2025). The instrument originally comprises 24 items structured in six domains: (i) physical competence, (ii) understanding, (iii) motivation, (iv) confidence, (v) knowledge, and (vi) physical activity behavior. The items of the first four domains are evaluated on a six-point Likert scale (strongly agree–strongly disagree) ranging from 5 to 0, and the PL-knowledge is composed of items with closed response categories (dichotomous true–false scale). In this study, we observed the first five subdomains (PL-competence, PL-understanding, PL-motivation, PL-confidence, and PL-knowledge) and the total score (PL-total) as variables representing the participants' PL status.

To evaluate HL, we used the validated Croatian version of the original European Health Literacy Survey Questionnaire (HLS-EU-Q) (Geets-Kesić et al., 2023; Kesic, Savicevic, et al., 2022; Sørensen et al., 2013). The assessment covered an individual's capacity to collect and comprehend basic health information and to obtain health services. It also assesses the ability of individuals to use the latter to make appropriate health decisions or to access, comprehend, evaluate and apply information regarding their health. The following subscores were observed in this study: (i) accessing healthcare-related information (HC-AC), (ii) understanding healthcare-related information (HC-U), (iii) appraising healthcare-related information (HC-AP), (iv) applying healthcare-related information (HC-APPL), (v) accessing information related to disease prevention (DP-AC), (vi) understanding information related to disease prevention (DP-U), (vii) appraising information related to disease prevention (DP-AP), (viii) applying information related to disease prevention (HP-APPL), (ix) accessing information related to health promotion (HP-AC), (x) understanding information related to health promotion (HP-U), (xi) appraising information related to health promotion (HP-AP), and (xii) applying information related to health promotion (HP-APPL). A general index of HL (HL-total) was created by applying a 4-point Likert scale comprising response options ranging from very difficult—1 to very easy—4. To calculate the score, indexing was applied according to the following formula: index = (mean-1) × (50/3). Scaling was applied to the HL range, with 0 representing the lowest score and 50 representing the maximum score. The range was then divided into four separate ranking bands as follows: inadequate (from 0-25), problematic (26-33), sufficient (34-42), and excellent (43-50) (Sørensen et al., 2013).

Statistics

The Kolmogorov-Smirnov test was applied to check the normality of the distributions for all the variables. Since all variables met the normality assumption, the means, minimum, maximum, and standard deviations were calculated as descriptive statistical parameters.

Univariate and multivariate analyses were applied to determine the associations between HL and PL. The univariate associations between five subdomains of PL and PL-total (first set), with all subscores of HL and HL-total (second set), were evaluated by calculating Spearman's correlation coefficients (Spearman's R). The multivariate associations between HL and P were checked by canonical correlation analysis. The canonical correlation analysis was applied with all subscores of PL included in the first set and all subscores of the HL included in the second set. Since PL-total and HL-total are essentially collinear with corresponding subscores (i.e., total scores are calculated on the basis of subscores; please see variables for details), PL-total and HL-total were not included in the calculation of the canonical correlation analysis.

Statistica version 13.5 (Tibco Inc. Palo Alto, CA, USA) was used for all analyses, and a p-level of 95% was applied.

Results

The results of the descriptive statistics for all the variables observed in this study are presented in Table 1. With an average score of 36.8±7.07, the HL of the tested participants was sufficient.

Table 1. Descriptive statistics of the studied variables

	Mean	Minimum	Maximum	Std.Dev.
Age (years)	70.80	61.00	80.00	5.57
PL-competence (score)	63.44	0.00	100.00	26.50
PL-understanding (score)	96.44	60.00	100.00	7.99
PL-motivation (score)	87.04	0.00	100.00	24.31
PL-confidence (score)	73.44	0.00	100.00	27.13
PL-knowledge (score)	82.72	44.44	100.00	16.51
PL-total (score)	80.62	40.56	95.00	11.49
HC-AC (score)	37.13	8.33	50.00	10.95
HC-U (score)	39.54	16.67	50.00	9.55
HC-AP (score)	32.04	12.50	50.00	9.35
HC-APPL (score)	40.46	20.83	50.00	7.62
DP-AC (score)	39.44	12.50	50.00	10.46
DP-U (score)	42.53	25.00	50.00	7.99
DP-AP (score)	35.85	20.00	50.00	8.11
DP-APPL (score)	31.11	16.67	50.00	10.35
HP-AC (score)	33.93	6.67	50.00	10.52
HP-U (score)	34.56	4.17	50.00	12.27
HP-AP (score)	41.54	22.22	50.00	8.51
HP-APPL (score)	36.93	16.67	50.00	9.99
HL-total (score)	36.86	24.11	48.23	7.07

Legend: PL – physical literacy, HC-AC - accessing healthcare-related information, HC-U - understanding healthcare-related information, HC-AP - appraising healthcare-related information, HC-APPL - applying healthcare-related information, DP-AC - accessing information related to disease prevention, DP-U - understanding information related to disease prevention, DP-AP - appraising information related to disease prevention, HP-APPL - applying information related to disease prevention, HP-AC - accessing information related to health promotion, HP-AP - appraising information related to health promotion, HP-U - understanding information related to health promotion, HP-APPL - applying information related to health promotion

The correlations between PL-total and HL-total are presented in Figure 1. The variables accounted for less than 3% of the common variance (p>0.05) (Figure 1).

The results of the canonical correlations between the PL subscores and the HL subdomains are presented in Table 2. In general, no significant multivariate correlation was found between sets of variables, with the first pair of canonical roots explaining 45% of the common variance (p>0.05).

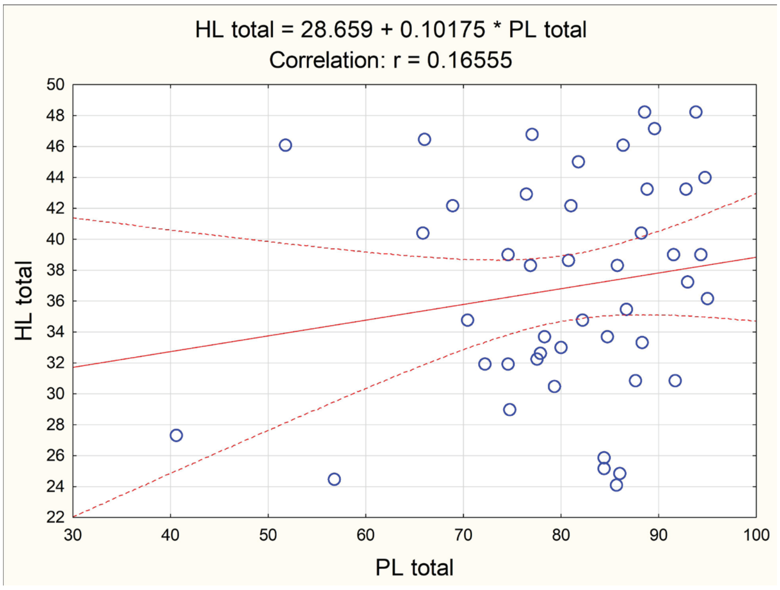

FIGURE 1. Correlation between total scores of health literacy and physical literacy

Table 2. Multivariate associations between health literacy subdomains (left set) and physical literacy subscores (right set) in older women—results of the canonical correlation analysis (Can R – canonical correlation)

Roots removed	Canonical R	Canonical R^2	Chi-square	p-level
0	0.67	0.45	70.40	0.17
1	0.53	0.28	38.84	0.69
2	0.40	0.16	21.44	0.87
3	0.37	0.13	12.47	0.82
4	0.30	0.09	4.96	0.76

Note that factor structure of the roots is not presented due to nonsignificant canonical correlations

Table 3. Pearson's correlations between health literacy and physical literacy

	PL-competence	PL-understanding	PL-motivation	PL-confidence	PL-knowledge	PL-total
HC-AC	0.04	0.33*	0.01	0.02	-0.05	0.06
HC-U	0.20	0.06	-0.04	-0.05	-0.29	-0.02
HC-AP	0.18	0.21	-0.18	0.12	-0.11	0.07
HC-APPL	0.18	0.08	-0.03	0.12	-0.22	0.09
DP-AC	0.16	0.27	-0.04	0.07	-0.03	0.13
DP-U	0.09	0.32*	-0.07	0.18	0.05	0.17
DP-AP	0.02	0.31*	-0.03	0.27	0.06	0.19
DP-APPL	-0.14	0.16	-0.16	0.18	-0.03	-0.04
HP-AC	0.06	0.22	-0.16	0.04	-0.06	-0.01
HP-U	-0.01	0.23	-0.14	-0.11	-0.12	-0.13
HP-AP	0.17	0.24	0.01	0.00	-0.26	0.03
HP-APPL	0.06	0.21	0.13	0.16	-0.19	0.14
HL-total	0.11	0.30*	-0.09	0.10	-0.14	0.16

Legend: * indicates statistical significance of p<0.05, PL – physical literacy, HC-AC – accessing healthcare-related information, HC-U – understanding healthcare-related information, HC-AP – appraising healthcare-related information, HC-APPL – applying healthcare-related information, DP-AC – accessing information related to disease prevention, DP-U – understanding information related to disease prevention, DP-AP – appraising information related to disease prevention, HP-APPL – applying information related to disease prevention, HP-AC – accessing information related to health promotion, HP-AP – appraising information related to health promotion, HP-U – understanding information related to health promotion, HP-APPL – applying information related to health promotion.

The univariate correlations between all the HL and PL variables are presented in Table 3. The PL understanding was significantly correlated with HC-AC (10% of the shared variance), DP-U (<10% of the shared variance), DP-AP (<10% of the shared variance), and HL-total (9% of the shared variance).

Discussion

There are several important findings of our study. First, PL-total and HL-total are nonsignificantly correlated, sharing less than 10% of the common variance. Therefore, our initial study hypothesis cannot be accepted. However, (second), PL understanding is significantly correlated with several HL subscores and the HL-total score.

Contrary to our initial expectations, the total HL and PL scores were not significantly correlated. As already mentioned in the introduction, studies that have investigated this problem in the adult population are generally scarce; however, to the best of our knowledge, no investigations have examined the associations between HL and PL among older persons in the territory of southeastern Europe. Therefore, further discussion of findings will, in some cases, lack direct scientific evidence, but some theoretical and practical explanations of the results will be offered.

One reason for the poor correlation between HL and PL may be the distinct nature of these constructs, particularly in the context of older adulthood. In brief, HL focuses on cognitive competencies, such as processing health-related information, understanding medical instructions, and making informed decisions within healthcare systems (Geets-Kesić et al., 2023; Sørensen et al., 2013). These abilities often develop through accumulated life experience, healthcare interactions, or formal education and may remain stable or even improve with increasing age. In contrast, PL emphasizes embodied capacities such as physical competence, motivation for movement, and confidence in performing physical tasks (Gilic et al., 2025). All of these factors tend to decrease with age due to physiological, psychological, and environmental barriers. For many older individuals, especially women, declining mobility, fear of injury, or chronic conditions may inhibit physical engagement, regardless of their understanding of its benefits (Cohen-Mansfield, Shmotkin, & Goldberg, 2010). This disconnect between knowing and doing highlights how the cognitive strengths associated with HL may not translate into higher PL in aging populations. Moreover, it is possible that divergence in these literacy domains becomes more pronounced with age, helping to explain the weak overall correlation observed in our study.

Another factor that may explain the weak correlation between H1 and PL is the reliance on compensatory health strategies, particularly among older adults. Individuals with high HL are often able to engage in alternative health-promoting behaviors that do not necessarily involve physical activity. For example, they may adhere strictly to medication regimens, follow dietary guidelines, or attend preventive health checkups—all of which contribute to better health outcomes without requiring high levels of physical competence or activity (Glass, Bellettiere, Jain, LaMonte, & LaCroix, 2021; Sørensen et al., 2021). In older women, this pattern may be even more pronounced due to age-related physical limitations, chronic conditions, or pain, which can restrict mobility and reduce motivation for movement (Glass et al., 2021). As a result, maintaining health may become more about managing illness than engaging in movement, leading to "health literacy without physical literacy". Consequently, their HL scores may remain high, whereas their PLs may remain low, contributing to the observed disconnect between the two constructs.

An additional reason for the poor correlation between HL and PL may lie in what can be described as lifestyle segmentation in aging populations. In older adults, particularly in older women, HL and PL often develop along divergent pathways. HL can continue to improve through interactions with healthcare providers, participation in educational programs, or exposure to health information via community centers, clinics, or media (Lima, Maximiano-Barreto, Martins, & Luchesi, 2024). In contrast, PL requires life-long engagement in physical behaviors, such as regular movement, the practice of motor skills, and the reinforcement of physical confidence (Gilic et al., 2025; Kesic, Peric, et al., 2022). As a result, HL may be high or stable, while PL was not sufficiently developed simply because of a lack of physical competence as a result of poor participation in physical activities earlier in life. This divergence in lifestyle experiences leads to a natural decoupling of the two literacies, which could explain the weak overall correlation between them.

From the perspective of our research, another key explanation for the observed weak correlation between total HL and PL scores is particularly possible and is related to the masking effect of composite scoring. Both HL and PL are multidimensional constructs, each composed of several distinct but interrelated domains (Blažević et al., 2024; Geets-Kesić et al., 2023). When these domains are averaged into a single total score, nuanced relationships between specific subdomains may be obscured. For example, health-related knowledge or critical appraisal skills may correlate strongly with PL components such as motivation or understanding but not necessarily with physical competence or activity behavior. This is even more possible in the older women we observed here because of their limited physical mobility. By aggregating all the domains, the statistical "noise" from unrelated subdomains dilutes the strength of meaningful interdomain connections, resulting in a weak overall correlation. This highlights the importance of conducting domain-level analyses, which in our case revealed stronger and more interpretable relationships, offering a clearer picture of how HL and PL interact within the aging female population.

Although the total scores of the HL and PL groups were weakly correlated, domain-level analysis revealed substantially greater intercorrelations, underscoring the importance of a multidimensional analytical approach. Specifically, the understanding component of PL emerged as the most robust correlate of HL across all domains. This suggests that the cognitive grasp of physical activity — its purpose, benefits, and safe application — is closely aligned with an individual's ability to navigate health information more broadly. Unlike more embodied or emotional aspects of PL, understanding may represent a cognitive intersection between the two literacies, especially between PL understanding and different facets of HL.

One of the possible explanations for the significant association between PL understanding and HL is related to shared cognitive dimensions. Specifically, the understanding of the PL reflects an individual's cognitive grasp of physical activity, including the reasons why it is important, how to perform it safely, and how it contributes to overall well-being (Gilic et al., 2023).

This domain closely aligns with several components of HL, particularly comprehension and appraisal of health information (i.e., interpreting medical advice, understanding disease risk factors, and evaluating preventive health strategies). The HL in general acknowledges conceptual awareness and informed decision-making rather than direct action or physical skill. In older women, this overlap may be especially important, as both types of understanding support autonomy, safety, and informed health behavior without necessarily requiring high levels of physical exertion. Unlike other PL components (e.g., competence or confidence), which may decline with age, the PL-understanding domain can remain robust and grow through health education or life experience. This may explain why understanding in PL showed the strongest and most consistent associations with HL. This finding actually suggests that cognitive understanding may act as a bridge between HL and PL in general.

Other possible explanations are specific for the participants in this study. Specifically, in older women, both HL and PL understanding may be shaped by similar educational influences, whether formal (e.g., structured health education programs, clinical consultations) or informal (e.g., community talks, media exposure, conversations with peers or family). These forms of learning contribute to a deeper awareness of health-related information, including both general health behaviors and physical activity principles. As a result, cognitive domains such as PL understanding tend to align more closely with HLs than do emotionally or behaviorally driven PL components (i.e., PL confidence or PL competence), which often require regular practice or engagement to develop and maintain. In aging populations, where physical activity may decline due to health limitations, education becomes a primary avenue through which individuals stay informed and make health-conscious decisions (Sardareh et al., 2024). This shared educational foundation reinforces the idea that some aspects of PL, particularly those tied to knowledge and understanding, are more cognitively proximal to HL than others are.

Additionally, for older women, understanding health and physical activity often plays a central role in maintaining self-care and independence, two priorities that become increasingly important with age. As daily functioning becomes more challenging, the ability to make informed decisions about medication, physical limitations, exercise safety, and disease prevention becomes essential to sustaining autonomy (Petrusevski, Morgan, MacDermid, Wilson, & Richardson, 2022). In this context, the cognitive dimension of understanding acts as a shared anchor between HL and PL, allowing older women to stay actively engaged in their health management even if their physical ability declines. Understanding fosters confidence in navigating health systems but also in recognizing the value of a physically active lifestyle, choosing appropriate activities, and avoiding injury. Unlike physically demanding components of PL, such as physical competence, or emotionally driven components, such as confidence and motivation, PL understanding remains relatively resilient to aging and can even be strengthened through lived experience. This makes it a particularly accessible and empowering resource for older women, who may face age- or gender-specific barriers to physical activity.

This study has several limitations that should be acknowledged. First, its cross-sectional design prevents conclusions from being drawn about causality between HL and PL. Additionally, the research was conducted in a specific regional and cultural context (urban center in southern Croatia), where traditional gender roles, health behaviors, and physical activity norms may differ from those of other populations, limiting generalizability. Finally, the lack of physical activity assessment prevents a fuller understanding of how actual movement behaviors are related to the PL and HL outcomes.

On the other hand, this study represents one of the first investigations into the relationship between HL and PL among older women and is likely the first conducted in Croatia and the broader territory of the former Yugoslavia. It addresses a notable research gap in an underrepresented demographic, offering culturally relevant insights.

Conclusion

This study examined the association between HL and PL in older women, revealing a weak correlation between the total scores of the two constructs. This suggests that, despite their shared relevance to health behavior, HL and PL may function as distinct domains, particularly in later life. Differences in cognitive versus embodied components, lifestyle patterns, and compensatory strategies likely contribute to this divergence.

However, domain-level analysis offered deeper insight, with the PL understanding emerging as the strongest correlate of HL across all subdomains. This finding highlights a shared cognitive foundation between the literacies, suggesting that understanding may serve as a key cognitive bridge — especially important for promoting autonomy and informed health behavior in older women.

Future research should expand on these findings by exploring HL–PL relationships in more diverse populations, including men, rural or less-educated groups, and different age segments across the life course. Longitudinal designs would help clarify how these literacies develop over time and interact in the presence of changing health conditions or physical limitations. In addition, intervention studies could test whether improving one form of literacy has meaningful effects on the other, particularly when understanding is targeted as a mediating domain.

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Conflict of interest
The authors declare that there is no conflict of interest.

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SportMont

ORIGINAL SCIENTIFIC PAPER

Perception of Physique Aesthetic, Fitness and Anthropometric Scores of Filipino Body Samples

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Abstract

Society equates beauty and fitness and this study aims to examine how perceived beauty and fitness correlate with actual fitness scores, addressing expectations in the fitness industry, from a Philippine-specific perspective. The study recruited 2,077 Filipino respondents (851 males, 1,043 females, 183 LGBTQ+), aged 19.41±3.13 years. An online questionnaire with 14 body images (7 males, 7 females) scoring models' aesthetic ratings (AR) and reporting their perceived fitness (PF) on a 10-point Borg scale. Models' anthropometric data, including percent body fat (%BF), body mass index (BMI), handgrip scores (HG), shoulder-to-waist ratio (SWR) and waist-hip ratio (WHR), were collected as reference in association assessments. The study found significant associations ($p<0.05$) between HG with SWR ($r^2=0.917$) and HG with %BF ($r^2=0.894$), and AR of males. Moderate negative relationship on AR and WHR (Cramer's V of 0.22) of women were found, with an inverted U trend on their BMI and %BF measurements. AR of models with optimal WHR (0.7) for women and SWR (1.6) for men were seen cross-sectionally decreasing and increasing respectively as respondents increase in age. Further research was recommended particularly on the roles of social factors, time and gender identity on AR with the different explored variables.

Keywords: *body aesthetics, perceived fitness, health factors*

Introduction

Within contemporary societal norms, a prevailing standard of beauty and physical fitness manifests as a slender and lean physique, denoted by the terms "thin" and "skinny". Antos, Paleka, and Bushman (2023) elucidate how this standard resonates with individuals, particularly adolescents, who perceive an ideal of beauty that aligns closely with the characteristics of an "extremely skinny woman". Song et al. (2023) corroborates these findings, highlighting gender disparities in the pursuit of thinness, with adolescent females exhibiting a heightened desire for thinness compared to males. Despite nuanced differences in aesthetic preferences across genders, adolescents uniformly endorse the notion that a slender body shape epitomizes beauty for women.

Beyond aesthetic perception, associations between body shape, fat mass, and perceptions of fitness and health emerge as focal points of inquiry. In the study conducted by Antos et al. (2023), participants labeled a model as "out of shape", suggesting a prevailing societal belief that engagement in physical exercise reflects a commitment to bodily well-being. This echoed by Herrera-Fomperosa et al. (2023), who challenge conventional assumptions by revealing a lack of correlation between traditional body physique ratings and risks of Metabolic Syndrome (MetS). Instead, their findings suggest that increases in muscle mass, as indicated by their alternative body physique system, are inversely associated with MetS risks. Thus, underscoring the notion that muscle mass may serve as a superior predictor of health and fitness, emphasizing the complex interplay between societal norms, body image perceptions, and health-related outcomes.

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Physical Activity and Body Beauty

Physical activity undoubtedly has a positive influence on an individual's physique alongside diet and nutrition. The level of fat-mass contributes largely to how the body structure will turn out. Having an ideal level of percent body fat of 15% for active men and 25% for active women (Potter et al., 2024) still achieves the optimal physique status as it hits the right balance of fat and fat-free mass.

Among the different types of physical activity, resistance training has a greater influence on body shape and physique as it optimally stimulates the muscles and maximizes the use of fat for energy. Resistance training groups (Leon, Flores, & Viramontes, 2011) show lower body fat percentage and higher muscle mass, and directly associated with aesthetics. However, while muscularity directly influences body form and aesthetics, too much muscle hypertrophy may also lead to dropping attractiveness scores, applying the inverted-U hypothesis. In a study on muscularity of males, Frederick and Haselton (2007) found that subjects with moderate muscularity are rated most attractive. Hence, visual fitness does not entail greater muscles will lead to greater scores.

Guided by the inverted U hypothesis, body shape can be associated with muscularity to a certain extent, and aesthetics and beauty are more attributed to proportion rather than size, as supported by a study on women (Perez Chavez et al., 2020). While for men, Shoulder-to-hip ratio is seen to be a factor for being more attractive, masculine, and better in fitness ability (Pazhoohi, Barza, & Kingstone, 2023). With the reviewed theories and concepts, this study aims to know and validate if anthropometric scores correspond to aesthetic scores of Filipino body models, and respondents perceived level of fitness matches the actual fitness scores of the models. This study also hypothesizes that male models exhibiting a higher shoulder-to-waist ratio (SWR), women possessing lower waist-hip ratio (WHR) and an optimal percentage of body fat (%BF) will be perceived as more aesthetically appealing and physically fit, resulting in higher ratings for both attributes.

In the fitness industry today, the proposition of healthy and fit body is skewed towards a body that "looks good" and "healthy". This study aims to know how perceived beautiful body and perceived physique fitness are associated with the actual fitness scores and profile of the body samples or models. The thin line between "body beautiful" and fitness is still undiscriminated in local gyms, as no accreditation or professional body that regulates the skills, knowledge and practices of fitness trainers. This belief seamlessly passed on to clients, creating inaccurate understanding of fitness and misconceptions. This study is valuable in addressing this, especially that Philippine-specific perspectives are manifested.

Methods

Sample

The study recruited a diverse sample from general population (N=2,077) aged 19.41±3.13 years, encompassing all gender identities, who possess a nuanced understanding and mature perspective regarding body beauty and aesthetics. The proponents aimed to recruit Filipino respondents within the legal age, excluding those with significant visual impairments. Additionally, the proponents ensured the representation of individuals with 851 males, 1043 females, and 183 respondents identifying within the LGBTQ+ spectrum at the Filipino context, thus fostering a comprehensive exploration of perspectives and experiences within the designated demographic cohort.

Instrumentation

The researchers utilized an online questionnaire as the primary data collection tool, facilitating the acquisition of responses from participants. The questionnaire consisted of 14 (7 males and 7 females) black and white, human body images of Filipino models in black undergarments, capturing from the chin (mental) to the mid-thigh (femoral) area. It has 3 sections covering respondent's participation consent, respondent's profile and rating sections where images are rated based on body aesthetic and perceived fitness level.

Model Profile

Actual anthropometric and fitness scores were collected at the time of models' (N=14) image collection. Measurements of %BF with Mean±SD=24.63±9.5, body mass index (BMI) with Mean±SD=23.14±3.69, handgrip test scores (HG) with Mean±SD=32.15±10.24, WHR for females with Mean±SD=0.86±0.08 and SWR for male subjects with Mean±SD=1.48±0.11. One female model possessed an ideal (golden ratio) WHR of 0.71 while 2 male counterparts possessed SWR of 1.6.

10-point Borg Scale

Concealing the actual scores and measurements, respondents rated the images in the categories of Physical Aesthetics (1– Not Physically Aesthetic, 10– Physically Very Aesthetic) and Perceived Fitness Level (1– Physically Unfit, 10– Physically Very Fit), labelled as Aesthetic Rating (AR) and Perceived Fitness (PF) respectively.

Study Procedure

Crafting Invitational Poster

Publication material served as the initial point of engagement, delineating the research's purpose, significance, and anticipated involvement for prospective respondents. Strategic dissemination across various digital platforms, encompassing social media networks, personalized email communications, and other pertinent digital channels, amplifies the reach and visibility of the study's call for participation.

Dissemination Strategy & Response Collection

Strategic dissemination across various digital platforms, encompassing social media networks, personalized email communications, and other pertinent digital channels, amplifies the reach and visibility of the study's call for participation. This step targeted respondents across the Philippines, from Luzon to Mindanao. The solicitation of mobile numbers solely for response control purposes underscores the commitment to safeguarding participant anonymity and privacy, thereby fostering a conducive environment for candid and uninhibited responses.

Ethical Considerations

Participation in the study is strictly voluntary as indicated in their approved informed consent form. The research protocol was approved by the University Research Ethics Office of Ateneo de Manila University with protocol number AdMUREC_24_018.

Statistics

Multiple regression analysis was employed to examine the predictive capacity of the explanatory variables—namely HG, SWR/WHR, %BF and BMI—on the aesthetic ratings of the models. Effect size was assessed using Cramér's V to determine the strength of association between categorical variables and to facilitate magnitude-based inferences regarding their relationships. Descriptive statistics, including means and standard deviations, were utilized to summarize demographic characteristics and overall response scores. Jamovi 2.6.26 and other online statistical calculators were used to perform the calculations.

Results

The findings are exhibited in the order of presenting the explanatory variables of AR of both males and females, relationship of BMI and AR, analysis of BMI and %BF as an explanatory variable for female AR, WHR of females and cross-sectional perception of different age groups on WHR and SWR. Overall, the data show significant, negative relationship between HG scores and %BF with r=-0.641. Significant positive relationship is also found between AR and PF with a strong r of 0.996. A weak negative association occurred between %BF and overall AR and PF with r of -0.27 and -0.29 respectively.

Male models' aesthetic ratings showed a weak negative association with percent body fat (Cramer's V =0.2), indicating that lower %BF tends to be mildly preferred. However, handgrip strength (HG) showed a stronger positive association with aesthetic ratings (r^2=0.89), suggesting that perceived strength is a more salient predictor of male attractiveness than leanness in this Filipino sample. This link with HG scores is evident in Tabe 1. Large associations found with male SWR (Cramer's V =0.25). In contrast, HG scores have small association with females' WHR measurements with Cramer's V of 0.09.

Table 1. Multiple Regression with Aesthetic Rating (AR) as Response Variable

		Aesthetic Rating (Male)	Aesthetic Rating (Female)
HG - SWR/WHR	r^2	0.918*	0.667
	F-statistic	22.290	4.007
HG - %BF	r^2	0.894*	0.400
	F-statistic	16.890	1.334
SWR/WHR - %BF	r^2	0.163	0.711
	F-statistic	0.389	4.923
SWR/WHR - BMI	r^2	0.335	0.719
	F-statistic	1.006	5.109

* Significant at 0.05.

Table 1 shows HG and SWR as a significant explanatory variable for male AR using a multiple regression test with a strong r^2 of 0.918. This is also observed with HG and %BF as predictor of male AR with r^2= 0.894 ($p<0.05$). Posing a very weak r^2 of 0.163 of SWR and %BF, this reiterates HG being a significant variable in male AR.

The dispersion of associations on AR is relatively greater for males (SD=0.39) comparing to females (SD=0.15). Table 1 show WHR and BMI being a moderate predictor of female AR with r^2=0.719. This is related to WHR and %BF as a predictor with r^2 of 0.711. HG and WHR show an r^2 of 0.667 while r^2=0.400 for HG and %BF as predictor of female AR. Variables with WHR exhibit lower dispersion in regression score (SD=0.027), making it an explanatory factor for female AR. This observation is validated visually by Figure 3.

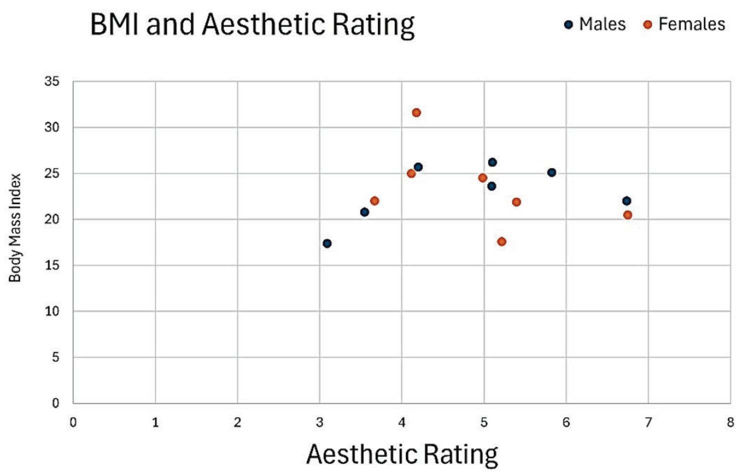

FIGURE 1. Scatter plot chart of BMI and Aesthetic Rating (AR) of Males and Females.

Figure 1 shows the average AR of each male and female body models by the respondents of the questionnaire, acquiring a mean AR of 4.80±1.28 for males and 4.90±1.03 for females. They are presented in relation to its association with models' BMI with mean of 22.97±3.15 for males and 23.3±4.42 for females. Female model with the highest AR exhibited a BMI of 20.5 while with the lowest unveiled a BMI of 22. The di-rection of male counterpart is in the opposite with highest AR has a BMI of 22 and with the lowest had 17.4. This opposite orientation is partially presented in Figure 1 visually. Female models show large negative associations having a Cramer's V of 0.63, while males display a positive medium association with 0.19.

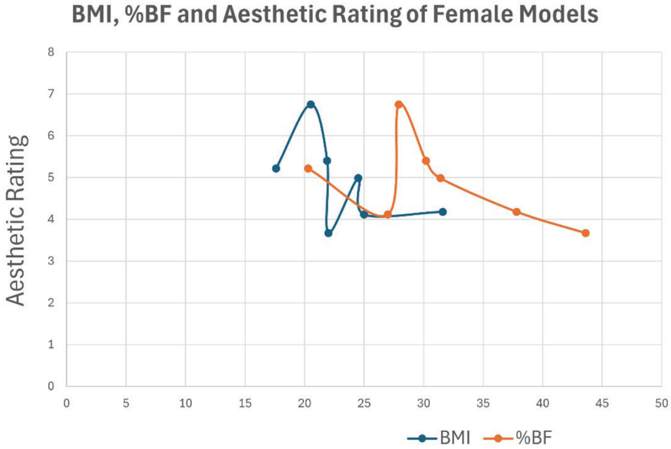

FIGURE 2. Inverted U relationship of %BF-BMI and Aesthetic Rating (AR) of Female Models.

For the female models, the trend in %BF and BMI measurements in relation to female AR is visually presented by Figure 2. Measurements of %BF yield to a mean±sd of 31.17±7.59, with %BF of with highest AR resulted to 27.9%, slightly above normal %BF values (Potter et al., 2024). Model with the second highest also exposed a above normal %BF of 30.2%. While those who got low %BF measure were also rated low, female model with the lowest AR revealed a high %BF measurement of 43.6%. Female BMI and %BF scores, in relation to AR, show an inverted U trend in a line graph. Outliers of the two variables show %BF of 27 and a BMI of 22, obtaining WHR measurements of 0.95 and 0.93 respectively. Their high WHR pulled their AR values, departing them from the trend, strengthening the influence of WHR in AR of participants.

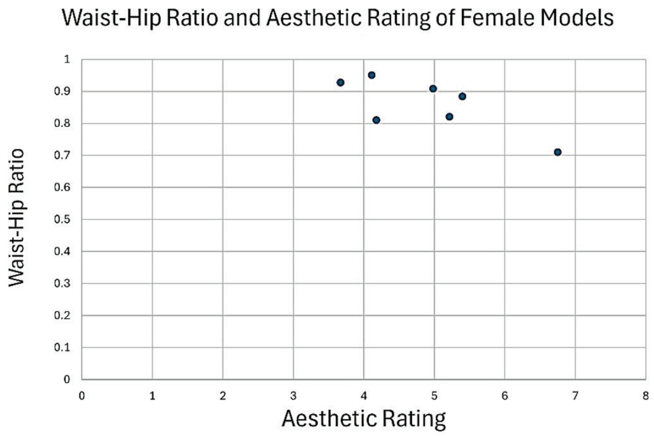

FIGURE 3. Relationship of Waist-Hip Ratio and Aesthetic Rating (AR) of Female Models.

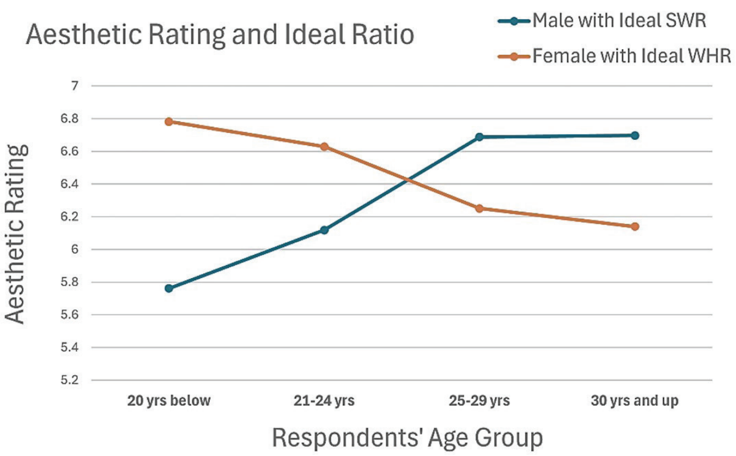

FIGURE 4. Ideal Shoulder-Waist Ratio of Male (1.60) and Waist-Hip Ratio of Female (1.71) Models and Cross-sectional Aesthetic Ratings (AR) of different age group.

Measurements of WHR among females as an explanatory variable maintained its influence on other factors in predicting AR. From Table 1 to Figure 2, WHR has impacted the scores and the trend. Figure 3 deliberately show how WHR measurements are associated with AR. The scatter-plot exhibits a descending trend visually where higher AR scores tend to possess low WHR. This negative relationship caused a moderate Cramer's V of 0.22, indicating a level of chance attributed in the result due to minimal participants being compared. Model with the highest AR of 6.75 possessed a WHR of 0.71, the golden value for WHR.

For male models, SWR were measured instead of WHR. While low predictive score on AR was presented in Table 1, SWR, comparable to BMI, posed a moderate association with AR, with Cramer's V of 0.28.

Results of males' SWR and females' WHR in reference to the golden ratio was highlighted in its relationship to AR. Figure 4 highlights cross-sectional comparison of AR from different age group, presenting an increasing trend in AR for male with the highest SWR, rating from 5.76 by respondents 20 years old and below, to an average of 6.70 rating by respondents 30 years and up. Mean rating of female with the golden ratio, however, shows decreasing trend from 6.78 to 6.14. Age, in this investigation, played a factor in changeability of perception of ideal and aesthetic human body.

Discussion

The society's standard of being thin as beautiful (Antos, Paleka & Bushman, 2023) has driven the development of this study. While being overweight is seen negatively not only in terms of beauty but also in health, findings exposed factors of perceived beauty does not only limit to body fat but predicted through numerous factors. This belief of being thin as beautiful is also observed among adolescents (Song et al., 2023) where females desire to be thinner. Their desire of having a lower BMI also inspired the study to look further on BMI and body appearance. Significant gender differences in beauty and the belief thin body shape as beautiful entailed the need for supplementary investigation and gathering of data.

Health & Beauty

Antos, Paleka and Bushman (2023) have reported previously that beauty is also viewed in someone who has care about bodily exercise and health, emphasizing the importance of exercisein beauty. Strong association between aesthetic and perceived fitness scores show its application in the Philippine setting. On the other hand, the idea of "thinness" is more applicable to BMI rather than %BF as weak associations was discovered with perceived fitness. Percent body fat classified obesity better as fat mass index is better associated with %BF.

Association of body physique rating and metabolic risk was earlier seen by Herrera-Fomperosa et al (2023), integrating physique with health concerns. Low association between body aesthetic and %BF has surfaced in several points in this study where overall AR is weakly associated with %BF. Models who possessed normal BF values, 15% for men and 25% for women (Potter et al., 2024), does not predict superior aesthetic ratings. While %BF as a factor is evident for men AR, further investigation is needed for %BF as an explanatory variable for metabolic risks as fat location, rather than index, may influence more metabolic dysregulation (Wong et al., 2021).

Health factors such as strength and body composition has been strongly observed in men with its significant association with body aesthetics, while for women, WHR contributed more. This has supported a previous study (Kościński, 2013) where health risk factors such as WHR has been identified at least as important as BMI for attractiveness. Women health factors BMI and WHR are moderate predictors of women aesthetic rating, and also possess a "Goldilock's zone" in levels of %BF.

Aesthetics and Physical Activity

Health factors were explored on its associations with aesthetic ratings, but the role of exercise and physical activity were also unraveled through the scores presented by strength tests and body composition. While large associations are found among male strength with form, and small associations for females, the link between exercise and body shape has been tackled in previous studies. Revisiting Leon, Flores & Viramontes' investigation of resistance training, comparing practitioners who practice resistance exercises in their training possess significantly lower %BF. Moreover, muscle mass is also significantly higher for groups who practice resistance activities (Leon, Flores, & Viramontes, 2011). Strength as well is largely associated with body shape of males than in females as certain level of BF is needed by women to maintain shape. Resistance training does not only normalize body fat levels, but coupled with muscle improvements.

While associations are small, strength, having or near to the golden ratio and beauty move in the same direction for females (Perez et al., 2020), and this represents unhealthy body mass with attenuate waist dictates preference for both sexes. Males in particular, have neurologically attentive through brain rewards centers to optimal WHR (~0.7) regardless of the BMI (Platek & Singh, 2010), seconding findings relating to WHR as an important explanatory variable in aesthetic ratings.

Larger SWR and strength scores showed important consideration backed by previous studies (Fan et al., 2004). While strength and muscularity are linked to attraction of opposite sex, hypertrophy while maintaining body shape has been consistent with past findings on inverted-U hypothesis on muscularity. Muscularity nevertheless shows to be a chief variable for attractiveness across several studies (Frederick & Haselton, 2007) and seen to be consistent to Filipino bodies. Validating SWR for men and WHR for women as important, it is imperative to note as well that ratings vary across cultures (Pazhoohi et al., 2024) and further analysis of social factors is encouraged. Furthermore, the tendency of older respondents to provide more favorable ratings for male bodies may indicate generational differences in aesthetic preferences, rather than reflecting variations in perception alone.

Conclusion and Recommendations

This study is among the first to explore the relationship between anthropometry, perceived fitness, and aesthetic preferences among Filipino respondents, offering a valuable perspective on body aesthetics. It has shown and addressed inquiries on how fitness scores and anthropometric measurements are linked to perception of Filipinos on aesthetic bodies and fitness. In summary, aesthetic ratings and perceived fitness have significantly shown strong correlations after weeks of survey implementation. Handgrip and strength scores with SWR and %BF are strong explanatory variables of body aesthetic for men. While for women, aesthetic ratings are negatively influenced by WHR of women. An inverted U relationship was also found with women's BMI and %BF with their aesthetic scores. Although limitations of few represented models, variations of different body types were acknowledged by respondents. Further research is always recommended specifically on how social factors affect perception of beauty, fitness and health; how these association change over time; and lastly, extensive and controlled representation of different gender identities in responses.

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Conflict of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Socio-Demographic Characteristics in Relation to the Knowledge and Attitudes of Physical Education Teachers about Sports Injuries Management in Enugu State, Nigeria

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Abstract

The study assessed the relationship between socio-demographic characteristics and knowledge and attitudes of sports injuries' management among physical education teachers (PETs) in secondary schools in Enugu State, Nigeria. An institutional-based cross-sectional study was conducted on 294 PETs between December 2023 and January 2024 across the six education zones in Enugu State. Knowledge of sports injuries management was measured using Knowledge Test Scale, while Attitude about sports injuries management was measured using Attitude Scale. Frequency, percentage, and binary logistic regression were used for data analyses. The Statistical Package for Social Sciences (SPSS) version 25 was used for the data analysis. The findings revealed that more than two-thirds (71.0%) of PETs had good knowledge of sports injuries management, while 29.0 per cent had poor knowledge. More than two-thirds (71.7%) of PETs expressed positive attitudes toward sports injuries' management. Only years of job experience (OR=2.263, 95% CI [1.100-4.658], p=0.027) was significantly associated with knowledge about sports injuries' management. Gender, educational qualification, and years of job experience (p>0.05) were not significantly associated with attitudes toward sports injuries' management among PETs. This research proves that good knowledge and positive attitudes can help in proper management of common sports injuries in secondary schools. However, there should be establishment of collaborations with healthcare professionals, such as athletic trainers or sports medicine physicians, who can provide expert guidance and support to PETsin managing sports injuries. This collaboration can involve workshops, consultations, and referrals when necessary.

Keywords: *knowledge, attitude, sports, sports injury management, physical education teachers, secondary schools*

Introduction

Injury is unavoidable in sports and has threatened the health of athletes participating in sports programmes and competition. Sports injury is one of the key problems facing sports. Chandra et al. (2008) revealed that 30 per cent of those who have played in high school sports teams had sports injury experience. About 8.6 million sports and recreation-related injuries in the United States occur each year, where males account for more than half (Centers for Disease Control and Prevention [CDC], 2016).

In Africa, adolescents appear to sustain one form or degree of sports injury from time to time. The percentage of individuals sustaining at least one serious sports injury ranged from 13.5 per cent through 38.1 per cent for males and 5.2 per cent through 20.2 per cent for females in most African country's (Drake et al., 2018). In Nigeria, sports injury of many form and degree have been reported by both male and female sportsmen, including: muscle strain, sprain, injuries to the lower limbs particularly the thigh, the knee, and injuries from Track and field events

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(Owoeye et al., 2008).

Sports generally involve some form of physical activity. Joseph and Oladipo (2016) described sports as all form of usually competitive physical activity which, through casual or organized participation, aims to use, maintain or improve physical ability and skills while providing entertainment to participants, and in some cases, spectators. These competitive physical activities can lead to sports injuries.

Sports injuries occur during athletic activities, and are common muscle bone or soft tissue injuries that occur during physical activities, including sprains, strains, and fractures. Sports injury is any impairment of the musculoskeletal system with signs and symptoms stemming from the practice of sport in either training or competition phase that compromised normal training in terms of form, duration, intensity or frequency (Prashant et al., 2017).

Sports injuries are classified into various forms. The National Institutes of Health (NIH, 2017) classified sports injuries as acute or traumatic and chronic/overuse regardless of the affected structure. The NIH stated that acute or traumatic injuries have a sudden onset and heal relatively quickly while chronic injuries are a result of overusing one area of the body while playing sport. Sports injuries can occur due to several factors. Risk factors of sports injuries are commonly classified as intrinsic and extrinsic risk factors (Caine & Goodwin, 2016). Intrinsic or personal factors that could put an athlete at risk for injury could be gender, age, weight/body composition and height (Rössler et al., 2017). Extrinsic factors include environmental factors that affect how a sporting activity is done (NIH, 2017). Examples of extrinsic factors are the sports specific protective equipment and conditions of the sports setting, such as rain, snow, and maintenance of the floor/field of playing surface (Wang et al., 2017).

The symptoms of sports injuries vary depending on the type of injury sustained. Symptoms of a sports injury include: weakness, instability, stiffness, swelling, numbness and tingling, pain, and redness (Jonathan, 2020). These symptoms of injuries may lead to complications or severe damage if not properly managed. Paul (2020) stated that injury always causes pain, which can range from mild to severe pain. Knowledge of the concept, risk factors and symptoms of injuries by physical education teachers (PETs) or coaches will assist in the management of sports injuries.

Sports injuries management (SIM) is a vital aspect of sports organization and administration in the schools which involves careful planning, organizing, controlling and coordinating of sports events to ensure the safety of athletes that take part in various activities for a successful competition and goal achievement (Nji & Chukwurah, 2015). Typically, most of the common sports injuries are mild to moderate and can be managed effectively depending on the severity of the injuries, with techniques such as the PRICE therapy method (Protect from injury, Restrict activity, Ice the injured area, Compression and Elevation). It is important to educate PETs on effective SIM (Babarinde et al., 2017). Knowledge of SIM is essential for PETs in secondary schools (SS).

A sound knowledge of SIM is very essential for a sports person, for a coach and an individual who are attached to the field of sports directly or indirectly (Parveen & Sharma, 2017). Knowledge in this study refers to the level of information and ideas PETs in SS have regarding SIM. Knowledge of sports injury management can motivate or influence PETs to develop positive attitude towards the way they handle and respond to sports injuries in SS in Enugu State.

Attitude is an individual's predisposed state of mind regarding a value and it is precipitated through a responsive positive or negative expression towards a person, place, thing, or event (the attitude object) which in turn influences the individual's thought and action (Richard, 2016).

There are socio-demographic variables that are capable of influencing the knowledge and attitude about SIM among PETs. These include: gender, educational qualification, and years of job experience. Kuo-Ming and Yi-Ching (2006) found that female students were evidently better than male students in terms of knowledge of SIM. Alomair et al. (2020) disclosed that the chance of poor knowledge and attitude for those participants with a bachelor's degree or higher is lower than that of those with a diploma or below. Prashant et al. (2017) revealed that the knowledge of SIM in coaches was based on experience gained. However, PETs are expected to possess good knowledge; and develop positive attitudes in order to be able to successfully manage sports injuries that come with PE and sports activities in SS.

Students in SS are actively involved in sporting activities which predisposes them to a lot of injury during sports and physical activities. It is likely that, PETs in Enugu State do not possess adequate knowledge of SIM. Also, PETs that may have the knowledge may not display positive attitudes toward SIM. Evidence regarding the knowledge and attitudes of SIM among PETs in the study area do not seem to exist. Therefore, this study becomes necessary. This problem needs to be addressed by assessing the level of knowledge and attitudes of PETs about SIM. The study findings would assist in planning workshops, seminars and training programmes that will enhance PETs' knowledge and attitudes about SIM.

Methods

Study design and setting

An institutional-based cross-sectional study was conducted between December 2023 and January, 2024 at the SS in the six education zones (Agbani, Awgu, Enugu, Nsukka, Obollo-Afor and Udi) across the three Senatorial Districts (Enugu North, Enugu East, and Enugu West).

Participants and Sampling procedures

The study participants consisted of PETs in SS in Enugu State, Nigeria. The total number of PETs in Enugu State is 294 as at the time of the study. Only PETs in public SS who are in good health and had no terminal health challenges were included in the study population. Hence, PETs in private SS were excluded from the study.

The sample size was 294 PETs. The total population of subjects is relatively small and manageable. Therefore, all the PETs were used for the study.

Measures

Data collection was done using a self-structured Knowledge Test Scale and Attitude Scale on SIM. The Test Scales consists of three parts: Part I consists of three socio-demographic characteristics (gender, educational qualification, and years of job experience) of the respondents. Gender was dichotomized into male and female. Educational qualification was categorized into three groups (Nigeria Certificate in Education (NCE), B.sc/B.Ed, and M.sc/M.Ed/Ph.D). Years of job experience was categorized into three groups (<5 years, 5-10 years, and 11 years +). Part II consists of 16 multiple choice questions covering knowledge about SIM, while Part III consists of nine (9) questions with non-dichotomous response options covering attitudes toward SIM. The respondents were required to place a thick (√) against the correct answer options lettered (A – D) for the knowledge assessment. The nine (9) attitudinal item statements used a four-point likert-type scale that indicates degrees of agreement or disagreement (strongly agrees, agree / disagree and strongly disagree).

In order to examine the face and content validity, the scales were given to a professional board of five experts on the subject (medical and public health sciences, human kinetics and sports studies) and an expert in methodology. After collecting the opinions of these experts, possible modifications were made. To assess the reliability (internal consistency), a trial test was performed on 50 PETs, and the Cronbach's alpha value was calculated, which yielded .81 for the Attitudes scale, while split half (Spearman-Brown Coefficient) yielded an index of 0.79, for the knowledge scale. The cut-off point for the calculations was 0.70.

Data collection procedure

This research was developed in accordance with the Ethical Principles of the World Medical Association Declaration of Helsinki for medical research involving human subjects (World Medical Association, 2013), and the research was approved by the Research Ethics Committee of the Faculty of Education, University of Nigeria, Nsukka (Ethical Clearance Code: UNN/FE/REC23/097).

Data were collected by administering the questionnaires to the 294 PETs. In order to obtain the participation of the respondents, the research team met with the Principal of the various SS drawn for the study, requesting their permission to study their subjects. After agreement with the Principals, informed consent (verbal) was obtained from the PETs, and it was explained to them how and when the data would be taken. Also, the research team explained the objectives of research for the participants and the latter were assured about the privacy of their personal data. After their consent was gotten, the researchers through the aid of the Principals administered 294 copies of the questionnaire to the respondents for completion. Participants filled out the questionnaires individually and it was only done once. The questionnaires were collected back immediately after filling out in order to ensure maximum return rate. Out of the 294 copies of the questionnaire administered, 269 copies were returned, which gave 91.5 per cent return rate. All the returned copies of the questionnaire were duly filled out, and used for the study analyses.

Data analysis

Afterwards, the returned questionnaires were sorted and cleaned. The analyses were performed using the IBM Statistical Package for Social Sciences (SPSS) software package, version 25. The standard descriptive statistics of frequency and percentage were applied to describe the data patterns.

Knowledge score was determined based on responses from 16 knowledge-based items. Each correct response attracted one point, while a wrong response attracted no point. Therefore, the knowledge scores were interpreted as follows: poor (0-8) and good (9-16). By this, the level of knowledge was determined by the highest percentage score for either of the two levels (poor and good). This procedure was followed by Upashe et al. (2015) to interpret level of knowledge in their study.

Attitudes toward sports injury management was interpreted as Positive (scores from 50% and above) and Negative (scores from 49% and below). This was achieved by dichotomizing the four Point Likert-type scales of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). Thus, responses indicating 'SA and A' were categorized as 'Agree" while responses indicating 'D and SD' were categorized as 'Disagree'.

In the multivariate logistic regression, knowledge and attitudes of sports injuries' management were used as response variables. Socio-demographic and economic variables or covariates (gender, educational qualification, and years of job experience) were considered as predictors. All tests were 2-tailed, and probability values less than or equal to 0.05 ($p \leq 0.05$) were considered significant.

Results

The final sample was 269; comprising 67 (24.9%) male and 202 (75.1%) female PETs in SS in Enugu State, Nigeria (Table 1). The vast majority of the respondents 241 (89.6%) had B.Sc/B.Ed as their highest qualification. The majority of the respondents 117 (43.5%) had taught/worked for 5-10 years.

Table 1. Frequency Table of Demographic Characteristics of Physical Education Teachers

Variable	n (%)
Gender	
Male	67 (24.9)
Female	202 (75.1)
Total	269 (100.0)
Educational Qualification	
Nigeria Certificate in Education (NCE)	2 (0.7)
B.Sc/B.Ed	241 (89.6)
M. Sc/M.Ed/Ph.D	26 (9.7)
Total	269 (100.0)
Years of Job Experience	
<5 years	59 (21.9)
5–10 years	117 (43.5)
11+ years	93 (34.6)
Total	269 (100.0)

Overall, more than two-thirds (71.0%) of PETs had good knowledge of SIM, while 29.0 per cent had poor knowledge (Table 2).

Only years of job experience ($p<0.05$) was significantly associated with knowledge about SIM among PETs in SS in Enugu State, Nigeria (Table 3). In a multivariate analysis, PETs s who had 11 years + job experience (OR=2.263, 95% CI [1.100-4.658], p=.027) were 2 times more likely knowledgeable about SIM than those who had < 5 years job experience. Gender and educational qualification were not significantly associated with knowledge about SIM among PETs in SS.

Overall, more than two-thirds (71.7%) of PETs expressed positive attitudes towards SIM (Table 4).

Gender, educational qualification, and years of job experience ($p>0.05$) were not significantly associated with attitudes toward SIM among PETs in SS (Table 5).

Table 2. Knowledge overall about Sports Injury in Secondary Schools in Enugu State, Nigeria

Variable	n (%)
Knowledge (summary index)	
Good knowledge	191 (71.0)
Poor knowledge	78 (29.0)

Table 3. Multivariate Logistic Regression of Covariates Adjusted for Knowledge about Sports Injury Management among Physical Education Teachers

Characteristics	Knowledge		Crude OR OR (CI)	Adjusted OR OR (CI)
	Good (%)	Poor (%)		
Gender				
Male	43 (64.2)	24 (35.8)	-	-
Female	148 (73.3)	54 (26.7)	1.530 (.849–2.756)	1.434 (.786–2.618)
Educational Qualification				
Nigeria Certificate in Education (NCE)	1 (50.0)	1 (50.0)	-	-
B.Sc/B.Ed	167 (69.3)	74 (30.7)	2.257 (.139–86.57)	1.853 (.111–30.984)
M. Sc/M.Ed/Ph.D	23 (88.5)	3 (11.5)	7.667 (.374–157.4)	5.123 (.241–108.9)
Years of Job Experience				
<5 years	34 (57.6)	25 (42.4)	-	-
5–10 years	85 (72.6)	32 (27.4)	1.963 (1.012–3.768)*	1.872 (.964–3.636)
11+ years	72 (77.4)	21 (22.6)	2.521 (1.240–5.123)	2.263 (1.100–4.658)*

Note. *p < 0.05; **p < 0.01; ***p < 0.001 OR = Odd ratios; CI = Confidence Interval. Ref Groups: Gender = Male[a] ; Educational Qualification = NCE[b]; Years of Job Experience = < 5 years[c]

Table 4. Physical Education Teachers' Attitudes toward Sports Injury Management

Items	Agree n (%)	Disagree n (%)	Decision
I believe that the purpose of managing sports injury is to reduce further damage	239 (88.8)	30 (1.2)	P
I am confident that rest can help limit the forces acting on the injured part of the body	261 (97.0)	8 (3.0)	P
I feel ice is not helpful at controlling inflammation	122 (45.4)	147 (54.6)	N
I believe that too-tight constriction cannot worsen the injured part	78 (29.0)	191 (71.0)	N
I am confident that supporting splint should be long enough to extend beyond the nearest joints of the injured site	93 (34.6)	176 (65.4)	N
If the athlete can move, I believe it is important to move an injured athlete to a safe area using a stretcher or a crutch	200 (74.3)	69 (25.7)	P
I feel ice and cold packs should not be applied directly to the skin	164 (61.0)	105 (39.0)	P
I believe that wrapping the injured part with an elastic bandage compresses the injured tissue and limits internal bleeding and swelling	150 (55.8)	119 (44.2)	P
I feel elevation of the injured part above the level of the heart does not reduce the volume and pressure of blood flow to the injured area	156 (58.0)	113 (42.0)	P
Overall %	71.7	28.3	P

Key: Positive attitude = 50% and above, Negative attitude = <50%

Table 5. Multivariate Logistic Regression of Covariates Adjusted for Attitudes toward Sports Injury Management among Physical Education Teachers

Characteristics	Attitudes		Crude OR OR (CI)	Adjusted OR OR (CI)
	+ve (%)	-ve (%)		
Gender				
Male	46 (68.7)	21 (31.3)	-	-
Female	147 (72.8)	55 (27.2)	1.220 (.668–2.228)	1.078 (.583–1.995)
Educational Qualification				
Nigeria Certificate in Education (NCE)	1 (50.0)	1 (50.0)	-	-
B.Sc/B.Ed	166 (68.9)	75 (31.1)	2.213 (.137–35.86)	1.806 (.110–29.75)
M.Sc/M.Ed/Ph.D	26 (100.0)	0 (0.0)	1615 (.000–.000)	1.299 (.000–.000)
Years of Job Experience				
<5 years	37 (62.7)	22 (37.3)	-	-
5–10years	88 (75.2)	29 (24.8)	1.804 (.919–3.641)	1.711 (.863–3.393)
11+ years	68 (73.1)	25 (26.9)	1.617 (.804–3.254)	1.304 (.637–2.669)

Note. $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$ OR = Odd ratios; CI = Confidence Interval; +ve = Positive, -ve = Negative. Ref Groups: Gender = Male[a] ; Educational Qualification = NCE[b]; Years of Job Experience = < 5 years[c]

Discussion

The study findings have shown that overall; PETs had good knowledge of SIM (Table 2). This finding was anticipated and therefore not surprising. This is because PETs in SS might have been attending seminars, workshops and conferences where issues of SIM is being discussed. However, the finding of this study is not in line with Praveen and Sharma (2017) who found that, majority of their study respondents lacked knowledge of SIM. The disagreement between the finding of the earlier study and this study may be due to lack of seminars/workshops on SIM, given to the study participants of the earlier study. The findings have implication for school authorities in sensitizing PETs about SIM. The outcome of this study is likely to increase the knowledge of SIM among PETs.

The findings that only years of job experience was significantly associated with knowledge about SIM among PETs, and that PETs who had 11 years + job experience were 2 times more likely knowledgeable about SIM than those who had <5 years job experience (Table 3) were not surprising and expected. This is because the more one stays in the job; the more one is exposed to situations that can improve his or her knowledge. This finding is in line with Gharsan and Alarfaj (2019) who reported that knowledge grades differed significantly according to their experience in teaching, with better knowledge among more experienced participants. However, the findings on gender and educational qualification being not significantly associated with knowledge about SIM among PETs were surprising and therefore unexpected. This is because both male and female PETs are exposed to the same experience which might influence their knowledge, and female PETs are expected to have more knowledge because male PETs sometimes think that they are better than females. Kuo-Ming et al. (2012) reported that knowledge of SIM was better in females than in males. This finding is in consonance with Bahrani et al. (2015) and Drake et al. (2018) who found that both male and female genders had significant knowledge of SIM. The findings have implication for ministry of education in organizing programmes aimed at creating awareness on SIM. It is expected that those with M.Ed/Ph.D should have very high knowledge. It is believe that the more level of education one attains, the more knowledge he or she acquires. This finding is not consistent with Alomair et al. (2020) who found that low sports injury knowledge was associated with having low educational qualification. With the findings, ministry of education would understand how to plan their programmes to cover SIM at every level of education.

The findings revealed that overall; more than two-thirds of PETs expressed positive attitudes toward SIM (Table 4). This finding was anticipated and thus not a surprise. This is because awareness and good knowledge of SIM makes PETs to have positive attitudes toward SIM, thus improving their responsiveness towards SIM. This finding is not in line with Veeresh et al. (2020) who found that attitude was moderately positive among respondents. The findings suggest major implication for school authorities. Given that attitude is strongly linked to behaviour, school authorities are expected to encourage PETs on SIM, which will help ignite their interest in the practice.

The findings on gender, educational qualification, and years of job experience not being significantly associated with attitudes toward SIM among PETs in SS (Table 5) are however, surprising and unexpected. This is because years of job experience is expected to influence PETs' SIM. However, this may be a result of lack of interest resulting from insufficient motivation and encouragement from educational authorities and government. This is not in line with Mortellaro (2020) who reported that respondents with higher level of job experience had positive attitude. The finding on gender was unexpected and therefore not surprising, and has implication for ministry of education on how to address non-chalant attitude of PETs towards SIM irrespective of their gender. The finding on educational qualification was not anticipated because educational level (higher) of any given group of individuals is expected to influence their attitude. This is consistent with the assertion of Mala et al. (2015) that respondents with higher qualification had positive attitude.

Strengths of this study include using both male and female PETs as participants. While the study examined knowledge and attitudes it did not explore the impact of these factors on student outcomes. Excluding private schools could affect generalization of the results, though delimiting to public schools was extensively handled. The use of a questionnaire alone to collect data is subject to recall and reporting bias, which may result in some degree of misclassification. Future research could investigate the relationship between teacher knowledge/practice and the severity of sports injuries among students.

Conclusion

A study of Enugu State, Nigeria secondary school PETs found that while the majority demonstrated good knowledge and positive attitudes about SIM, only years of experience (11+ years) greatly has importance with knowledge. Gender and educational qualification are not very important factors considered in SIM knowledge or attitude. However, negative attitude towards SIM by some PETs could be improved upon, if principals in SS carry out adequate awareness seminars targeted towards physical education in order to improve their level of knowledge. There should be establishment of collaborations with healthcare professionals, such as athletic trainers or sports medicine physicians, who can provide expert guidance and support to PETs in managing sports injuries. This collaboration can involve workshops, consultations, and referrals when necessary. SS in Enugu State should establish mentorship programmes pairing experienced PETs with newer ones. This will facilitate the transfer of practical knowledge and skills, providing newer teachers with on-the-job support and guidance in SIM.

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Conflict of interest

The authors have declared no competing or conflicting of interests.

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ORIGINAL SCIENTIFIC PAPER

Physical and Performance Differences Between More and Less Experienced Wrestlers

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Abstract

This study aimed to compare anthropometric characteristics, body composition, and physical performance parameters between more and less experienced wrestlers to determine the influence of competitive experience on key performance indicators. A total of 47 male wrestlers were divided into two groups based on their competitive experience: more experienced (n=22, >6 years) and less experienced (n=25, <6 years). Anthropometric measurements included body mass, height, body mass index (BMI), and body fat percentage (BF%). Performance assessments consisted of the countermovement jump (CMJ), handgrip strength (HGS), and the Specific Wrestling Fitness Test (SWFT). Group differences were analyzed using t-tests for independent samples, and discriminant canonical analysis. More experienced wrestlers had significantly lower body fat percentage (p=0.04) and better performance in the SWFT repetitions test (p=0.001) compared to their less experienced counterparts. They also exhibited a lower heart rate response during the SWFT (p=0.01), indicating better recovery capacity. Also, competing experience was correlated to SWFT repetitions (R=0.51) and SWFT index (R=-0.45). Wrestling experience appears to be associated with wrestling-specific performance. However, the experience did not significantly influence absolute strength or explosive power. These findings suggest that training programs for less experienced wrestlers should emphasize wrestling-specific performance development to improve performance.

Keywords: *combat sports, physiological adaptation, training experience, muscular endurance, cardiovascular fitness*

Introduction

Wrestling is a highly demanding combat sport that requires a combination of strength, endurance, power, agility, and technical skills to achieve competitive success (Yoon, 2002). Physical and physiological characteristics play a critical role in determining an athlete's performance, with experience level often being a key differentiating factor. Prior research has demonstrated that more experienced wrestlers tend to exhibit superior aerobic and anaerobic conditioning, muscular endurance, and body composition, which are essential for high-level competition (Chaabene et al., 2017; García-Pallarés, López-Gullón, Muriel, Díaz, & Izquierdo, 2011). Body composition and fitness parameters are known to impact performance outcomes in wrestling. A lower body fat percentage (BF%) has been associated with improved strength-to-weight ratio and movement efficiency, contributing to better overall wrestling performance (Kraemer et al., 2001). Indeed, prior research suggests that elite wrestlers consistently maintain lower BF% levels compared to lower-tier competitors, as it allows them to generate greater force relative to their body mass and sustain high-intensity performance throughout matches (Chaabene et al., 2017).

Additionally, sport-specific endurance and muscular strength play a significant role in determining match outcomes, as wrestling requires short bursts of explosive force combined with sustained efforts over multiple rounds (Kraemer et al., 2001; Yoon, 2002). These attributes are commonly assessed through performance tests that measure anaerobic endurance, muscular power, and overall conditioning (Karnincic, Curby, & Cavala, 2015). One such test is the Specific Wrestling Fitness Test (SWFT), which evaluates wrestling-specific endurance and power, simulating real-match conditions by requiring

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athletes to perform repeated suplex throws under time constraints (Marković et al., 2021). The ability to execute repeated high-intensity movements efficiently is crucial in wrestling, where prolonged bouts require rapid recovery and sustained power output (García-Pallarés et al., 2011). These tests provide valuable insights into the physiological demands of wrestling and help identify areas where athletes may need further conditioning or strength development. Additionally, SWFT has also been validated in the sample of Croatian wrestlers and exhibited good discriminant validity (Skugor, Gilic, et al., 2023; Skugor, Stajer, Zugaj, Gilic, & Karnincic, 2023).

While previous studies have examined these attributes in elite wrestlers, limited research has focused on how experience level influences these physiological characteristics within a national selection context (García-Pallarés et al., 2011; Skugor, Gilic, et al., 2023). Theoretically, wrestlers with greater competitive experience have undergone years of progressive training, potentially leading to adaptations in strength, endurance, and body composition that distinguish them from less experienced counterparts. Investigating these differences is critical for understanding how competing experience contributes to physiological development and can inform training periodization strategies to optimize athlete performance at various competitive stages. Therefore, this study aimed to examine anthropometric characteristics, body composition, and physical performance parameters in more and less experienced wrestlers, to determine the influence of competitive experience on key performance indicators. Understanding these differences could help optimize training programs and talent identification for wrestling development.

Methods

Participants

This research included 47 Croatian wrestlers aged 16-19 years. Wrestlers were divided into two groups based on their competitive experience: more experienced (n=22, >6 years) and less experienced (n=25, <6 years). At least three years of wrestling experience was prerequisite for study entry. In this manner, researchers hoped to ensure that wrestlers could successfully perform the exams and had the necessary knowledge of wrestling tactics. Having a disease or other health issue that limits a wrestler's ability to do the tests as best they can was the exclusion criterion. Participants signed an informed permission form after being briefed on the testing methods and the investigation's objectives (legal guardians signed an informed consent form for participants under 18 years of age). The study was accepted by the University of Split's Faculty of Kinesiology's Ethical Board (Ref. no. 2181-205-02-05-22-0012).

Variables and testing procedures

The study included anthropometric measurements, generic fitness tests, and sport-specific fitness tests.

Anthropometric measurements consisted of body height, body mass, and body fat percentage, which was estimated using the sum of skinfolds measured on the triceps and calf muscles with a Harpenden skinfold caliper (British Indicators, Burgess Hill, England) and calculated using the Slaughter-Lohman formula.

Generic fitness tests included the countermovement jump (CMJ), and handgrip strength test (HGS). The CMJ was assessed using the Optogate system (Microgate, Bolzano, Italy). For the CMJ, wrestlers stood in a shoulder-width stance with hands on their hips and performed a maximal vertical jump, preceded by a knee bend and downward movement. Each wrestler completed three trials, with the best jump height used for analysis. The HGS was measured using an electronic hand dynamometer (Camry, Model EH101, Zhongshan Camry Electronic Co. Ltd., China). Wrestlers performed three trials of maximum effort, with the arm adducted and elbow flexed at 90°. The best result (i.e., the highest recorded value) was used for further analysis.

A Specific Wrestling Fitness Test (SWFT) was used to assess sport-specific fitness. This test, recently developed by Markovic, has demonstrated appropriate reliability and validity in wrestlers. The test requires participants to perform maximum-effort suplex throws using a weighted dummy over three 30-second rounds, with 20 seconds of rest between rounds. The dummy weight was adjusted based on weight categories: Wrestlers weighing 55–67 kg used a 23 kg dummy; Wrestlers in the 72–87 kg category used a 25 kg dummy; Wrestlers over 90 kg used a 30 kg dummy. Athletes wore heart rate monitors (POLAR H10, Polar Inc., Lake Success, NY, USA) during the test and throughout the rest period. Heart rate was recorded immediately after the test and one minute post-exercise. The test results included the total number of throws and the SWFT index, calculated as the sum of heart rate values divided by the total number of throws, as proposed by the authors of the test (Marković et al., 2021; Marković, Toskić, Kukić, Zarić, & Dopsaj, 2022).

Statistical analysis

The normality of the variables was checked by the Shapiro-Wilks test. Descriptive statistics included means and standard deviations. The differences in anthropometric characteristics, body composition, and physical performance parameters between more and less experienced wrestlers were checked using independent samples t-test. Additionally, discriminant canonical analysis was used to evidence eventual multivariate differences between groups based on wrestling experience. Pearson's correlation coefficients were used to determine the correlation between competing experience and performance variables. All analysis were performed using program Statistica (TIBCO, Palo Alto, CA), with applying a level of significance of 0.05.

Results

Differences in anthropometric characteristics, body composition, and physical performance parameters between more and less experienced wrestlers are presented in Table 1. More experienced wrestlers had significantly lower body fat percentage (p=0.04) and better performance in the SWFT repetitions test (p=0.001) compared to their less experienced counterparts. They also exhibited a lower heart rate response during the SWFT (p=0.01), indicating better conditioning.

Table 2 displays the findings of the discriminant canonical analysis. It is visible that variables included in the analysis were not significant in a multivariate manner for discriminating wrestlers according to competitive experience.

A moderate positive correlation was found between the number of repetitions completed in the SWFT and the competing experience. Also, the heart rate index in the same test showed a moderate negative correlation with competing experience. The generic performance tests (CMJ and HGS) did not display significant correlations with competing experience (Figure 1).

Table 1. Descriptive statistics and differences in anthropometric characteristics, body composition, and physical performance parameters between more and less experienced wrestlers

Variable	More experienced (n=22)		Less experienced (n=25)		T-test	
	Mean	SD	Mean	SD	t-value	p
Age (years)	18.18	1.47	17.28	1.70	1.94	0.06
Competing experience (years)	8.73	2.14	4.44	1.56	7.91	0.001
BM (kg)	74.69	12.63	82.05	15.03	-1.80	0.08
BH (cm)	176.01	7.64	180.04	5.91	-2.04	0.05
BMI	23.95	2.48	25.22	3.83	-1.32	0.19
BF%	13.61	4.27	17.72	7.94	-2.16	0.04
CMJ (cm)	37.16	4.84	34.82	6.82	1.26	0.21
HGS (kg)	48.37	8.42	49.75	7.25	-0.58	0.57
SWFT REPS	27.95	3.79	24.67	3.00	3.24	0.001
SWFT index HR	12.45	2.04	14.13	1.96	-2.81	0.01

Note. BM – body mass, BH – body height, BMI – body mass index, BF% body fat percentage, CMJ – countermovement jump, HGS – handgrip strength, SWFT – specific wrestling fitness test, HR – heart rate, REPS – repetitions

Table 2. Discriminant canonical function analysis for differences between more and less experienced wrestlers in all variables.

	Root
Body mass	-0.50
Body height	-0.51
Body fat percentage	-0.56
Countermovement jump	0.37
Handgrip strength	-0.17
SWFT total throws	0.87
Eigenvalue	0.28
Canonical R	0.46
Wilk's lambda	0.78
Chi-square	9.36
p-value	0.15
Centroid: More experienced	0.58
Centroid: Less experienced	-0.46

Note. SWFT – specific wrestling fitness test

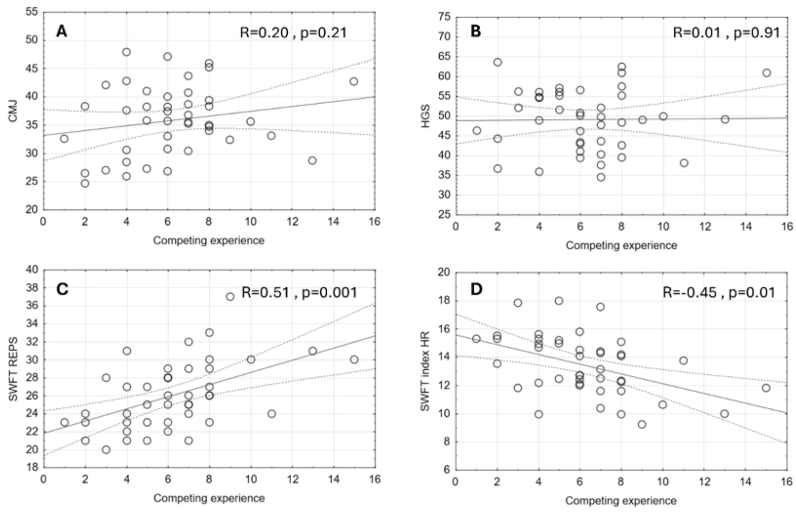

FIGURE 1. Correlation graphs and correlation coefficients (R) between A) Countermovement jump; B) Hand grip strength; C) Specific wrestling fitness test repetitions; D) Specific wrestling fitness test heart rate index and competing experience. CMJ – countermovement jump, HGS – handgrip strength, SWFT – specific wrestling fitness test, HR – heart rate, REPS - repetitions

Discussion

This study investigated the influence of competing experience on anthropometric characteristics, body composition, and physical performance parameters in wrestlers. There are several most significant results: (i) more experienced wrestlers had better sport-specific performance results than less experienced ones, but they did not differ in the generic performance variables; (ii) competing experience was significantly correlated to sport-specific performance variables, while it was not correlated with generic performance variables.

Differences in anthropometric characteristics, body composition, and physical performance parameters between more and less experienced wrestlers

Generally, the findings of this study indicate that more experienced wrestlers demonstrate a lower body fat percentage, and superior sport-specific endurance, as reflected by their higher performance in the SWFT repetitions test and lower heart rate response during SWFT. These results align with previous research suggesting that longer training exposure and high-intensity competition contribute to improved cardiovascular efficiency and muscular endurance in combat athletes (Franchini, Del Vecchio, Matsushigue, & Artioli, 2011; Tortu, Birol, & Aksarı, 2023). The ability to execute repeated high-intensity movements efficiently is crucial in wrestling, where prolonged bouts require rapid recovery and sustained power output (García-Pallarés et al., 2011).

Raw explosive power and grip strength may not be exclusively influenced by years of training or competition experience, as seen by the lack of discernible differences in CMJ and HGS between wrestlers with and without more experience. Rather, these characteristics might be more impacted by training specificity, genetic predisposition, or tactical adjustments made over time. This is consistent with earlier studies on professional judo athletes, which showed that movement patterns, technical efficiency, and tactical execution frequently outperform absolute strength as the main factors influencing success (Franchini et al., 2011). Despite their contributions to particular facets of wrestling, such as takedowns and grip control, CMJ and HGS don't seem to be reliable indicators of competitive success. This supports the idea that wrestling performance is a complex process that calls for a combination of technical proficiency, stamina, and strategic application rather than merely discrete physical prowess (Chaabene et al., 2017).

On the other hand, experienced wrestlers' notable better results in SWFT performance highlight how important muscular and sport-specific endurance are in competition. Athletes must sustain their strength and power output while maintaining technical execution under fatigue during wrestling matches, which require frequent high-intensity bursts of activity (Yoon, 2002). Experienced wrestlers' better SWFT results imply that extended exposure to competitive settings improves muscular endurance and cardiovascular efficiency, enabling them to recuperate more effectively in between intense exchanges (Miarka et al., 2020). These results emphasize the necessity of focused conditioning regimens to close the endurance capacity disparity, especially for wrestlers with less experience. To maximise performance outcomes and recovery capabilities, training regimes should prioritize interval-based endurance drills, conditioning exercises unique to wrestling (García-Pallarés et al., 2011).

Correlation between competing experience and performance variables

As evidenced by the moderately positive connection between competing experience and the number of repetitions performed in the SWFT, the correlation analysis's findings imply that sport-specific endurance and efficiency are critical to wrestling performance. According to Franchini et al. (2011), this result is consistent with earlier studies emphasizing the value of muscle endurance and repeated high-intensity efforts in combat sports. One of the most important factors in determining wrestling performance is the capacity to perform technical maneuvers under exhaustion, maintain grip strength, and sustain repeated explosive motions. Furthermore, the hypothesis that seasoned wrestlers may have better cardiovascular efficiency, enabling them to maintain high performance with less physiological stress, is further supported by the observed negative connection between heart rate index and competitive experience in SWFT (Marković et al., 2022). Precisely, a lower HR index displays better recovery capacity of the athlete (Marković et al., 2022). Similar trends have been reported in other combat sports, where elite athletes demonstrate lower heart rate responses due to better technical execution and improved energy system utilization (Andreato, Lara, Andrade, & Branco, 2017; Bridge, Ferreira da Silva Santos, Chaabène, Pieter, & Franchini, 2014).

Conversely, CMJ and HGS showed almost no correlation with competing experience, suggesting that generic physical fitness may not directly translate to competitive success in wrestling. While explosive lower-body power and grip strength are undoubtedly important for certain wrestling manoeuvres, their independent contribution to the overall competition experience appears limited (James, Haff, Kelly, & Beckman, 2016). Rather, wrestling performance might depend more on the capacity to combine various technical, tactical, and physical elements in situations unique to the sport (Chaabene et al., 2017). This research supports the idea that, given the dynamic and high-intensity character of wrestling, success depends more on the ability to employ strength and power effectively than it does on having the most of each of these qualities. Future studies should look more closely at how training regimens can improve efficiency and endurance unique to a certain sport that is necessary for peak competitive performance.

Conclusions

This study highlights the key physical and performance differences between more and less experienced wrestlers, emphasizing the role of training experience in conditioning, body composition, and muscular endurance. More experienced wrestlers exhibited lower body fat percentage, better sport-specific endurance, and superior cardiovascular efficiency, as evidenced by their higher SWFT performance and lower post-test heart rate response. However, no significant differences were found in handgrip strength or jumping performance, suggesting that absolute strength and explosive power may not be solely experienced-dependent. Moreover, there was no significant correlation between competing experience and generic fitness performance. At the same time, there was a moderate correlation with wrestling-specific performance variables, which further proves that competing experience influences more sport-specific variables compared to generic fitness variables.

These findings have important implications for wrestling training and athlete development, particularly for less experienced wrestlers, who may benefit from targeted endurance training, sport-specific conditioning, and body composition management to improve their competitive readiness. Future research should explore longitudinal training adaptations and the impact of specific training interventions on performance progression in combat sports.

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Conflict of interest
Authors declare no conflicts of interest.

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ORIGINAL SCIENTIFIC PAPER

Strength Training with Blood Flow Restriction: Effect on Factors Associated with Sarcopenia in Older Women

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Abstract

Sarcopenia is a major health problem for older adults. Traditional muscle strength training can lead to a reduction in sarcopenia, but high loads make it difficult to apply for older adults. The aim of this study was to evaluate the effect of strength training with partial blood flow restriction (PBFR) on factors associated with sarcopenia in older Mexican women. Analytical and longitudinal research with a pre-post quasi-experimental design was carried out. Sixteen older women participated in the study (70.87±5.47 years, height of 150.11±3.69 cm, and a body weight of 66.6±9.9 kg). Muscular strength training with partial blood flow restriction to the lower limbs for 12 weeks was performed. Muscle mass index was evaluated, the general muscle strength was calculated using hand dynamometry; the functionality was evaluated with the time get up and go test and specific strength with the Chair stand test. A statistical difference pre- and post-intervention in the strength of the right hand ($p<0.05$), and the specific strength ($p<0.05$) was found, without changes in the muscle mass index and functionality ($p\geq0.05$). It was concluded that strength training with loads between 20%-50% combined with PBFR, for lower limbs in older adults, generates positive effects on general and specific strength, a parameter related to sarcopenia.

Keywords: *elderly, quality of life, physical condition, blood occlusion, strength, functionality*

Introduction

Currently, the population age curve is increasing worldwide, which imposes the need to implement actions for the health care of an aging society (Domingo-del-Val, 2022). In Mexico, it was estimated that in 2021 there were 12 older adults (OA) for every 100 inhabitants, equivalent to 14.5 million OA, representing 11% of the total Mexican population, with a tendency for this proportion to increase (Consejo Nacional de Población, 2021), so it is necessary to generate health conservation or recovery strategies for this age group.

Among the most important health problems in people over 60 years of age, sarcopenia is considered one of the main disorders associated with morbidity and limitation of daily life activities (Contreras-Hernández, 2021). Its importance is such that it was integrated into the International Classification of Diseases in 2016 (Martín Sierra et al., 2021).

Sarcopenia is described as a multifactorial disorder (Malafarina et al., 2013), among which is the lack of physical activity; characterized by loss of muscle mass, strength and functionality, thus increasing the risk of falls and decreased quality of life of those who suffer from it (Cruz-Jentoft y Sayer, 2019). The prevalence of this disorder worldwide is 5-13% and 50% in people aged 60, 70, and 80 years, respectively, estimating that the percentage will increase by 2025 (Cortés et al., 2018). In Mexico, it was observed that 13% of the population of a sample of more than 5000 OA suffered from sarcopenia (Contreras-Hernández, 2021), in addition it has been indicated that sarcopenia has a higher prevalence in Mexican women compared to men of the same nationality (Espinel-Bermúdez et al., 2018), although worldwide the relationship of sarcope-

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nia with sex varies according to the reference classification (Petermann-Rocha et al., 2022).

Traditional muscle strength training can lead to decreased sarcopenia and increased strength; It is suggested that in order to enhance muscle hypertrophy, a considerable volume and multiple repetitions should be used (American Ascociation of Sport Medicine, 2009). However, these specific characteristics, such as the use of high loads (between 60-85%) and a training duration ranging from 50 to 90 minutes, make it difficult to apply them in elderly individuals (Castro-Coronado et al., 2021; Lim & Goh, 2022).

On the other hand, it has been studied that training with partial blood flow restriction (PBFR) generates positive effects on muscle size and strength without the need to use high intensities, obtaining favorable results using low-intensity work (Cristina-Oliveira et al., 2020). PBFR is a technique that consists of using a compression device near the muscle to be worked, performing sets with weights lower than those usually recommended to promote hypertrophy and increase muscle strength. This training technique can be carried out using a common elastic bandage or through more advanced devices, such as a pressure cuff (Villalba, 2022). Although the benefits of this type of strength training in different populations are known, its application in elderly women is still sparsely explored, the physiological and biomechanical specifications to older women and the effects that PBFR training can have on this specific population group have not been addressed, therefore, the objective of this study was to evaluate the effect of strength training with PBFR on factors associated with sarcopenia (strength, functionality and muscle mass index) in woman Mexican older adults, belonging to the programs of the National System of Integral Development of the Municipal Family of Puebla (SMDIF). The aim of this study was to evaluate the effect of strength training with partial blood flow restriction (PBFR) on factors associated with sarcopenia in older Mexican women

Methods

This is an analytical, longitudinal research with a quasi-experimental pre-post design that evaluated the effect of a 12-week PBFR training in lower limbs (LL) on factors associated with sarcopenia (strength, functionality, and muscle mass) in 16 older adults.

Participants

The participants were 16 elderly women (70.87±5.47 years, height of 150.11±3.69 cm, and a body weight of 66.6±9.9 kg), incorporated into SMDIF program in the municipality of Puebla, Mexico; selected through convenience sampling and with the following inclusion criteria: being a woman, being over 60 years old, belonging to the SMDIF program, medical leave to exercise. Exclusion criteria: hypertension, diabetes, circulatory conditions, and/or having any medical restriction to perform physical exercise.

Materials and instruments

Although there is no consensus on universal diagnostic criteria for sarcopenia, existing proposals include measurement of muscle mass, muscle strength, and functionality (Montero-Errasquín & Cruz-Jentoft, 2022). Therefore, for the present study, it was determined to establish the presence of sarcopenia by relating three tests: Dynamometry, the most clinically used method to determine muscle strength (Muresan et al.,2020; Rodrguez-Rejn et al., 2019). The measurement of hand grip strength was used, which also serves to anticipate independence and mobility in older adults, since it is directly related to the amount of muscle mass (Agüero et al., 2017), a digital hand dynamometer SMEDLEY T-19 (Solid, England) was used.

Muscle mass index, which was obtained through the formula MMI = Kg of muscle/height m2. To calculate the MMI of the participants it was used the ENFA® method (Nutritional Assessment by Anthropometric Fractionation), proposed by Drinkwater and Ross (1980), which allows for a precise estimation of muscle mass. This approach is based on a kinetoanthropometric model, integrating 25 anthropometric measurements, including height in a bipedal and sitting position (expressed in centimeters), body weight (in kilograms), seven body circumferences, seven skinfolds, and eight bone diameters. To optimize the accuracy and reproducibility of the data, the anthropometric evaluations were carried out by a single trained evaluator, who performed three consecutive measurements per variable, establishing the average of the records obtained as the final value, with a precision of one tenth of a unit. To obtain the measurements, high-precision and methodological quality instruments were used, including a SECA® 213 stadiometer (Bad Homburg, Germany), a SECA® 813 digital scale (Bad Homburg, Germany), a Delux stainless steel metal measuring tape (Gráculus®), a PCA-01 scientific caliper (Gráculus CronoDiet®), a Gráculus Antropometría® MEX anthropometer, and a high-precision anthropometer (Gráculus CronoDiet®). During the evaluation process, strict adherence to the ENFA® methodological standards was guaranteed, ensuring the validity, reliability, and reproducibility of the results, thus contributing to a rigorous and scientifically supported anthropometric characterization in the field of clinical nutrition.

The time get up and go test was used to evaluate functionality, which covers balance and gait, it is used as a standard to assess the propensity to fall and as an integral component in the complete geriatric evaluation. The time in seconds was registered using a TYR Z-200 Stopwatch (Gálvez-Cano, et al., 2010).

Additionally, the Chair stand test was used to evaluate lower extremity strength, recognized as an indicator of muscle performance, functional fitness, flexibility, and aerobic endurance. It is a simple test that involves moving from sitting to standing, the participants performed the maximum number of repetitions in a 30-second interval. This test is also used as a predictor of falls and impairment in daily activities (Mehmet et al., 2020).

Procedure

For the development of this research, the guidelines of the Declaration of Helsinki were followed; in addition, the procedures were approved by the Ethics Committee of the Faculty of Physical Culture of the Meritorious Autonomous University of Puebla (no. CEI220418). A meeting was held with the OA who attends the SMDIF programs, with the intention of inviting them to participate in the study. The PBFR training strengthening program was presented, and the doubts that arose were clarified. OA who agreed to participate in the study, signed an informed consent.

The lower extremity strength of each participant was evaluated by the Chair stand test before starting the 12-week training period, and after it, the presence of sarcopenia was also evaluated by: dynamometry, MMI, and the Time get up and go test.

Experimental Treatment

The PBFR strength training protocol consists of 30–35-minute sessions 3 times a week for 12 weeks and it was carried out as follows: Prior to each session, a 10-minute warm-up was carried out, which included cephalocaudal lubrication with joint movements in periods of 10 seconds of each body segment, as well as aerobic exercises with intensity corresponding to 30% of the reserve heart rate. Then a tourniquet-type cuff was applied to the upper end of the thigh, adjusted in a way that partially limits arterial blood flow with a continuous application (13 cm elastic bands were used and flow restriction was determined by clinical criteria such as pain and numbness). To ensure the PBRF the restriction pressure must be high enough to block venous return from the muscles, but at the same time low enough to allow arterial blood flow (Bahamondes-Ávila et al., 2020). The strengthening activities with PBRF were developed in the form of strength circuits and 1 minute per exercise was executed in each section of the circuit; based on previous studies, it was decided to use loads of between 20% and 50% of the 1RM (Bahamondes-Ávila et al., 2020.), without a certain number of repetitions. The exercises were performed in such a way that the OA could complete them with the highest possible quality (Andres et al., 2020), with 1-minute breaks at the end of each circuit. The main part of the training lasted 15-20 minutes, and finally, a 5-minute cooldown was applied

Statistical analysis

Descriptive statistics, including minimum, maximum, mean, and standard deviation, were used to describe the study population. To identify differences between pre- and post-measured, a Wilcoxon non-parametric statistical test was applied. Absolute reliability was calculated using the typical measurement error (TME), the coefficient of variation (CV%), and the smallest worthwhile change (SWC) (Hopkins, 2000). Statistical significance was set a priori at $p<0.05$. IBM SPSS v 21 program was used for statistical analysis

Results

Descriptive variables

The study population consisted of 16 women with an average age of 70.87±5.47 years, and height of 150.11±3.69 cm, and a body weight of 66.6±9.9 kg.

Variables of Interest

The group of the study showed significant changes after the 12 weeks of PBFR (Table 1 and 2) in right-hand strength (DRigth, 18.16±5.07; 18.59±4.86; $p<0.05$; difference 0.05, TME 0.37, CV% 2.00, SWC 0.10), and chair test (12.25±2.08; 16.37±3.87; $p<0.05$, difference 2.7, TME 1.92, CV% 13.42, SWC 0.54). Not been like in the timed up-and-go test (8.87±1.03; 8.86±1.02; $p\geq0.05$, difference 0.4, TME 0.25, CV% 2.87, SWC 0.07). At last, the time spent on the PBFR strength training program was not sufficient to induce changes in MMI (9.61±1.44; 9.75±1.48; $p>0.05$, difference 0.4, TME 0.28, CV% 2.92, SWC 0.08).

Table 1. Descriptive data of variables

Variable	Basal	Post-training	p value	Hedges's g effect size (95%CI)
DRight	18.16±5.07	18.59±4.86	0.008	0.018
MMI	9.61±1.44	9.75±1.48	0.078	0.095
Time get up test	8.87±1.03	8.86±1.02	0.050	0.068
Chair test	12.15±2.08	16.37±3.87	0.000	1.350

Note. Values represented in M ± SD and CV. Size interpretation of Hedge´s effect 0.20= small 0.50= medium, 0.80= large

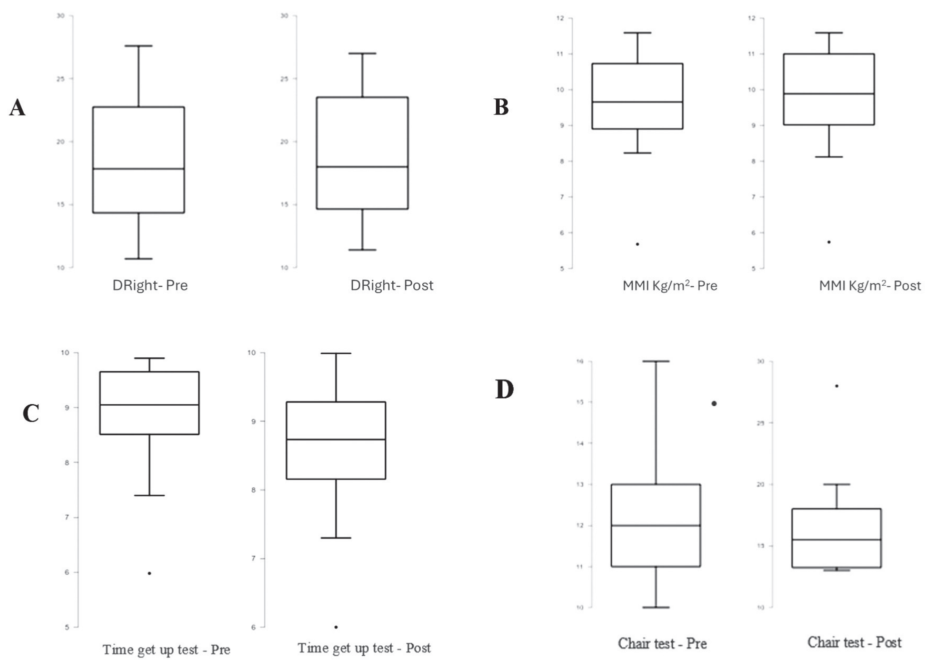

FIGURE 1. Box and whisker plot (A) DRight, (B) MMI, (C) Time get up test (D) Chair test

Table 2. Mean change of variable after physical exercise

Variable	Difference (Post-Pre)	ETM	CV (%)	SWC
DRight	0.5	0.37	2.00	0.10
MMI	0.4	0.28	2.92	0.08
Time get up test	0.4	0.25	2.87	0.07
Chair test	2.7	1.92	13.42	0.54

Note. Sandard measurement error, coefficient of variability (CV), and minimal significant change in the original units in which the variable was measured (SWC)

Discussion

The discussion was based on the different factors that affect sarcopenia, exploring their complexity and variability in the population studied. In addition, the implications for health and quality of life were analyzed, as well as discrepancies with other similar studies. This approach will allow for a deeper understanding about the effect of PBFR training on functionality and strength and will contribute to the formulation of effective prevention and treatment strategies.

PBFR muscle strength and functionality

The sequelae related to sarcopenia, such as deterioration of muscle strength and function, which affects a large population as they age, generate high morbidity (Lim & Goh, 2022), which leads to a decrease in the quality of life and well-being of those who suffer from it. The results of the present investigation point to the improvement of the functionality and strength of the participants in the study, who reported a mean previous 18.16±5.07 and post intervention 18.59±4.86 ($p<0.05$) with which it is possible to benefit the patient, delaying the functional decline curve that brings with it the decrease in muscle strength with respect to age, which affects the ability to independently perform activities of daily living, in addition to reducing the risk of falls and the possibility of suffering musculoskeletal injuries.

The findings of this study are consistent with the results of previous research, which report increases in strength after PBFR training (Centner et al., 2019). The risk of falls represents one of the most common health problems in people over 60 years of age, and its impact is directly linked to decreased functionality. In this context, the assessment of gait and balance emerges as an essential and effective component to identify those individuals at risk of falls, and the practical form for this assessment is the Get Up and Go Test (Terra Jonas et al., 2014). Regarding the results of this test in this study, it is shown that no statistically significant results were achieved, but it is necessary to mention that despite not having a significant impact on physical activities, slight modifications can influence the improvement of the quality of life of older adults, remembering that autonomy in the execution of daily activities, considered as independence, it has a positive relationship with mental well-being (Segovia Díaz de León & Torres Hernández, 2011). On the other hand, Carol et al., (2022), explains that practically 9 out of 10 people who took the functional execution tests presented, as the get up and go test, may present values suggestive of fragility, a situation that could very likely lead to the fact that those people who would not be candidates to take the functional execution tests, may present some degree of fragility in relation to their established dependency situation, cognitive impairment, advanced illness or some other end-of-life situation.

PBFR and muscle mass

In contrast, even though a study from Flores-Garcia (2019) showed results of muscle hypertrophy in only 6 or 8 weeks of training with PBFR RPFS, in the present study of 12 weeks, a significant result was not achieved in this area. This result may be due to the way in which muscle mass was measured, which was generalized in the context of measuring sarcopenia (by dynamometry) and not through a measurement of specific perimeters that indicated hypertrophy in a particular region (González Pérez et al., 2019), as proposed by Alva, et al in 2014 to be evaluated through the measurement of calf circumference (CC) and mean muscle circumference of the arm (MMCA), observing in the comparison between the results that in 37.5% of the participants there was agreement in the diagnosis of sarcopenia. Even Yeguez and Sánchez (2019) cite that "the World Health Organization (WHO) recommends the use of CC, since it considers that it provides the most sensitive measure of the muscle mass of the elderly, considering it greater than the circumference of the arm." It may also be due to what Loenneke et al. (2012) indicated that the results can vary according to the width of the band used to restrict blood flow. In addition, Karabulut et al. (2010) indicated gains in muscle mass in older women from week 16 onwards. However, despite not presenting statistically significant results, the contribution of PBFR training to maintenance and a slight increase in muscle mass is observed (Centner et al., 2019). The use of training methods such as blood flow restriction is under development; in this regard, this is a study that investigates the effects on a vulnerable population such as older women. Despite the results identified and contributions made to this area of study, there are limitations with respect to the sample size and the lack of a control group, aspects that should be covered by future research with the purpose of highlighting the benefits of this training method.

Conclusions

It is concluded that strength training with loads between 20%-50% combined with PBFR, for lower limbs in women older adults, generates positive effects on some components related to sarcopenia, general strength (handgrip) specific strength (Chair stand test). However, it was not possible to establish a significant difference in terms of muscle mass. These results identify key areas for the research and development of more effective therapeutic strategies with alternative strength training methods like blood flow restriction. Based on these results, key areas are identified for the research and development of more effective therapeutic strategies.

Future studies with this type of training are suggested that are related to the prevention and/or early treatment of sarcopenia, considering it as an opportunity to reduce sequelae and improve the quality of life of those affected by this condition.

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Conflict of interest
The authors declare that they have no competing interests

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ORIGINAL SCIENTIFIC PAPER

Prevalence and Correlates of Injury Occurrence in Basketball Referees: Preliminary Retrospective Study

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Abstract

Studies dealing with injury occurrence in basketball refereeing are scarce. The aim of this preliminary investigation was to retrospectively observe injury occurrence and analyze some specific predictors of injury in high-level basketball referees. The participants were basketball referees from Croatia and Bosnia and Herzegovina (all males, n=39, 25–45 years of age, with more than 5 years of experience in basketball refereeing). Data were collected via structured, previously validated questionnaire, and the variables included specific sociodemographic factors, basketball refereeing factors, and medical (injury-related) factors. Differences between injured and non-injured referees were calculated via t tests and chi-square tests, whereas associations between predictors and injury occurrence (criterion) were evaluated via logistic regression for binarized criterion. Injury occurrence was relatively low, with only 15% of referees reporting an injury during the previous competitive season. A higher level of basketball refereeing (more advanced competitive level) was associated with a greater likelihood of being injured (OR=1.44, 95% CI: 1.02–1.98). Additionally, referees who used dietary supplements were more likely to be injured during the previous competitive season (OR=1.51, 95% CI: 1.01–2.05). Although preliminary, the results emphasize the need for structured prevention strategies and support systems tailored specifically to the challenges of high-level officiating.

Keywords: *risk factors, protective factors, logistic regression, anatomical locations*

Introduction

Basketball is a dynamic and fast-paced sport that demands high levels of physical fitness, technical skill, and mental alertness from its participants (Fox, Stanton, & Scanlan, 2018; Iglesias-Torres, Gonzalez-Artetxe, Scanlan, & Arcos, 2024). Played and followed worldwide, it involves quick transitions, constant movement, and close player interactions, making it one of the most intense team sports (Selmanovic, Jeličić, & Dizdar, 2023). Within this high-energy environment, referees play a central role in managing the game flow and upholding the rules (Pojskic, Uzicanin, Suarez-Iglesias, & Vaquera, 2024; Ruiz, Albaladejo-Garcia, Reina, & Moreno, 2024). Their presence ensures fairness, discipline, and consistency, all of which are crucial to the integrity of the sport. Referees must make rapid decisions under pressure, often in challenging or emotionally charged situations, requiring a deep understanding of the game and strong focus (Leicht, 2008). In elite basketball, where the speed and skill level of play are extremely high, the demands placed on referees are particularly intense (Leicht, Connor, Conduit, Vaquera, & Gomez, 2021). They must maintain a clear view of the action, stay physically close to the play, and communicate effectively with players, coaches, and officials. As the game evolves with new tactics and technologies, so too does the role of the referee—who must continually adapt, learn, and perform at a professional level. The contribution of referees is therefore vital not only for rule enforcement but also for shaping the overall experience and fairness of the game.

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The health status of referees is a crucial factor in the quality and consistency of officiating across various team sports (Gabrilo, Ostojic, Idrizovic, Novosel, & Sekulic, 2013; Lima, Devran, Oz, Webb, & Bayraktar, 2023). In football, handball, volleyball, or basketball, referees are required to maintain high levels of physical and mental readiness to meet the demands of competitive play. Their role involves continuous movement, sustained attention, and split-second decision-making, often under pressure from both players and spectators. In basketball, for example, referees must closely follow fast-paced transitions, monitor multiple player interactions simultaneously, and position themselves optimally to observe infractions—all of which require cardiovascular endurance, agility, and concentration (Leicht, 2008; Pojskic et al., 2024). Similar physical demands are evident in sports, such as soccer, where referees may cover up to 10 kilometers in a single match (Gabrilo et al., 2013). Maintaining optimal health enables referees to perform consistently, avoid fatigue-induced errors, and manage the psychological stress of officiating high-stakes games. Moreover, a referee's physical condition can directly influence their authority in the field and credibility among players and coaches (Garcia-Santos, Pino-Ortega, Garcia-Rubio, Vaquera, & Ibanez, 2019). As sports become more professionalized and physically demanding, the expectation for referees to be in peak health has increased accordingly. Ensuring their well-being is not only beneficial for individual officials but also vital for the integrity and fairness of the sports they oversee.

Although referees are often perceived as neutral observers, their role in modern sports demands considerable physical involvement, exposing them to a range of injury risks (Corrigan, O'Keeffe, Whyte, & O'Connor, 2023; Kordi, Chitsaz, Rostami, Mostafavi, & Ghadimi, 2013; O'Connor, Sherlock, Moran, & Whyte, 2022). Like athletes, referees must remain in motion for most games, often sprinting, changing direction rapidly, and maintaining high alertness throughout. In sports such as soccer and basketball, the physical intensity of officiating is particularly high because of the pace of play and the need for continuous positioning. These demands increase the risk of overuse injuries, muscle strains, joint stress, and even acute trauma. Basketball referees, in particular, experience high levels of repetitive lower-limb impact due to frequent running on hardwood surfaces and quick directional changes. Studies across various team sports have reported that referees are prone to musculoskeletal injuries similar to those of players, although their risk profiles may vary on the basis of age, match frequency, and physical preparedness (Gabrilo et al., 2013; Heyn & Fleckenstein, 2021). The cumulative load from frequent officiating without adequate recovery or conditioning can heighten vulnerability to both chronic and acute injuries. Furthermore, unlike professional athletes, referees may not always have access to structured fitness programs, medical support, or rehabilitation, which can delay recovery or increase recurrence (Gabrilo et al., 2013). Recognizing these risks is essential for developing effective prevention and management strategies tailored to the specific demands faced by referees in each sport.

Referees in team sports are susceptible to a variety of musculoskeletal injuries, most commonly affecting the lower extremities. In basketball, ankle sprains, calf strains, and patellar tendinopathy are frequently reported due to constant sprinting, pivoting, and sudden stops on hard indoor surfaces (Paula, Cunha, & Andreoli, 2021). Similarly, soccer referees often experience hamstring pulls, Achilles tendon injuries, and groin strains resulting from long-distance running and abrupt directional changes (Gabrilo et al., 2013). Overuse injuries such as plantar fasciitis and iliotibial band syndrome are also common, especially in referees who officiate multiple games per week without adequate rest. Lumbar spine discomfort and lower back pain are prevalent across sports because of prolonged standing, twisting motions, and a lack of core stability. Upper body injuries, although less frequent, can occur from falls or collisions, particularly in crowded court situations. Chronic joint stress and degenerative conditions such as osteoarthritis may also develop over time, especially in older referees or those with poor biomechanics. These injuries can significantly affect performance, lead to match absences, and, in some cases, cause early retirement from officiating duties (Paula et al., 2021).

Despite the physical and mental demands placed on referees in team sports, the scientific literature on injury occurrence and associated risk factors in this population remains relatively limited—particularly in the context of basketball (Paula et al., 2021). While numerous studies have explored injuries in athletes, referees are often overlooked as active participants who are equally vulnerable to physical strain and musculoskeletal issues. Most available research focuses on soccer referees, with an evident lack of studies addressing injury profiles, mechanisms, or predictive factors in basketball officiating. This gap is particularly concerning given the unique biomechanical and environmental demands of refereeing in basketball, such as officiating hard court surfaces and managing fast-paced transitions. Without targeted data, the development of effective prevention and intervention strategies remains challenging. Therefore, the aim of this study was to analyze the occurrence of injuries among basketball referees and to identify specific factors that may be associated with an increased risk of injury. The findings can contribute to better health management, training protocols, and support systems for referees, similar to those developed for athletes in various sports (Al Attar et al. 2022).

Materials and methods

The participants in this study were basketball referees from Croatia and Bosnia and Herzegovina (all males, n=39, 25-45 years of age). All the participants had been involved in basketball refereeing for more than five years and were engaged in refereeing basketball competitions at the highest national level, while the majority were involved in refereeing international games (including top-level European competitions). They were invited to participate in the study by individual contacts and were informed that their participation was voluntary and anonymous and that no personal information would be asked. The study was initially approved by the Ethical Committee of the corresponding author's institution.

Data were collected via a structured, previously validated questionnaire (Zaletel et al., 2017). For this study, the variables included specific sociodemographic factors, reference factors, and medical factors. The sociodemographic variables observed in the study included participants' age (in years), educational level (elementary school, high school, college/university level), and marital status (single, partnership/marriage). The specific refereeing factors included experience in basketball refereeing (5–7 years, 8–10 years, 11–15 years, >15 years) and basketball refereeing level (national competitions, international–regional competitions, international–European competitions), consumption of dietary supplements (no, from time to time, irregularly, regularly), usage of pain killers (no, from time to time, regularly), injury occurrence over the last competitive season (No, I did not experience any injury; Yes, once; Yes, I suffered multiple injuries over the last season), and location of the injury (participants were provided with an image of the human body, and they highlighted the body location where they suffered the injury over the last competitive season; please see Results for presentation). For the purpose of the later statistical analyses, injury occurrence was additionally dichotomized and participants were grouped into "Injured" and "Noninjured", accordingly.

Statistical analyses included calculations of the means and standard deviations (for age), whereas frequencies and percentages were reported for the remaining variables due to their nonparametric nature. Differences in study variables on the basis of injury occurrence were evaluated via the chi-square test ($\chi 2$) and independent samples t test (for age). The associations between the study variables and injury occurrence were established via logistic regression analysis for dichotomized criteria (injured vs. noninjured), with odds ratios (OR) and 95% confidence intervals (95% CI) reported.

Statistica ver. 14.1 (Cloud Software Group Inc., Palo Alto, USA) was used for all calculations, and a p-level of 95% was applied.

Results

No significant difference in age was detected between injured and noninjured referees (t test =0.34, p>0.05). The number of reported injuries and the locations of the injuries are presented in Figure 1. The participants reported six injuries during the last competitive season, which resulted in 15% injured referees. Calves were the most commonly injured location (with one reoccurrence of the injury for this body location), followed by groins (one in total, one reoccurrence), hamstrings (one injury in total), and shoulders (one injury in total).

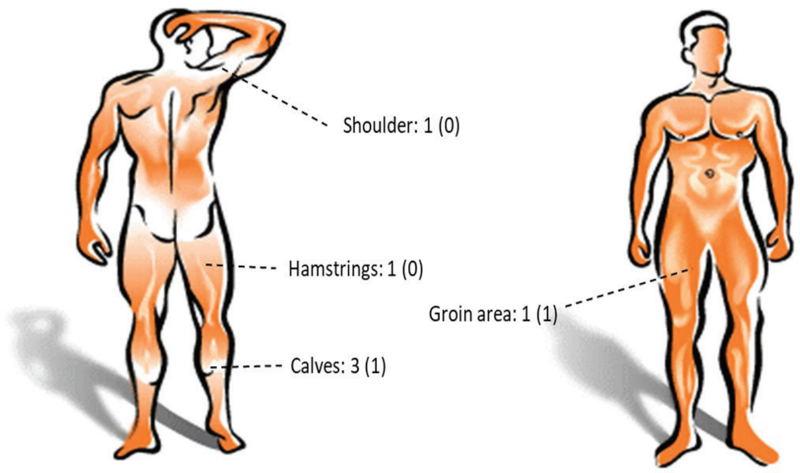

FIGURE 1. Injured body locations and number of reported injuries (the number in parentheses represents multiple injuries to the same body location)

Descriptive statistics and differences in the study variables between injured and noninjured referees are presented in Table 1. In general, no significant differences between groups in terms of injury occurrence were detected for the study variables. However, it must be noted that the analysis of differences was not performed because null frequencies for three of the six observed variables

Table 1. Descriptive statistics (F – frequency, % - percentage) and differences in study variables between injured and noninjured basketball referees calculated by Chi square test (χ^2)

	Non injured		Injured		χ^2 test	
	F	%	F	%	χ^2	p-level
Educational level *						
High school	18	54.55	2	33.33		
College/University level	15	45.45	4	66.67	0.91	0.33
Marital status						
Married/Partnership	13	39.39	3	50.00		
Single	20	60.61	3	50.00	0.23	0.62
Experience in refereeing						
5-7 years	3	9.09	0	0.00		
8-10 years	7	21.21	2	33.33		
11-15 years	11	33.33	2	33.33		
>15 years	12	36.36	2	33.33	NA	NA

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Table 1. Descriptive statistics (F – frequency, % - percentage) and differences in study variables between injured and noninjured basketball referees calculated by Chi square test (χ^2)

	Non injured		Injured		χ^2 test	
	F	%	F	%	χ^2	p-level
Refereeing level						
National competitions	10	30.30	0	0.00		
International - regional competitions	14	42.42	1	16.67		
International - European competitions	9	27.27	5	83.33	NA	NA
Usage of the pain killers						
No	18	54.55	5	83.33		
From time to time	5	15.15	1	16.67		
Regularly	10	30.30	1	16.67	0.87	0.66
Dietary supplementation						
No	8	24.24	0	0.00		
From time to time (sporadically)	5	15.15	0	0.00		
Irregularly	11	33.33	1	16.67		
Regularly	9	27.27	5	83.33	NA	NA

Legend: * - none of the participants reported elementary school level, NA – χ^2 test was not applicable due to null frequencies

The results of the logistic regressions for the binarized injury-occurrence criterion are presented in Table 2. Two of the six predictors were significantly associated with the criterion. Specifically, a more advanced refereeing level was associated with a greater likelihood of being injured (OR=1.44, 95% CI: 1.02--1.98). Additionally, referees who used dietary supplements were more likely to be injured during the previous competitive season (OR=1.51, 95% CI: 1.01–2.05).

Table 2. Analysis of the associations between study variables and injury occurrence in basketball referees calculated by logistic regression

	Odds Ratio	95% Confidence Interval
Educational level	0.98	0.57-1.61
Marital status	0.99	0.46-1.61
Experience in refereeing	1.06	0.38-1.91
Refereeing level	1.44	1.02-1.98
Usage of the pain killers	1.03	0.22-1.95
Dietary supplementation	1.51	1.01-2.05

Discussion

This study aimed to retrospectively evaluate the prevalence and correlates of injury occurrence in basketball referees, with the following results. Fewer than 15% of the tested participants reported injury occurrence during the last competitive season. A greater risk for injury occurrence was associated with an advanced level of refereeing. Referees who were injured were more likely to consume dietary supplements.

The finding that fewer than 15% of basketball referees reported an injury in the past year suggests a relatively low rate of injury occurrence compared with some other sports professions and previous reports from basketball (Gabrilo et al., 2013; Paula et al., 2021). There are several explanations for such findings. First, this may reflect effective self-management strategies and appropriate physical conditioning of the basketball referees studied herein. Specifically, this study was conducted in two countries with long tradition in basketball and where basketball is one of the most popular sports. As a result, basketball referees' physical demands are well known, referees are specifically trained, and their specific conditioning status is monitored. Additionally, it is probable that referees, especially those with more experience, have developed efficient movement patterns that reduce unnecessary strain and minimize risk. However, underreporting cannot be ruled out, as some referees may not perceive certain injuries as severe enough to be reported as injuries. This is especially possible considering the retrospective study design (please see later limitations of the study for more details)

The relatively low injury rate observed among basketball referees in this study aligns partially with findings from previous research in other officiating populations, although comparisons remain limited owing to scarce and heterogeneous data. For example, studies on soccer referees often report higher injury rates—ranging from 30% to over 50% annually—most likely because of longer match durations and greater field coverage (Gabrilo et al., 2013; Szymski et al., 2022). In contrast, the shorter bursts of activity and controlled indoor environment in basketball may contribute to fewer overall injuries. However, the prevalence of lower limb injuries, particularly groin and calf strains, appears consistent across sports, reinforcing the idea that rapid directional changes and sprint-recovery cycles are common mechanisms of injury among referees. This is supported by our second finding, namely, the high prevalence of injuries to the lower extremities.

Indeed, injuries among the studied basketball referees were most commonly reported in the lower extremities. This is not surprising given that these regions are known to be heavily engaged during the high-demand movements typical in basketball and basketball refereeing, such as repeated sprints, lateral shuffling, and abrupt changes in direction (Stojanovic, Terrence Scanlan, Radovanovic, Jakovljevic, & Faude, 2023). The need to maintain optimal positioning throughout the game requires referees to perform sudden accelerations, decelerations, and pivots, often without prior anticipation—placing substantial mechanical stress on the musculotendinous structures of the lower body. Groin strains, in particular, are associated with quick lateral movements and twisting motions, whereas calf injuries are frequently linked to rapid propulsion and deceleration on hard court surfaces. Importantly, unlike athletes, who may have more structured warm-up and recovery routines, referees might engage in these demanding actions without adequate neuromuscular preparation, further increasing injury susceptibility.

Our results revealed a greater risk of injury with increasing competition level, and this is consistent with studies done on athletes, where higher performance level indicated higher risk for being injured (Skomrlj et al. 2024). There is no doubt that referees officiating at advanced competitive levels are exposed to significantly greater physical and psychological demands during matches. These games are typically faster, more intense, and involve highly skilled athletes, requiring referees to adjust their position constantly, maintain high-speed movement, and make quick decisions under pressure (Sansone et al., 2025; Suarez Iglesias, Leicht, Pojskic, & Vaquera, 2021). In this environment, even small delays in reaction or poor positioning can have critical consequences, leading to greater stress and physical workload. The frequency of directional changes, sprinting, and sustained attention required at more elite levels may contribute to cumulative musculoskeletal strain. Moreover, high-level referees are subject to increased scrutiny from coaches, players, fans, and media, which adds a psychological dimension that further elevates the intensity of their role, increasing the risk of being injured.

Beyond the match itself, referees engaged in high-level competitions often face additional off-court stressors that can impact injury risk. Extensive travel, frequent schedule changes, and pressure to maintain peak performance with limited rest intervals can lead to fatigue and inadequate recovery (Huyghe, Scanlan, Dalbo, & Calleja-Gonzalez, 2018; Ochoa-Lacar et al., 2022). Disrupted sleep patterns, long hours spent in transit, and limited access to consistent training or rehabilitation routines may further compromise their physical readiness. Over time, these external demands can reduce the body's capacity to recover and adapt, increasing the vulnerability of referees to both overuse injuries and acute strains. Therefore, the combination of intense in-game demands and lifestyle-related stressors highlights the need for tailored injury prevention strategies for referees operating at the highest levels of competition.

Greater injury occurrence is evident in referees who consume dietary supplements more often. One possible explanation for such findings is that individuals who have previously sustained injuries may be more proactive about their health and recovery, whereas previous injury is known to be the most significant predictor of future injury (Fulton et al., 2014). Experiencing an injury could prompt referees to seek additional support for tissue repair, inflammation reduction, or performance optimization, leading them to incorporate supplements such as protein powders, collagen, omega-3 s, or joint-support formulas. This pattern reflects a common behavior in both athletes and active professionals, where injury history influences future health practices (Bjelanovic et al., 2023; Kozjek, Tonin, & Gleeson, 2025). Moreover, some referees may view supplementation as a way to accelerate recovery or prevent reinjury, particularly in the absence of regular access to physiotherapy or medical care. In this context, supplementation may act more as a compensatory strategy rather than a direct cause of injury. Therefore, the observed association may reflect a reactive approach rather than a predictive approach, indicating that previous injury is a driving factor behind increased supplement use.

Another possible interpretation is that referees who operate at higher competitive levels are more likely to engage in structured nutrition and supplementation practices as part of their overall performance routine. These individuals may be more likely to invest in maintaining optimal physical conditions due to the elevated demands of elite officers—leading to more frequent use of vitamins, minerals, and performance-enhancing supplements. At the same time, higher-level referees typically have better access to sports nutrition information, peer networks, or institutional guidance, which may normalize supplement use. It is also possible that these referees are more aware of or influenced by athletic culture, where dietary supplementation is often seen as a standard component of recovery and performance (Garthe & Maughan, 2018). In this scenario, supplement use might be greater not because of injury itself but because of the environment and performance expectations associated with top-level officiating. This behavior, while health-oriented, may coincide with increased exposure to physical stress and injury risk at higher competitive levels (please see previous discussion), creating an indirect link between supplementation and injury prevalence.

This study has several limitations that should be acknowledged when interpreting its findings. First, the retrospective component of injury history is susceptible to recall bias, as referees may not accurately remember or report past injuries, especially minor injuries. Additionally, the relatively small sample size of 39 participants limits the generalizability of the results to broader reference populations. The study also had a preliminary design with a limited range of variables, restricting deeper exploration of potential injury predictors such as biomechanical, nutritional, or psychosocial factors. Future research with larger samples and more comprehensive data collection is needed to build on these findings.

On the other hand, one of the main strengths of this study is that it is among the first to specifically investigate injury occurrence in basketball referees, filling a notable gap in the literature. The study involved referees who operate at a highly competitive level, which enhances the relevance of the findings to elite officiating environments. Moreover, the study was conducted in countries with a strong basketball culture and high-quality competitions, ensuring that participants were regularly exposed to demanding game conditions.

Conclusion

This study revealed relatively low injury rates among basketball referees, with fewer than 15% of participants experiencing injuries over the past competitive season. The most affected regions were the lower extremities, particularly the groin, calves, and ankles—areas subjected to high mechanical loads during refereeing. These findings suggest that basketball referees, particularly those in countries with strong basketball traditions, may benefit from effective physical conditioning and movement efficiency. Nonetheless, the possibility of underreporting and the limitations of retrospective recall must be considered when interpreting injury prevalence.

A clear pattern emerged, indicating that referees operating at more advanced competitive levels face a greater risk of injury. The increased speed, intensity, and scrutiny of elite matches impose greater physical and psychological demands on referees. When coupled with frequent travel, inconsistent recovery, and heightened performance pressure, these factors may cumulatively contribute to musculoskeletal overuse and acute injuries. These findings emphasize the need for structured prevention strategies and support systems tailored specifically to the challenges of high-level officiating.

The observed association between injury occurrence and dietary supplement use among referees may have two overlapping explanations. On the one hand, referees with a history of injury may adopt supplements as a compensatory recovery strategy, especially in the absence of formal medical support. On the other hand, advanced-level referees may engage more proactively in supplementation as part of broader performance and health maintenance routines. While the data do not imply causation, the link between supplementation and injury warrants further exploration, ideally through prospective studies that examine behavior, recovery practices, and competitive level in tandem.

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Conflict of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Differences in Running Performance of Football Players Compared to Higher- and Lower-Ranked Opposing Teams in the Montenegrin First League

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Abstract

Match running performance (MRP) of football players is one of the most frequently analyzed parameters in modern football. However, it remains unclear whether MRP depends on the quality of the opponent. This longitudinal study aimed to determine whether there are differences in the running performance of football players based on the quality of the opposing team. The performance of the FK Buducnost (Podgorica) team was analyzed over ten league matches, five against top-ranked teams and five against teams from the lower half of the Montenegrin First League table during the 2022/23 season. Using Global Positioning System Technology (GPS; K-Sport Universal, Montelabbate, Italy), various movement parameters were examined, including distance at high-intensity speed (14–19 km/h), distance at very high-intensity speed (19–25 km/h), distance at sprinting speed (>25 km/h), total distance, number of sprints, distance at very high acceleration (>3 m/s^2), distance at very high deceleration (<-3 m/s^2), distance per minute, maximum speed, number of accelerations (>3 m/s^2), number of decelerations (<-3 m/s^2), average heart rate (HR average), and maximum heart rate (HR max). An independent Student's t-test showed no significant differences between the groups in any parameters, indicating that MRP did not vary based on the quality of the opposing team. The findings suggest that players maintain a similar level of running performance regardless of whether they compete against stronger or weaker teams within the same competition level. Future research should further explore differences in relation to the competition level of football players.

Keywords: *match running performance, soccer, opponent ranking, physical fitness, high-speed running*

Introduction

The physical demands of modern football have significantly increased in recent years, and this trend continues to rise. Competitive football requires players to perform a variety of actions during a match, such as running, sudden stops, jumping, turning, and changing direction (Drust, Atkinson, & Reilly, 2007). To successfully meet these challenges, players must possess a high level of physical fitness, enabling them to execute different types of movements at high intensity while delaying the onset of fatigue (Dittrich, da Silva, Castagna, de Lucas, & Guglielmo, 2011; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007).

The physical fitness of football players has been widely studied, often through assessments of motor performance, and more recently through real-match conditions by analyzing match running performance (MRP) (Ehrmann, Duncan, Sindhusake, Franzsen, & Greene, 2016; Kubayi & Toriola, 2020; Morgans, Orme, Bezuglov, & Di Michele, 2023). The application of Global Positioning System (GPS) technology has further advanced performance analysis, al-

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lowing for the precise collection of data on players' movement during matches, including total distance covered, distance covered at various speeds, number of accelerations and decelerations, and more (Aquino et al., 2020).

The running performance of football players has become a focal point of research in recent years (Mohr, Krustrup, & Bangsbo, 2003; Paul, Bradley, & Nassis, 2015). Analyses of match demands reveal that a footballer performs between 1,000 and 1,200 movement changes per match, translating to one change every 5 to 6 seconds. These movements typically include walking (25%), low-speed running (37%), submaximal running (20%), sprinting (11%), and backward running (7%) (Di Salvo et al., 2007; Marković & Bradić, 2008). During a football match, professional players cover a distance of between 9 and 14 kilometers, with 5–15% of that distance involving high-intensity running (Modrić, Veršić, Morgans, & Sekulić, 2023). According to Marković and Bradić (2008), players perform a sprint approximately every 90 seconds, with each sprint lasting between 2 and 4 seconds. Notably, most of these sprints last only 1 to 2 seconds and cover distances of 5 to 10 meters, with a total of 100 to 200 sprints per match. These findings emphasize the importance of the anaerobic alactic (phosphagen) energy system, particularly during initial bursts and accelerations.

Recent studies on MRP have focused on various factors that may influence these indicators. Some key research has examined differences in MRP between teams from top European leagues and those from lower-quality leagues (Modric et al., 2023), while other studies have analyzed how MRP can affect match outcomes (Modrić et al., 2022; Teixeira et al., 2021) or how it is influenced by tactical formations and team setups (Aquino et al., 2017). Additionally, researchers have explored the relationship between MRP and players' aerobic capacity (Metaxas, 2021; Modric, Versic, & Sekulic, 2021).

When it comes to differences among football players of varying ranks, one study investigated disparities in physical fitness between players from leading and average teams (Radaković, Majkić et al., 2025). However, a small number of studies have examined MRP of football players in relation to the quality of the opposing team (Lago, Casais, Dominguez, & Sampaio, 2010; Rampinini et al., 2007; Teixeira et al., 2021). Moreover, no such study has been conducted with professional football players competing in the Montenegrin First League. Therefore, the aim of this study was to determine whether there are differences in football players' running performance based on the quality of the opponent. The findings of this study will contribute to the existing literature on the influence of opponent quality on MRP and provide insight into the current condition of elite Montenegrin football players in this regard.

Methods

Sample and study design

The sample included male football players from the football club FK Budućnost (Podgorica, Montenegro). Data were collected from one team during their 10 group-stage matches—five against top-ranked teams and five against teams from the lower part of the table in the Montenegrin First League during the 2022/23 season. The opposing teams were categorized as top- or low-ranked based on their position in the league standings. Only outfield players were analyzed, while goalkeepers were excluded from the study (Konefał et al., 2019; Modrić et al., 2021). The players were informed about the aims of the study and provided written consent to participate. The identities of the players and teams were kept anonymous to ensure confidentiality, by the principles of the Declaration of Helsinki. Additionally, this research was approved by the Institutional Board of the Montenegrin Sports Academy.

Procedures

During ten competitive league matches, FK Budućnost players were equipped with portable Global Positioning System (GPS) technology. The GPS devices (K-Sport Universal, Montelabbate, Italy) were securely placed in special vests worn underneath their jerseys and were designed not to interfere with player comfort. This system enables precise tracking of all player activities during the match and has been used similarly in previous research (Rampinini et al., 2015). After each match, all data were extracted using specialized data analysis software (K-Fitness, K-Sport International, Italy).

Variables

Using the described GPS system, numerous movement parameters were analyzed, including high-intensity running distance (14–19 km/h), very high-intensity running distance (19–25 km/h), sprinting distance (>25 km/h), total distance covered, number of long-distance sprints >3 m^2, very high deceleration (<-3 m/s^2), distance per minute, maximum speed, number of accelerations (>3 m/s^2), number of decelerations (<-3 m/s^2), average heart rate (HR average), and maximum heart rate (HR max). The specified running speed thresholds for football players were determined based on previous research (Katanic et al., 2025; Modrić et al., 2021; Radaković, Katanić, Stanković, Masanovic, & Fišer, 2024).

Statistics

All collected data were subjected to basic descriptive statistical analysis, including the calculation of means and standard deviations. To determine statistically significant differences between groups, an independent samples t-test was applied. Data processing and statistical analyses were performed using IBM SPSS Statistics software, version 26 (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p<0.05$.

Results

In terms of the distance covered at different speeds (Table 1), there were no significant differences between matches against higher-ranked and lower-ranked teams: for the 14–19 km/h zone (t=-0.009; p=0.993), 19–25 km/h (t=0.100; p=0.923), or sprints >25 km/h (t=0.089; p=0.931). The total distance covered was slightly greater against weaker opponents (10.385.80±627.30 m vs. 10.054.40±537.75 m), but the difference was also not significant (t=-0.897; p=0.396).

Similarly, other parameters such as the number of sprints, distance and number of accelerations and decelerations, maximum speed, as well as average and maximum heart rate values did not differ significantly with respect to the opponent team's ranking.

Table 1. Differences in Movement Performance of FK Budućnost Podgorica Players Compared to Higher- and Lower-Ranked Opposing Teams in the Montenegrin First League.

Variables	Higher-Ranked Opponents	Lower-Ranked Opponents	t	p
14-19 km/h (m)	1489.00±136.98	1489.80±142.03	-0.009	0.993
19-25 km/h (m)	651.20±81.01	657.60±118.65	-0.100	0.923
>25 km/h (m)	159.20±25.98	157.20±42.92	0.089	0.931
Total distance (m)	10054.40±537.75	10385.80±627.30	-0.897	0.396
Num Of Sprints	11.00±1.22	10.40±2.07	0.557	0.593
Dist Accelerations	147.00±9.92	138.00±20.04	0.900	0.394
Dist Decelerations	164.20±12.87	147.40±20.01	1.579	0.153
Dist/min	88.80±5.17	90.80±6.42	-0.543	0.602
Speed Max (km/h)	29.84±0.93	30.20±0.54	-1.623	0.143
Num Accelerations >3	30.60±2.97	28.40±4.67	0.889	0.400
Num Decelerations <-3	49.20±4.44	43.40±5.13	1.912	0.092
HrAverage	136.20±12.56	132.80±10.99	0.456	0.661
HRmax	217.20±4.60	215.00±4.53	0.762	0.468

Discussion

This study investigated whether the running performance of football players varies depending on the competitive level of the opposing team. The main findings of this study indicate that the physical performance of FK Budućnost players did not differ depending on the ranking of the opposing team. These results suggest that the players maintained a consistent level of physical output throughout the matches, regardless of the competitive strength of their opponents.

Our results showed that football players covered approximately the same total distance against higher-ranked opponents as they did against lower-ranked opponents (10,054.40±537.75 m vs. 10,385.80±627.30 m). These data indicate that Montenegrin professional football players covered total distances comparable to those reported in studies of players from Serbia (10,799 m; Radakovic, Katanic, et al., 2025), Croatia (10,298 m; Modric, Versic, Sekulic, & Liposek, 2019), and Spain during the mid-season (10,698 m; Ponce-Bordón, López-Gajardo, Lobo-Triviño, Pulido, & García-Calvo, 2024). This generally corresponds to the well-established fact that football players cover between 9 and 13 km per match (Andrzejewski, Chmura, Pluta, & Konarski, 2015; Gómez Piqueras, González Víllora, Castellano, & Teoldo, 2018) and shows that Montenegrin players competing in the top domestic league are on a similar level to players from other European leagues regarding this parameter.

Furthermore, in high-intensity sprint zones of 19–25 km/h and above 25 km/h, Montenegrin players covered similar distances (651.20±81.01 m vs. 657.60±118.65 m, and 159.20±25.98 m vs. 157.20±42.92 m, respectively). These distances are slightly higher than those recorded among professional footballers in Croatia (461.83 m and 155.89 m; Modric et al., 2019) and slightly lower than those from Serbia (611 m and 488 m; Radakovic, Katanic, et al., 2025), particularly referring to sprinting distances, with Serbian players covering more distance at sprint speed.

The players' maximum running speed averaged 29.84±0.93 km/h against higher-ranked opponents and 30.2±0.54 km/h against lower-ranked opponents. These maximum speeds align with those reported for professional players in the study by Katanic et al. (2025), where values varied by team position, ranging from 29.34 km/h (8.15 m/s) to 30.53 km/h (8.48 m/s).

When comparing our results with recent studies, we observe that the running performance parameters of Montenegrin players are consistent with those of professional footballers in other European leagues. This indicates that the Montenegrin league is keeping pace with European leagues in this important aspect—player movement performance—which provides valuable insight into players' physical fitness.

In our study, HRmax values were slightly higher: 217.20±4.60 bpm in matches against higher-ranked opponents and 215.00±4.53 bpm against lower-ranked teams. Similarly, the average heart rate (HRaverage) was also higher in games against stronger opponents (136.20±12.56 bpm) compared to matches against weaker teams (132.80±10.99 bpm). Although these differences were not significant, certain trends are visible that may suggest that cardiovascular load and match intensity increase with the quality of the opponent. This highlights the importance of cardiovascular endurance in sustaining high-intensity running throughout the match.

The main findings of this study indicate that the physical performance of FK Budućnost players did not differ depending on the quality of the opposing team, meaning that players maintain a similar level of running performance regardless of whether they compete against stronger or weaker teams within the same competition level. Similar to our results, Lago et al. (2010) found no difference in high-intensity running performance in relation to the quality of the opponent. However, they reported that when facing stronger opponents, the reference team covered a greater total distance, as well as greater walking and jogging distances, which were not included in our study. Thus, the only difference compared to our parameters was that their study found a variation in total distance depending on the opponent.

In contrast, our findings differ from those reported by Teixeira et al. (2021), who found that total distance covered, high-intensity running distance, and the number of accelerations/decelerations depended on the quality of the opponent. Additionally, Rampinini et al. (2007) showed that the reference team achieved significantly greater total distance and high-intensity running distance when playing against the strongest teams compared to the weakest ones, although there was no significant difference in very high-intensity running distance.

The findings from these studies indicate a specific physical response of football players depending on the competitive situation and the quality of the opponent. This is particularly important given that high-intensity running plays a crucial role in elite football performance (Krustrup, Zebis, Jensen, & Mohr, 2010; Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008) and may serve as a discriminating factor between players at higher and lower competition levels (Andersson, Randers, Heiner-Møller, Krustrup, & Mohr, 2010; Nielsen et al., 2004). It is well known that periods of high-intensity exertion during a match place considerable demands on football players, leading to increased activation of the cardiorespiratory system (Krustrup et al., 2006). Therefore, it is essential for players to possess a high level of cardiorespiratory endurance to meet these intense demands.

Nonetheless, the discrepancy between our findings and those of the aforementioned authors may be due to differences in methodology among the studies, as well as the small sample size in our study. This study is limited by the fact that it included players from only one club, which may restrict the generalizability of the findings. As such, these results should be interpreted with caution. Additionally, the analysis of movement performance did not take player positions into account. Therefore, a recommendation for future research would be to include a larger sample of football players, preferably from different clubs, and to compare running performance based on playing positions within the team.

Conclusion

This study aimed to determine whether there are differences in football players' running performance based on the quality of the opponent. Based on the analysis of the results, it was determined that there are no differences in movement performance and physical fitness relative to the quality of the opponent. The findings suggest that players maintain a similar level of running performance regardless of whether they compete against stronger or weaker teams within the same competition level. However, future research should further explore differences in relation to the competition level of football players.

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Conflict of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Exploring Motivation and Enjoyment as Key Determinants of Sustained Physical Activity Across Diverse Demographics

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Abstract

This study explores the relationship between motivation for physical activity participation and enjoyment levels across various demographic groups. A total of 384 participants (44.5% female, 55.5% male) were selected using a convenience sampling method in Turkiye. All participants were either high school (32.3%) or university (67.7%) students, representing varied educational backgrounds and sports experience, with 47.7% holding a sports license. Participants completed the Motivation Scale for Participation in Physical Activity (MSPPA) and the Physical Activity Enjoyment Scale (PACES). Findings indicate that female participants scored significantly higher than males in both PACES (M=49.88 vs. M=48.05; p=0.05) and MSPPA (M=65.56 vs. M=62.33; p<0.01), highlighting gender-based differences in motivation and enjoyment. Surprisingly, possessing a sports license did not significantly impact motivation or enjoyment, suggesting that formal sports involvement may not be a primary determinant of sustained engagement. Educational level played a role. High school students showed greater motivation from environmental factors (M=22.37 vs. M=21.15; p=0.04), while university students reported higher demotivation (M=16.99 vs. M=14.62; p<0.01). A weak but significant positive correlation was found between age and both motivation (r=0.16; p<0.01) and enjoyment (r=0.14; p<0.01), suggesting that older individuals may experience greater intrinsic benefits from physical activity. These findings provide valuable insights for designing intervention programs prioritizing intrinsic motivation and enjoyment in physical activity. Such programs should foster autonomy, competence, and relatedness in various settings, including schools, workplaces, and community sports initiatives. Future research should examine how motivation and enjoyment influence the long-term adoption of physical activity as a lifestyle.

Keywords: *motivation, internal-external, well-being, physical exercise*

Introduction

Research on public health must focus on understanding individual motives for exercise and their enjoyment of physical activity because these elements act as vital maintainers for lifelong physical participation (Yan et al., 2023; Wang et al., 2024). Researchers need to investigate demographic variable motivations as these findings form the foundation to develop specific interventions which boost physical activity levels and health outcomes (Jamous et al., 2024; Peels et al., 2020; Rodrigues et al., 2023). The importance of physical activity guidelines stands crucial for cardiovascular health as well as hypertension management which requires systematic exercise programs (Börjesson et al., 2016; Singh, Pattisapu, & Emery, 2020). Research evidence supports that enjoying physical exercise and exercise barriers influences the extent to which people maintain active lifestyles (Orhan et al., 2024; Rodrigues et al., 2020).

Physical activity guidelines establish an essential system to develop widespread exercise habits (Alawamleh &

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AlKasasbeh, 2024; Olson et al., 2023). The motivational climate analysis demonstrates how it affects enjoyment and activity participation levels, thus highlighting the need for physical activity-supportive settings (Escartí & Gutiérrez, 2001; Robinson, 2023). Research on motivation and enjoyment in physical activity has not adequately explained how these elements connect with educational characteristics and sports participation among different demographic groups. The scientific research community lacks sufficient investigation of social environment impacts on physical activity and the availability of exercise facilities for minorities based on economic levels and educational classification. A noticeable difference in population exists mainly among diverse demographic groups, which base their behaviour patterns on their cultural heritage and economic and social conditions (Fazelpour & Steel, 2022; Virgona & Kashima, 2024). Participation in physical exercise leads to prolonged durations and superior public health effects when health promotion methods combine various human life experiences (Roychowdhury, 2020; Swift et al., 2018).

Physical activity participation by people primarily depends on motivational levels (Cheval & Boisgointer, 2021; Orhan et al., 2024). Research using the Self-Determination Theory (SDT) shows that motivation develops along intrinsic and then extrinsic stages since people first reach intrinsic motivation through internal satisfaction, yet external rewards support intrinsic motivation (Deci et al., 2017; Legault 2017; Manninen et al., 2022). Multiple studies demonstrate how intrinsic motivation enables people to sustain physical exercise practices and obtain greater satisfaction throughout the activity duration (Almagro et al., 2020; Ednie & Stibor, 2017; Esmaeilzadeh et al., 2022). Research evidence demonstrates that improved self-confidence drives individuals to participate actively in physical exercise (Bond et al., 2016; Yu et al., 2024). World Health Organization guidelines specify that physical activity promotion and sedentary behaviour reduction depends strongly on motivation (Bull et al., 2020; WHO, 2020). People face multiple perception barriers preventing their physical activity motivation because they do not have enough time to participate and lack suitable support systems and adequate physical facilities (Hasan et al., 2023; Orhan et al., 2024; Salmi et al., 2023). Building effective exercise-level enhancement strategies requires a basic understanding of individual population barriers and motivational enhancement approaches (Rodrigues et al., 2020; Spiteri et al., 2019).

Physical exercise demands sustained enjoyable experiences (Orhan et al., 2024; Rodrigues et al., 2021). Studies show that exercise sustainability remains longer among people who find pleasure in their workout routines (Gjestvang et al., 2021; Teixeira et al., 2022). The connection between enjoyment as a motivational element produces enhanced exercise engagement that results in greater rewards (Denford et al. 2019; Kuvaja-Köller et al. 2023). A strong relationship exists between physical exercise and enjoyment because it promotes the maintenance of active behavior while enhancing psychological wellness (Akroush et al., 2024). Studies confirm that disabled individuals maintain their physical exercise schedules because of enjoyment (Hollomotz 2018; Orhan et al. 2023). Research demonstrates that exercise adherence relies directly on enjoyment levels while these elements constitute essential aspects of motivational theory (Rodrigues et al., 2020). Children and adolescents mainly decide to participate in sports based on how they believe in their competency skills and the motivational elements of their physical activities (Cairney et al., 2012; Navarro et al., 2020).

Physical activity motivation, enjoyment, and other aspects respond to individual characteristics, including age groups, gender and socio-economic position. The motivational elements that drive different age categories and male and female populations differ (Mocanu et al., 2021; Portela-Pino et al., 2019). People who face barriers to physical activity access because of their social status and financial constraints (Ilić et al., 2024; Orhan et al., 2024) will experience reduced motivation and happiness. Physical activity participation rates alongside health outcomes vary among different population segments; thus, the participation levels and health outcomes are affected (Ke et al., 2022; Pedersen et al., 2021). The environment and social components determine the ease and obstacles people encounter when they want to participate in physical activities. Research discovered multiple elements influencing middle-aged and older adults to participate in physical exercise while examining the barriers preventing them (Meredith et al., 2023; Spiteri et al., 2019). The motivation patterns between males and females and their exercise barriers present distinct differences in adolescent populations (Ivanović & Ivanović, 2022; Portela-Pino et al., 2020).

This study provides evidence for creating specific intervention programs to enhance motivation and enjoyment levels in physical activities and establish healthier lifestyles for different populations. Such interventions are essential for breaking down barriers to physical activity and enhancing quality of life through consistent exercise engagement. The research explores how motivation toward physical exercise influences enjoyment levels based on specific demographic factors among individuals.

Materials and Methods

This research, which aims to examine the relationship between individuals' motivations for participating in physical activity and their levels of enjoyment from physical activity along with some demographic variables, is a descriptive study in a relational screening model. While relational studies do not establish causality, they allow for reasonable inferences about cause-and-effect relationships when employing advanced statistical techniques (Fraenkel & Wallen, 2009).

Study Group

The research study group was formed using the convenience sampling method. The research study group was formed using convenience sampling, with all data collected from participants residing in Türkiye. This method was chosen for its practicality, though it may limit the generalizability of findings. Convenience sampling, based on accessibility and feasibility, is a method preferred for quickly collecting information on some research topics (Büyüköztürk, 2010). Of the 384 people selected through convenience sampling, 44.5% (n=171) are female, and 55.5% (n=213) are male. All participants were current students at the time of data collection, having either completed high school (32.3%, n=124) or being actively enrolled in a university program (67.7%, n=260); no other educational levels were represented. Additionally, 47.7% (n=183) of the participants held an active sports license, while 52.3% (n=201) did not. The mean age of the participants was 23.52 years. Data were collected via an online survey form (see Table 1).

Table 1. Distribution of participants in the research sample by gender, sports license status, and education level

Variable	Category	n	%	Total (n)	Total (%)
Gender	Female	171	44.5	384	100.0
	Male	213	55.5		
Sports License	Yes	183	47.7	384	100.0
	No	201	52.3		
Education Level	High School	124	32.3	384	100.0
	University	260	67.7		

Data Collection Tool

In the study, the Motivation Scale for Participation in Physical Activity (MSPPA) developed by Demir and Cicioğlu (2018) and the "Enjoyment of Physical Activities Scale" (PACES) adapted into Turkish by Özkurt et al. (2022) were used. A personal information form containing demographic information was created to determine the individuals' age, education level, and whether they have a sports license.

Motivation Scale for Participation in Physical Activity (MSPPA)

The scale was developed by Demir and Cicioğlu (2018). The scale items are rated on a 5-point Likert scale (1 = Strongly Disagree, ..., 5 = Strongly Agree). The analyses revealed a three-factor structure with eigenvalues above 1: Individual Reasons, Environmental Reasons, and Lack of Motivation. The Individual Reasons factor includes items 1, 2, 3, 4, 5, and 6, with an explained variance of 25.53% and a Cronbach's Alpha of 0.89. The Environmental Reasons factor includes items 7, 8, 9, 10, 11, and 12, with an explained variance of 20.52% and a Cronbach's Alpha of 0.86. The Lack of Motivation factor includes items 13, 14, 15, and 16, with an explained variance of 8.62% and a Cronbach's Alpha of 0.82. The eigenvalues of these factors are 4.08, 3.28, and 1.37, respectively. The measurement tool, consisting of 16 items, explains 54.69% of the total variance. The fit indices resulting from the DFA analysis applied to the scale are as follows: χ^2=239.34; df=101; χ^2/df=2.36; RMSEA=0.06; AGFI=0.88; NFI=0.91; CFI=0.95; GFI=0.91; PNFI=0.68; IFI=0.95. Scores obtained from the MSPPA indicate very low motivation for participation in physical activity (1-16), low (17-32), moderate (33-48), high (49-64), and very high (65-80). Items 3, 9, 13, 14, 15, and 16 are reverse-scored.

Physical Activity Enjoyment Scale (PACES)

The scale was adapted into Turkish by Özkurt et al. (2022). It consists of a single dimension and eight items that evaluate positive emotions such as expected or perceived pleasure and enjoyment from physical activities. The scale items are rated on a 7-point Likert scale (1 = Strongly Disagree, ..., 7 = Strongly Agree). There are no reverse-scored (negative) items in the scale. A higher average score on the scale indicates a high level of enjoyment from physical activities, while a lower average score indicates a low level of enjoyment. In their analysis, Özkurt et al. (2022) determined that the Turkish scale version explains 76% of the total variance. The fit indices obtained from the DFA showed that they are within acceptable and good fit ranges (χ^2/df=2.368, GFI=0.98, CFI=0.99, TLI=0.99, RMSEA=0.042, SRMR=0.010).

Analysis of Data

Before analysis, the dataset was screened for errors, outliers, normality violations, and multicollinearity issues. It was observed that no data had been entered erroneously. The data analysis was performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk Test was used to determine the normality of the distribution, and it was found that the data followed a normal distribution (p>0.05). The t-test was used for pairwise comparisons. Pearson's Product-Moment Correlation Coefficient was used to determine the relationships between variables. The significance level was set at p<0.05. T-tests were selected to compare gender, education level, and sports license status due to the binary nature of these variables.

Results

Table 2 reveals that female participants scored significantly higher than males in overall PACES and MSPPA measures, particularly in the Individual Reasons and Lack of Motivation sub-dimensions (p<0.05). The observed gender difference in motivation (t=2.84, p<0.05) corresponded to Cohen's d of 0.29, indicating a small-to-moderate effect size. Similarly, the correlation between age and enjoyment (r=0.14, p<0.01) suggests a weak but significant positive relationship. This suggests that female participants are better than males in terms of motivation for participation in physical activity and enjoyment from physical activity.

Table 2. T-test results of individuals' motivation for participation in physical activity and enjoyment from physical activities by gender

Variables	Female (n = 171)		Male (n = 213)		t	p
	$\bar{X}$	S	$\bar{X}$	S		
PACES	49.88	7.82	48.05	8.91	1.89	0.05*
MSPPA	65.56	9.82	62.33	10.03	2.84	0.00*
Individual Reasons	26.53	4.02	25.35	3.96	2.60	0.01*
Environmental Reasons	22.08	5.05	21.33	5.36	1.25	0.20
Lack of Motivation	16.94	4.09	15.64	4.87	2.47	0.01*

* p<0.05

Table 3 demonstrates that possessing a sports license did not yield significant differences in PACES and MSPPA scores, challenging assumptions that formal sports participation inherently enhances motivation and enjoyment.

Upon examining Table 4, it is seen that there is a significant difference between the sub-dimension scores of Environmental Reasons and Lack of Motivation and the education levels of the individuals ($p<0.05$). It is observed that this difference is in favour of high school students in the Environmental Reasons sub-dimension and favour of university students in the Lack of Motivation sub-dimension. However, there is no significant difference between the total scores of PACES, the total scores of MSPPA, the sub-dimension scores of Individual Reasons, and the individuals' education levels ($p>0.05$).

Table 3. T-test results of individuals' motivation for participation in physical activity and enjoyment from physical activities by sports license variable

Variables	Yes (n = 183)		No (n = 201)		t	p
	$\bar{X}$	S	$\bar{X}$	S		
PACES	49.24	9.02	48.36	8.26	0.91	0.36
MSPPA	64.36	10.09	62.93	10.03	1.26	0.20
Individual Reasons	26.07	3.81	25.59	4.14	1.07	0.28
Environmental Reasons	21.78	5.38	21.48	5.16	0.52	0.60
Lack of Motivation	16.49	4.43	15.86	4.77	1.22	0.22

* $p<0.05$

Table 4. T-test results of individuals' motivation for participation in physical activity and enjoyment from physical activities by education level

Variables	High School (n = 124)		University (n = 260)		t	p
	$\bar{X}$	S	$\bar{X}$	S		
PACES	48.11	10.02	49.06	7.58	-0.98	0.32
MSPPA	62.45	10.54	64.12	9.74	-1.46	0.14
Individual Reasons	25.45	4.70	25.98	3.54	-1.16	0.24
Environmental Reasons	22.37	5.08	21.15	5.29	2.06	0.04*
Lack of Motivation	14.62	5.29	16.99	3.97	-4.62	0.00*

* $p<0.05$

Upon examining Table 5, it is seen that there is a positive and significant relationship between the total scores of PACES and MSPPA, the sub-dimension scores of Individual Reasons and Environmental Reasons, and their ages ($p<0.01$). However, no relationship was found between age and the Lack of Motivation sub-dimension ($p>0.05$).

Upon examining Table 6, it is seen that there is a positive and significant relationship between the total scores of PACES and MSPPA ($r=0.59$), Individual Reasons ($r=0.68$), Environmental Reasons $r=0.39$), and Lack of Motivation ($r = 0.25$) ($p<0.01$).

Table 5. Relationship between individuals' motivation for participation in physical activity and enjoyment from physical activities and age

Variables	n	PACES	MSPPA	Individual Reasons	Environmental Reasons	Lack of Motivation
Age	384	0.14**	0.16**	0.17**	0.19**	-0.01

**$p<0.01$, *$p<0.05$

Table 6. Relationship between individuals' total motivation scores for participation in physical activity and its sub-dimensions and enjoyment levels from physical activities

Variables	1	2	3	4	5
1. PACES	1.00	0.59**	0.68**	0.39**	0.25**
2. MSPPA		1.00	0.79**	0.74**	0.64**
3. Individual Reasons			1.00	0.46**	0.32**
4. Environmental Reasons				1.00	0.18**
5. Lack of Motivation					1.00

**$p<0.01$, *$p<0.05$

Discussion

This study examined the relationship between participants' motivation for physical activity and enjoyment levels, contributing to the existing literature on motivational dynamics. A key finding of this study was that female participants exhibited significantly higher motivation and enjoyment levels than males, aligning with prior research suggesting that social and environmental factors may contribute to these disparities

(Moradi et al., 2020; Pedersen et al., 2021; Rosselli et al., 2020). The study results demonstrate how attributes like gender and age influence motivation levels, which supports the need to develop targeted intervention approaches for better engagement between different population groups. The higher levels of intrinsic motivation and enjoyment observed among females may stem from a stronger internal drive for health and well-being, as well as social and cultural factors that encourage or support physical activity more among women in certain contexts (Navarro et al., 2020; Portela-Pino et al., 2020). The social expectations and cultural traditions contribute to gender-specific motivations for physical exercise. Additionally, studies have documented gender differences in physical activity preferences and barriers, suggesting that interventions aimed at enhancing motivation and enjoyment may need to be tailored to address gender-specific needs (Liu et al., 2023; Logan et al., 2022; Oyibo & Vassileva, 2020).

Research findings show that having a sports license does not consistently boost the motivation or enjoyment of physical exercise participation. Having a sports license does not create better intrinsic motivation and greater physical activity enjoyment for individuals. Research indicates that participation in recreational sports does not enhance motivation or pleasure, while other variables control these effects (Rodrigues et al., 2020). People's performance depends more heavily on internal aspects such as personal interest, environmental support, and self-efficacy. According to research on exercise dependence, many elements drive individuals to exercise. The relationship between formal sports interaction and enjoyment remains complex because participants seek recognition from outside sources or find satisfaction within themselves (Ahorsu et al., 2023; Astuti et al., 2024).

The educational levels of participants directly affected their motivation since high school students received external reinforcement, which led to increased motivation, yet university students displayed decreased motivation as a result. High school students demonstrated greater environmental motivation, while university students showed higher demotivation. Personnel at different educational levels display various life priorities because of their changing circumstances. High school students are likely to make decisions regarding their physical activity based on social environments and community involvement. University students struggle with internal stresses and time limitations, leading to reduced motivation for physical activity (Spiteri et al., 2019). Previous studies demonstrate that education influences physical activity since more educated individuals tend to have better health understanding and additional responsibilities restricting their exercise time (Bull et al., 2020; Orhan et al., 2024).

The relationship between user age and enjoyment connects directly to motivation, demonstrating the requirement for development teams to consider different life stages while designing apps for exercise promotion. Physical activity produces greater motivation and enjoyment benefits for people of advanced ages because they have greater health awareness and changing life priorities (Logan et al., 2022). However, the weak correlation suggests that other confounding factors, such as prior exercise experience and social support, may also play a role. Research shows that physical activity relates to age, where older adults get motivated by healthcare reasons and social contact to enjoy exercising better and stay with their fitness routines (Weinstein & Szabo, 2023). This study's strong relationship between motivation and enjoyment underscores their interconnectedness. As intrinsic motivation increases, so does enjoyment of physical activities, which likely enhances adherence to regular exercise. The results support the Self-Determination Theory, which states that intrinsic motivation derived from personal satisfaction and enjoyment is the foundation for continuing behaviours like physical activity for long-term periods (Rodrigues et al., 2020). Research has established activities that increase autonomy levels, competence, and relatedness and reduce barriers for people to begin exercising more. Numerous studies confirm that intrinsic motivation supports long-term physical exercise adoption because it leads to successful intervention development (Antunes et al., 2024; Kelso et al., 2020).

The study produces important findings about physical exercise motivation and enjoyment patterns to support population-specific intervention design. Intervention programs for physical activity need to boost enjoyment and intrinsic motivation specifically among unaffiliated adults with limited education access to sports activities (Spiteri et al., 2019). Interdisciplinary research (Ahorsu et al., 2023; Orhan et al., 2024; Orhan et al., 2025) confirms exercise enjoyment and motivation serve as essential influences for promoting regular exercise practice among individuals with higher participation hurdles. Different movement patterns in female groups call for creating gender-specific physical activity enhancement tactics. The targeted application of practices leads to enhanced outcomes when we want different age groups to maintain their physical activity practices. Researchers who design tailored health programs matching demographic groups and their motivation needs achieve better health intervention results with greater outcomes (AlKasasbeh & Amawi, 2023; Chaeroni et al., 2024; Weinstein & Szabo, 2023). This study needs qualitative methodologies such as interviews and focus groups for detailed work on individual drivers and obstacles because it depends on quantitative findings. The development of successful programs through general health practice depends heavily on understanding the motivational aspects of humans and their experiences with physical activity and pleasure. Activating internal motivation drives and eliminating barriers to work satisfaction for various demographic groups will improve health outcomes and participant rates.

Further studies must explore the extended impacts of motivation-based research and cultural factors on physical activity patterns. Research examining the modifications of motivation patterns through different stages in life would reveal more information about maintaining physical activity practice. The obtained knowledge allows designers to create school-based workplace and community fitness programs with enjoyment-driven motivation strategies. Health professionals and policymakers need to create solutions that specifically address demographic requirements. Future research needs to use longitudinal research methods to track motivational developments affecting different age groups across social-economic settings. Additional research will generate a deeper understanding of keeping different activities and populations actively involved.

Conclusions

This study highlights the critical role of intrinsic motivation in sustaining physical activity participation among individuals with diverse demographic characteristics. The research demonstrates that females exhibit better levels of motivation and enjoyment than males, and the presence of a sports license does not influence these results. Education level also influences motivation, with high school students being more affected by environmental factors and university students experiencing higher demotivation. According to research, older participants demonstrated more motivation and enjoyed exercising to a greater degree. These insights emphasize the need for interventions that foster intrinsic motivation through enjoyable, supportive environments in gyms, schools, and community programs. Future interventions should incorporate gender-specific approaches, addressing barriers that limit male participation while leveraging social and enjoyment-driven strategies to sustain female engagement. Age-adapted programs can increase individuals' participation in physical activity if they are compatible with their wellness goals.

The results indicated that female participants had significantly higher motivation and enjoyment scores than males, particularly in subdimensions such as Individual Reasons and Lack of Motivation. High school students were more motivated by environmental factors, while university students reported higher levels of demotivation. The absence of significant differences based on sports license status suggests that formal athletic involvement alone does not enhance intrinsic motivation. Moreover, age positively correlated with motivation and enjoyment, reflecting a potential increase in intrinsic value placed on physical activity in older individuals.

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Conflict of Interest
The authors report no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Effects of the Otago Exercise Program on Balance Among Nursing Home Residents: A 12-Week Quasi-Experimental Study

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Abstract

Balance impairments and fall risks significantly affect the well-being of nursing home residents, compromising mobility and independence. Addressing these challenges requires comprehensive interventions that combine physical and psychological components. This study aimed to evaluate the impact of a 12-week intervention with the Otago Exercise Program (OEP), on improving balance among nursing home residents aged 65 and older. A quasi-experimental design was implemented with 42 participants, divided into an experimental group (EG; n=24) and a control group (CG; n=18). The CG had an average age of 69.44±2.70 years, height of 162.22±9.08 cm, and weight of 65.78±17.99 kg, while the EG had an average age of 74.50±6.40 years, height of 159.50±11.31 cm, and weight of 76.97±14.83 kg. The experimental group engaged in structured OEP sessions with 3 sessions per week. Balance was assessed pre- and post-intervention using the Leonardo Mechanograph platform. The experimental group showed significant improvements in static and dynamic balance compared to the control group, particularly in tests requiring sensory integration and postural adjustments under challenging conditions (e.g., Romberg and Semi-Tandem with eyes closed). Functional mobility also improved, as evidenced by better performance in the Chair Raising Test. The OEP, effectively improves balance and mobility in nursing home residents, with assessments via the Leonardo platform confirming robust gains in functional and biomechanical metrics. These findings provide evidence for adopting multifaceted interventions in fall prevention strategies, particularly in resource-limited care settings.

Keywords: *otago exercise, balance, older adults, nursing homes, health*

Introduction

Aging is a dynamic and inevitable process that spans the entire human lifespan, requiring continuous adaptation to evolving physical and functional challenges (Asejeje et al., 2024). This progression is accompanied by physiological changes such as mitochondrial dysfunction, inflammatory dysregulation, hormonal decline, and a reduced metabolic rate. These alterations contribute to the degeneration of multiple systems, leading to diminished nerve function, bone mass, muscle strength, and overall physical capacity (Cesari et al., 2013; Chang & Lin, 2015; Nascimento et al., 2019; Sieber, 2017). A critical consequence of these changes is impaired balance, which significantly increases fall risk among older adults.

Falls represent a major global public health concern, particularly in individuals aged 65 and older (World Health Organization, 2025). In the United States, falls are the leading cause of both fatal and non-fatal injuries in this age group (Kakara et al., 2023). European statistics further emphasize the burden, with over 30% of older adults experiencing a fall annually a figure that escalates in institutional settings

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(Rubenstein & Josephson, 2002). Globally, between 10% and 20% of falls result in serious outcomes such as injury, hospitalization, or death (Rubenstein, 2006). In community-dwelling older adults, fall rates are consistent across regions such as the United States and the United Kingdom, with approximately 29–30% affected and 5% requiring hospitalization for injuries like fractures (Bergen et al., 2016).

Beyond physical harm, falls often lead to psychological consequences such as fear of falling, which in turn contributes to reduced physical activity and functional decline. Structured exercise interventions have emerged as an effective strategy to counteract this cycle. Evidence shows that balance-focused programs can reduce fall incidence by 20–30% (Sherrington et al., 2019).

Among these interventions, the Otago Exercise Program (OEP) is widely recognized for its efficacy. Developed in New Zealand in the late 1990s, the OEP combines strength and balance exercises with walking routines, using minimal equipment (Campbell et al., 1997; Campbell et al., 1999). It comprises 17 exercises five for strength and 12 for balance and can be safely implemented by community-dwelling older adults (Campbell & Robertson, 2003; Liu & Latham, 2009; Mgbeojedo et al., 2023; Sherrington et al., 2011). The program's adaptability has led to various delivery formats, including group sessions and video-guided modalities, enhancing accessibility (García-Gollarte et al., 2023).

Meta-analyses confirm that the OEP improves static, dynamic, and anticipatory balance, while also reducing fear of falling (Chiu et al., 2021). These findings are further supported by a systematic review and meta-analysis by Thomas et al. (2010) which demonstrated that the OEP significantly reduces both fall rates and all-cause mortality among older adults. Similarly, modified versions of the program have proven effective in enhancing balance and stability, broadening its applicability across various older populations (Martins et al., 2018).

Moreover, beyond physical improvements, exercise-based interventions like the OEP positively impact psychological well-being. Karinkanta et al. (2012) found that regular participation in structured physical activity not only enhances health-related quality of life but also alleviates fear of falling, a factor strongly associated with reduced mobility and autonomy.

These benefits are particularly relevant in nursing home settings, where residents face compounded risks related to balance impairment, reduced autonomy, and increased healthcare needs. As global life expectancy increases, the need for multifaceted strategies to support healthy aging becomes more pressing. Physical activity interventions tailored to older populations have demonstrated effectiveness in delaying frailty, enhancing autonomy, and improving quality of life (Márcio et al., 2019; Nezhkina et al., 2022). Balance training presents a promising approach to mitigating fall risk and promoting functional independence (Ribeiro et al., 2017; Sampaio et al., 2024).

Despite existing supporting the OEP, limited research has been conducted on its application within institutionalized populations of advanced age. Moreover, this study is among the first to explore the effectiveness of the OEP among older adults residing in Albania nursing homes, addressing a significant gap in regional and demographic-specific data.

This study aims to evaluate the effectiveness of the OEP in improving balance and reducing fall risk among nursing home residents aged 65 and older. The findings will contribute to the development of evidence-based fall prevention strategies and support efforts to enhance the quality of life in institutionalized older adults.

Methods

Research Design

This study employed a quasi-experimental design to evaluate the effectiveness of the Otago Exercise Program (OEP) in improving balance and reducing fall risk in older adults residing in nursing homes. Participants were allocated to either an experimental group (EG) or a control group (CG), and assessments were conducted pre- and post-intervention over a 12-week period. Written informed consent was received from all participants of the study. The study protocol was registered and received ethical approval (Prot. Nr. 1108/2). The trial adhered to clarify guidelines and the Declaration of Helsinki principles.

Participants

A total of 42 participants aged 65 years and older were recruited from both state and private nursing homes in Tirana, Albania. Initially, 24 individuals were assigned to each group. However, the control group was reduced to 18 participants due to attrition: two individuals passed away and four were transferred to a specialized mental health facility due to severe psychological deterioration. The final group sizes were 24 for the EG and 18 for the CG. The CG had an average age of 69.44±2.70 years, height of 162.22±9.08 cm, and weight of 65.78±17.99 kg, while the EG had an average age of 74.50±6.40 years, height of 159.50±11.31 cm, and weight of 76.97±14.83 kg.

The inclusion criteria for the study required participants to be residents of a nursing home, either state-run or privately operated, and aged 65 years or older. Participants needed to be able to walk independently or with the assistance of mobility aids. Additionally, eligibility required documentation of at least one fall within the previous 12 months. Finally, participants had to demonstrate the capacity to complete the EQ-5D-3L questionnaire, which assesses health-related quality of life.

During the initial visit, the following procedures were conducted: (1) establishing rapport with the participant; (2) providing a clear explanation of the program's objectives; (3) collecting clinical history and screening for safety and adherence-related factors; (4) performing baseline balance and strength evaluations; and (5) prescribing the appropriate exercise protocol (Campbell & Robertson, 2003).

Procedure and Assessments

Participants underwent baseline and post-intervention evaluations using the Leonardo Mechanography platform (Novotec Medical GmbH, Pforzheim, Germany software package 4.2) to assess static and dynamic balance. Assessments followed the Standard Test Procedures supported by Leonardo Mechanography – Basic Version (BAS), as recommended by the manufacturer (Novotec Medical GmbH, n.d.). The following standardized tests were employed: Romberg EO-SEA (Eyes Open – Arms Forward – Standard Ellipse Area), Romberg EC-SEA (Eyes Closed – Arms Forward – Standard Ellipse Area), Romberg EO-rPL (Eyes Open – Arms Forward – Relative Pathlength), Semi-Tandem EO-SEA (Eyes Open – Side Arms – Standard Ellipse Area), Semi-Tandem EO-rPL (Eyes Open –

Side Arms – Relative Pathlength), Semi-Tandem EC-rPL (Eyes Closed – Side Arms – Relative Pathlength), Chair Rising Test.

Intervention Protocol

The experimental group participated in a 12-week structured exercise regimen following the OEP. Sessions were conducted three times per week, lasting 45–60 minutes each, for a total of 135–180 minutes weekly. The program included warm-up, strength, and balance training components (Campbell & Robertson, 2003), as outlined in Table 1. Progression was monitored to ensure safety and promote gradual improvement in functional mobility.

Table 1. Structure of the Otago Exercise Program (OEP) Intervention

Component	Description
Duration	12 weeks
Frequency	3 sessions per week (45–60 minutes/session)
Total Weekly Time	135–180 minutes
Warm-up	6 preparatory exercises
Strength Training	5 lower-limb exercises using ankle cuff weights (starting at 1 kg)
– Knee flexors & extensors	
– Hip abductors	
– Ankle dorsiflexors & plantar flexors	
Balance Exercises	12 dynamic and progressively challenging exercises:
– Initially performed with support	
– Progressively performed independently	
Repetitions	2 sets of 10 repetitions before progressing to more difficult versions
Intensity	Moderate intensity; no excessive fatigue
Cool-down	2 recovery/stretching exercises

Statistical Analysis

Descriptive statistics were calculated to summarize participants' demographic and baseline data. The Shapiro-Wilk test was applied to assess the normality of distribution. Given the non-parametric nature of the data, we used Mann–Whitney U test: to compare differences between the intervention and control groups. Also, we used the Wilcoxon Signed-Rank test: to evaluate within-group changes from baseline to post-intervention. All statistical analyses were conducted using SPSS software version 23 (IBM SPSS, Version 23.0, Armonk, NY, USA). A p-value of <0.05 was considered statistically significant.

Results

The table 2 reveals minimal changes in anthropometric measures for both groups. The control group, with an average age of 69.44 years, showed a slight increase in weight (65.78 kg to 66.76 kg) and BMI (25.13 to 25.28 kg/m²). Similarly, the experimental group, older on average (74.50 years), also experienced minor increases in weight (76.97 kg to 77.98 kg) and BMI (30.30 to 30.68 kg/m²).

If the body measurement data of both groups were alike, the results would probably be more important, since the 5-year age gap favoring the control group and the obesity of the experimental group are factors that affect the expected results after the experiment.

According to the results from table 3, by the Mann-Whitney U Test suggest that the intervention had a significant effect on postural stability, as reflected in the Romberg EO-rPL

Table 2. Anthropometric Data of Control and Experimental Groups Before and After the Intervention

Group	Variables	M±SD
Control	Age (years)	69.44±2.70
	Height (cm)	162.22±9.08
	Weight (kg) - pre	65.78±17.99
	Weight (kg) - post	66.76±18.06
	BMI (kg/m²) - pre	25.13±6.70
	BMI (kg/m²) - post	25.28±6.17
Experimental	Age (years)	74.50±6.40
	Height (cm)	159.50±11.31
	Weight (kg) - pre	76.97±14.83
	Weight (kg) - post	77.98±15.87
	BMI (kg/m²) - pre	30.30±5.36
	BMI (kg/m²) - post	30.68±5.65

Notes: M= Mean, SD= Standard Deviation

and Romberg EC-rPL measures. Specifically, the experimental group showed a significant improvement in postural control with both eyes open and closed, as indicated by the reduction in relative path length (rPL).

However, no significant differences were found in the Romberg EO-SEA and Romberg EC-SEA measures, which suggests that the intervention did not impact balance in terms of the standard ellipse area when standing with eyes open or closed.

Table 3. Differences between Groups at the end of the Experiment (check by Mann Whitney U test) –Romberg Test

Measurements Test U	N	Mean Rank	Sum of rank	U	Sig	p	Interpretation
C_Romberg EO-SEA (cm^2)	18	22.33	402.00	201	0.703	>0.05	No significant difference
E_Romberg EO-SEA (cm^2)	24	20.88	501.00				
C_Romberg EC-SEA (cm^2)	18	25.67	462.00	141	0.057	>0.05	No significant difference
E_Romberg EC-SEA (cm^2)	24	18.38	441.00				
C_Romberg EO-rPL (mm/s)	18	26.25	472.50	131	0.03	<0.05	Significant difference
E_Romberg EO-rPL (mm/s)	24	17.94	430.50				
C_Romberg EC-rPL (mm/s)	18	28.56	514.00	89	0.001	<0.05	Significant difference
E_Romberg EC-rPL (mm/s)	24	16.21	389.00				

Notes: C=Control Group, E=Experimental Group;.Romberg EO-SEA = Romberg Eyes Open - Arms Forward - Std. Ellipse Area; Romberg EC-SEA = Romberg Eyes Closed - Arms Forward - Std. Ellipse Area; Romberg EO-rPL = Romberg Eyes Open - Arms Forward - rel. Pathlength Area; Semi Tandem EO-SEA = Romberg Eyes Open - Side Arms - Std. Ellipse Area; Semi Tandem EO-rPL = Romberg Eyes Open - Side Arms - rel. Pathlength Area; Semi Tandem EC-rPL = Romberg Eyes Closed - Side Arms - rel. Pathlength Area.

The results of the Mann-Whitney U Test from table 4 suggest that the intervention had a significant effect on balance and strength. Specifically, the experimental group showed significant improvements in postural control during both Semi Tandem EO-SEA, Semi Tandem EC-SEA, and Semi Tandem EO-rPL measures, indicating better balance performance. However, no significant difference was found in the Semi Tandem EC-rPL measure, suggesting no change in balance control when eyes were closed. The experimental group also showed a significant improvement in the Chair Raising Test, demonstrating enhanced strength or functional capacity after the intervention.

Table 4. Differences between Groups at the end of the Experiment (check by Mann Whitney U test) –Semi Tandem Test and Chair Raising Test

Measurements Test U	N	Mean Rank	Sum of rank	U	Sig	p	Interpretation
C_Semi Tandem EO-SEA (cm^2)	18	28.06	505.00	98.00	0.003	<0.05	Significant difference
E_Semi Tandem EO-SEA (cm^2)	24	16.58	398.00				
C_Semi Tandem EC-SEA(cm^2)	18	30.11	542.00	61.00	0.000	<0.05	Significant difference
E_Semi Tandem EC-SEA(cm^2)	24	15.04	361.00				
C_Semi Tandem EO-rPL (mm/s)	18	27.89	502.00	101.00	0.003	<0.05	Significant difference
E_Semi Tandem EO-rPL (mm/s)	24	16.71	401.00				
C_Semi Tandem EC-rPL (mm/s)	18	25.00	450.00	153.00	0.109	>0.05	No significant difference
E_Semi Tandem EC-rPL (mm/s)	24	18.88	453.00				
C_Chair Raising Test (s)	18	27.31	491.50	111.50	0.008	<0.05	Significant difference
E_Chair Raising Test (s)	24	17.15	411.50				

Notes: C=Control Group, E=Experimental Group; Romberg EO-SEA = Romberg Eyes Open - Arms Forward - Std. Ellipse Area; Romberg EC-SEA = Romberg Eyes Closed - Arms Forward - Std. Ellipse Area; Romberg EO-rPL = Romberg Eyes Open - Arms Forward - rel. Pathlength Area; Semi Tandem EO-SEA = Romberg Eyes Open - Side Arms - Std. Ellipse Area; Semi Tandem EO-rPL = Romberg Eyes Open - Side Arms - rel. Pathlength Area; Semi Tandem EC-rPL = Romberg Eyes Closed - Side Arms - rel. Pathlength Area.

The results from table 5 indicate that most variables showed no statistically significant differences between the before and after measurements in both control and experimental groups. However, a notable exception is the Romberg EO-rPL (Eyes Open, Path Length) variable for the experimental group, which demonstrated a significant reduction (p=0.04)

This suggests that the intervention applied to the experimental group had a measurable impact on postural stability with eyes open, as indicated by the decreased path length. Other variables, while some showed trends toward significance (e.g., Romberg EC-rPL in the experimental group), did not reach the statistical threshold for significance.

According to table 6, the experimental group showed statistically significant improvements across multiple variables, particularly in postural stability and functional performance, such as in the Chair Raising Test and Semi Tandem rPL variables. The control group also demonstrated some significant improvements, but these were more limited compared to the experimental group.

These findings suggest the intervention's effectiveness in enhancing balance and functional mobility, especially in challenging conditions such as eyes-closed tasks.

Table 5. Wilcoxon Paired Z-Test Results for Romberg Test Performance

Variables	Group	Wilcoxon Pair - Z test	Sig	p	Interpretation
Romberg EO-SEA (cm^2)	CG	-0.544	0.586	>0.05	No significant difference
	EG	-0.029	0.977	>0.05	No significant difference
Romberg EC-SEA (cm^2)	CG	-0.109	0.913	>0.05	No significant difference
	EG	-1.386	0.166	>0.05	No significant difference
Romberg EO-rPL (mm/s)	CG	-0.240	0.811	>0.05	No significant difference
	EG	-2.057	0.040	<0.05	Significant difference
Romberg EC-rPL (mm/s)	CG	-0.152	0.145	>0.05	No significant difference
	EG	-3.371	0.059	>0.05	No significant difference

Notes: CG=Control Group; EG=Experimental Group; Romberg EO-SEA = Romberg Eyes Open - Arms Forward - Std. Ellipse Area; Romberg EC-SEA = Romberg Eyes Closed - Arms Forward - Std. Ellipse Area; Romberg EO-rPL = Romberg Eyes Open - Arms Forward - rel. Pathlength Area.

Table 6. Wilcoxon Paired Z-Test Results for Semi Tandem and Chair Stand Tests Performance

Variables	Group	Wilcoxon Pair - Z test	sig	p	Interpretation
Semi Tandem EO-SEA (cm^2)	CG	-1.459	0.145	>0.05	No significant difference
	EG	-1.886	0.059	>0.05	No significant difference
Semi Tandem EC-SEA(cm^2)	CG	-3.114	0.002	<0.05	Significant difference
	EG	-3.686	0.000	<0.05	Significant difference
Semi Tandem EO-rPL (mm/s)	CG	-0.849	0.396	>0.05	No significant difference
	EG	-3.743	0.000	<0.05	Significant difference
Semi Tandem EC-rPL (mm/s)	CG	-2.373	0.018	<0.05	Significant difference
	EG	-4.286	0.000	<0.05	Significant difference
Chair Raising Test (s)	CG	1.415	0.157	>0.05	No significant difference
	EG	2.214	0.027	<0.05	Significant difference

Notes: Semi Tandem EO-SEA = Romberg Eyes Open - Side Arms - Std. Ellipse Area; Semi Tandem EO-rPL = Romberg Eyes Open - Side Arms - rel. Pathlength Area; Semi Tandem EC-rPL = Romberg Eyes Closed - Side Arms - rel. Pathlength Area.

Discussion

The findings of this study underscore the effectiveness of the (OEP) in enhancing balance among older adults residing in nursing homes. This intervention directly addresses major challenges associated with aging, including reduced mobility and increased fall risk two key contributors to morbidity and loss of independence (Ambrose et al., 2013; Rubenstein & Josephson, 2002; Rodrigues et al., 2023; Xu et al., 2022).

Beyond its physical benefits, the OEP may also offer psychosocial advantages by promoting group activities and fostering interpersonal engagement, which are vital in reducing social isolation in institutionalized older adults (Bjerk et al., 2018). Notably, the experimental group showed significant improvements in demanding balance tasks, such as tests performed with eyes closed. These outcomes are likely driven by neuromuscular adaptations induced by the OEP, which focuses on enhancing lower-limb strength and proprioceptive function (Chiu et al., 2021).

These improvements in balance performance can be explained through multiple interconnected physiological and neurological mechanisms. The OEP enhances lower-limb strength and muscular coordination, which are critical for stability under challenging conditions, including visual deprivation (Sherrington et al., 2017). Repeated practice of functional movements likely enhances loops (Lacroix et al., 2016). In parallel, motor learning induced by balance training, may promote sensorimotor integration and neuroplastic adaptations in cortical and subcortical areas responsible for postural control, such as the cerebellum and prefrontal cortex (Nicolson et al., 2021; Sehm et al., 2014). Moreover, interventions involving dynamic balance under constrained conditions have been shown to increase activity in neural networks associated with executive function and spatial orientation, domain known to deteriorate with age (Li et al., 2021; Voelcker-Rehage & Niemann, 2013). Thus, the OEP, likely generates a synergistic effect by improving both biomechanical and neurocognitive components of balance.

Our results reinforce the substantial body of evidence supporting the OEP as a core component of fall prevention strategies. The program's emphasis on balance and strength training aligns with previous studies that report a 20–30% reduction in fall incidence among community-dwelling older adults (Li et al., 2021; Racey et al., 2021; Sadaqa et al., 2023; Sherrington et al., 2017; van Gameren et al., 2021). Furthermore, there is growing evidence that such interventions may also enhance cognitive functions particularly executive function and spatial awareness through balance training (Lacroix et al., 2016; Nicolson et al., 2021).

The use of the Leonardo Mechanograph platform added methodological rigor by providing high-resolution biomechanical data, which further substantiated the intervention's effectiveness (García-Gollarte et al., 2023; Hoang et al., 2021;

Wiegmann et al., 2019; Wiegmann et al., 2022). The observed improvements in postural control likely resulted from the synergistic effects of physical, cognitive, and emotional stimuli inherent in this multifaceted intervention. The OEP appears to facilitate motor learning, particularly under challenging conditions such as tasks requiring postural adjustments with visual deprivation.

Importantly, this holistic approach not only addresses fall risk but also contributes to broader aspects of well-being, such as promoting active aging, maintaining functional independence, and mitigating chronic conditions including hypertension and type 2 diabetes through sustained physical activity (Márcio et al., 2019; Ribeiro et al., 2017).

This study provides actionable insights for healthcare professionals and policymakers. Structured and scalable interventions that incorporate culturally appropriate elements have significant potential, especially in resource-constrained settings. The flexibility of the OEP, which can be delivered in both group and individual formats, enhances its applicability across various institutional environments (Campbell & Robertson, 2003). Additionally, leveraging digital platforms or partnerships with community organizations could facilitate broader, more cost-effective implementation (García-Gollarte et al., 2023; Liu & Latham, 2009).

Nevertheless, the quasi-experimental design of this study limits the generalizability of the findings. Larger randomized controlled trials are needed to validate these results and explore long-term effects. Future research should also examine the feasibility of embedding such programs within existing healthcare systems, considering workforce training, infrastructure, and sustainability (Sherrington et al., 2019; WHO, 2025).

Moreover, evaluating the cost-effectiveness of the intervention is crucial, given the escalating healthcare costs associated with falls in older populations (WHO, 2025). Examining potential gender differences in intervention outcomes may also provide insights into tailoring strategies to meet the diverse needs of older adults (Li et al., 2021; Nicolson et al., 2021).

Conclusion

The OEP is a highly effective and practical strategy for reducing fall risk and improving balance among older adults living in nursing homes. These findings highlight the value of culturally adaptable, evidence-based interventions in enhancing the effectiveness of traditional fall prevention strategies. The use of advanced biomechanical assessment tools, such as the Leonardo Mechanograph, strengthens the evidence base and supports broader adoption in clinical and community settings.

As populations continue to age, integrating scalable, low-cost, and multifaceted exercise programs like the OEP into healthcare systems will be essential for promoting healthy aging and reducing the economic burden of fall-related injuries. Especially considering that numerous socio-economic factors influence barriers to physical activity (Ilić et al., 2024).

Future research should explore the long-term sustainability, cost-effectiveness, and adaptability of such interventions across diverse populations and care environments.

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Conflict of Interest

The authors declare no conflict of interest related to this study. The research was conducted independently, and no financial or personal relationships influenced the design, execution, or reporting of the findings.

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ORIGINAL SCIENTIFIC PAPER

Rethinking Sociodemographic Predictors of Physical Literacy and Health Literacy in Older Females

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Abstract

Health literacy (HL) and physical literacy (PL) are theoretically influenced by sociodemographic status, but studies rarely have examined this problem in older persons from southeastern Europe. This study aimed to evaluate the associations between certain sociodemographic indices and PL and HL in older females from Croatia. The sample of participants included 47 urban females (60-83 years of age) from southern Croatia. Sociodemographic factors included age (in years), educational level (elementary school level, high school education, college/university level), and socioeconomic status (below average, average, above average). The PL and HL were evaluated via standardized questionnaires (PL - Perceived Physical Literacy Questionnaire for Adults, HL - European Health Literacy Survey Questionnaire). No significant correlation between age and total scores of HL and PL was detected (Pearson's R=0.15 and 0.09 for HL-total and PL-total, respectively, p>0.05). The highest level of understanding of information related to health promotion was found in college/university educated participants (F test=3.34, p<0.05). PL competence was highest in participants with above-average socioeconomic status (F test=4.19, p<0.05). Despite some significant associations, sociodemographic factors were poorly related to the HL and PL status of older women. The results highlight that PLs and HLs are likely more strongly influenced by lifelong habits, accumulated experience, and consistent exposure to health systems and information.

Keywords: *physical competence, health behavior, postmenopausal women, correlation*

Introduction

Health literacy (HL) is a critical determinant of health outcomes, particularly among older adults, who often face increasing healthcare needs and chronic disease burdens. For females aged 60 years and above, especially in southeastern Europe, adequate HL plays a central role in navigating complex health systems, understanding medication regimens, and making informed decisions about preventive and therapeutic interventions (Bobinac, 2023). Research consistently shows that low HL is associated with poorer self-rated health, higher hospitalization rates, and reduced use of preventive services in this demographic. Furthermore, age-related cognitive changes, lower educational attainment, and limited digital literacy can compound challenges in accessing and interpreting health information (Findley, 2015). Older women may also experience sociocultural barriers, such as traditional gender roles and limited autonomy, which can restrict their engagement with health education resources. Improving HL in this group is therefore vital not only for enhancing individual quality of life but also for reducing avoidable health disparities and healthcare costs.

Physical literacy (PL), which encompasses motivation, confidence, physical competence, knowledge, and understanding to value and engage in physical activity, is increasingly recognized as a cornerstone of healthy aging (Petrusevski, Morgan, MacDermid, Wilson, & Richardson, 2022). For

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older women, maintaining PL is crucial for sustaining functional independence, preventing falls, and managing chronic conditions such as osteoporosis, arthritis, and cardiovascular diseases. In southeastern Europe, where health inequalities and sedentary lifestyles among aging populations are particularly pronounced, low levels of PL can accelerate physical decline and reduce overall quality of life. Moreover, older females often face specific barriers, such as reduced access to fitness infrastructure, social isolation, and gendered expectations regarding activity levels (Kowalczyk, Nowicka, & Sas-Nowosielski, 2017). A strong foundation in PL can foster a sense of self-efficacy and body awareness, which support lifelong engagement in movement and exercise. Interventions that promote age- and gender-sensitive approaches to PL have been shown to enhance not only physical functioning but also mental well-being and social participation in older women (Jones et al., 2018). Therefore, supporting PL in this population is an essential public health goal, with benefits extending to individuals, families, and healthcare systems alike.

Identifying and understanding the sociodemographic factors associated with health and PL is essential for designing effective, targeted public health interventions. In the context of HL, these factors—such as age, education, income, marital status, and place of residence—play pivotal roles in shaping an individual's ability to access, understand, and apply health-related information (García-García & Pérez-Rivas, 2022). Older women with lower educational attainment or income often face significant barriers to HL, including limited access to healthcare information, digital tools, and formal health education (Estrela, Semedo, Roque, Ferreira, & Herdeiro, 2023). In southeastern Europe, cultural norms and gendered expectations can further restrict women's engagement with health services, particularly in rural or underserved areas. Additionally, social isolation or the absence of supportive networks may hinder comprehension and decision-making in health-related contexts.

Like with HL, identifying sociodemographic factors that influence PL is essential for promoting active aging and reducing functional decline in older women. PL is shaped not only by individual motivation and physical capability but also by broader social determinants such as education, income, the environment, and cultural expectations (Gilic, Sekulic, Munoz, Jaunig, & Carl, 2025). Women over 60 years of age who have lower socioeconomic status or limited educational backgrounds may have fewer opportunities to engage in structured physical activity or lifelong movement learning, leading to reduced physical confidence and competence. Geographic location could also play a role: those in rural or economically marginalized areas often face infrastructural limitations, such as a lack of access to safe recreational spaces or age-appropriate programs (McCreery, Penney, & Jeanes, 2024). Furthermore, gendered roles and caregiving responsibilities may discourage older women from prioritizing their own physical activity. Recognizing these sociodemographic disparities is vital for developing inclusive PL interventions that not only improve movement competence but also support autonomy, well-being, and sustained participation in active lifestyles.

Not surprisingly, studies specifically investigated the associations between sociodemographic factors and HL and PL. For example, rural residence, low wealth, and low education are associated with poor HL, which can be explained primarily by restricted health service use and, by extension, poor access to HL resources (Wongnaah, Osborne, Duodu, Seidu, & Ahinkorah, 2025). Consistently, a lower educational level was associated with lower HL, even in rural Bangladesh, Vietnam and the Netherlands (Fottrell et al., 2025; Nguyen, Giang, Bui, & Nguyen, 2025; Vlaanderen, Mughini-Gras, Bourgonje, & van der Giessen, 2024). Moreover, studies have rarely investigated the sociodemographic correlates of PL, and even if this has been the case, authors have evaluated the associations between sociodemographic factors and physical activity (as one of the PL facets).

Therefore, this study aimed to evaluate the associations between sociodemographic characteristics, HL and PL, specifically for older females from urban center. Specifically, we were particularly interested in this age group and urban environment since we intended to identify associations between the studied variables precisely. Initially, we hypothesized that sociodemographic characteristics would be significantly but weakly correlated with HL and PL.

Methods

Participants

The study sample consisted of 47 women aged 60--80 years, all of whom were residents of the city of Split, located in southern Croatia. Recognizing the strong influence of sociocultural factors on both HL and PL, we deliberately limited the geographic scope to a single urban area to minimize cultural variability among participants. The sample included women with a broad range of health statuses—from those without any diagnosed conditions to individuals managing serious health issues such as diabetes, cardiovascular diseases, and arthritis. Over 60% of women reported participation in some form of recreational physical activity. The participants were personally invited to join the study and participate in testing at the Faculty of Kinesiology, University of Split, Croatia. Before data collection, they were fully informed that participation was voluntary and that they could withdraw at any time. The study team explained all potential benefits and risks, and written informed consent was obtained from each participant. The inclusion criteria were as follows: being female, aged over 60 years, residing in the city of Split, having adequate physical independence and motor function to travel to the testing site unaided, and possessing sufficient cognitive ability to comprehend and complete questionnaires on HL and PL. The exclusion criteria included being under the age of 60, having cognitive impairments affecting questionnaire completion, or lacking the motor function and independence required to reach the testing location. The study protocol was approved by the Ethics Committee of the Faculty of Kinesiology.

Variables

In this study, we observed sociodemographic factors (independent variables), HL, and PL (dependent variables).

Sociodemographic variables were self-reported and included age (in years), educational level (elementary school, high school, college/university level), and socioeconomic status (below average, average, above average).

HL was evaluated via the validated Croatian version of the European Health Literacy Survey Questionnaire (HLS-EU-Q), as reported in prior studies (Blažević, Blazevic, & Sekulic, 2024; Geets-Kesić, Maras, & Gilić, 2023). This tool measures an individual's ability to access, understand, evaluate, and apply health-related information for making informed health decisions and utilizing healthcare services. The study examined twelve HL subdomains: (i) accessing healthcare information (HC-AC), (ii) understanding healthcare information (HC-U), (iii) appraising healthcare information (HC-AP), (iv) applying healthcare information (HC-APPL), (v) accessing disease prevention information (DP-AC), (vi) understanding disease prevention information (DP-U), (vii) appraising disease prevention information (DP-AP), (viii) applying disease prevention information (DP-APPL), (ix) accessing health promotion information (HP-AC), (x) understanding health promotion information (HP-U), (xi) appraising health promotion information (HP-AP), and (xii) applying health promotion information (HP-APPL). A general HL index (HL-total) was calculated via a 4-point Likert scale with response options ranging from very difficult (1) to very easy (4).

The PL was assessed via the Perceived Physical Literacy Questionnaire for South Eastern Europe (PPLQ-SEE), which was recently developed and studied for reliability and validity (Gilic et al., 2025). This instrument consists of 24 items distributed across six core domains: (i) physical competence, (ii) understanding, (iii) motivation, (iv) confidence, (v) knowledge, and (vi) physical activity behavior. Items from the first four domains are rated on a six-point Likert scale ranging from 5 (strongly agree) to 0 (strongly disagree), whereas the knowledge domain includes dichotomous (true–false) items. In the present study, we focused on five subdomains—PL-competence, PL-understanding, PL-motivation, PL-confidence, and PL-knowledge—along with a total PL score (PL-total) as indicators of participants' PL levels.

Statistics

The Kolmogorov–Smirnov test was used to check the normality of the distributions for all the variables. As a result, descriptive statistics included calculations of the means; minimum, maximum and standard deviations for age; and PL and HL indicators, while frequencies and percentages were reported for the remaining variables.

To identify the associations between age and HL- and PL-derived variables, we calculated Pearson's correlations. Analysis of variance (ANOVA) was used to establish the effects of educational status and socioeconomic status on HL and PL, with Scheffe post hoc test calculations, when appropriate.

Statistica ver 14.5 (Tibco Inc., Palo Alto, CA, USA) was used for all calculations, and a p-level of 95% was applied.

Results

The descriptive statistics for all the studied variables are presented in Table 1. Generally, all the HL and PL variables showed appropriate distributions, with the expected theoretical ranges of scores achieved.

Table 1. Descriptive statistics for the study variables

	Mean	Minimum	Maximum	SD
Age (years)	70.34	60.00	82.00	5.88
PL-competence (score)	64.15	0.00	100.00	26.46
PL-understanding (score)	96.60	60.00	100.00	7.85
PL-motivation (score)	87.59	0.00	100.00	23.92
PL-confidence (score)	74.15	0.00	100.00	26.83
PL-knowledge (score)	82.98	44.44	100.00	16.36
PL-total (score)	81.09	40.56	95.56	11.50
HC-AC (score)	37.59	8.33	50.00	10.94
HC-U (score)	39.63	16.67	50.00	9.51
HC-AP (score)	32.36	12.50	50.00	9.29
HC-APPL (score)	40.60	20.83	50.00	7.50
DP-AC (score)	39.89	12.50	50.00	10.45
DP-U (score)	42.85	25.00	50.00	7.96
DP-AP (score)	36.24	20.00	50.00	8.21
DP-APPL (score)	31.21	16.67	50.00	10.71
HP-AC (score)	34.40	6.67	50.00	10.59
HP-U (score)	34.33	4.17	50.00	12.55
HP-AP (score)	41.91	22.22	50.00	8.50
HP-APPL (score)	37.32	16.67	50.00	9.98
HL-total (score)	37.14	24.11	48.23	7.11
	F	Cumulative F	%	Cumulative %
Educational level				
Elementary school	9	9	19.1	8.5
High school	28	37	59.6	78.7
College/University level	8	45	17.0	95.7

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Table 1. Descriptive statistics for the study variables

	Mean	Minimum	Maximum	SD
Missing	2	47	4.3	100.0
Socioeconomic status				
Below average	6	6	12.8	8.5
Average	31	37	66.0	78.7
Above average	10	47	21.3	100.0
Missing	0	47	0.0	100.0

Legend: PL – physical literacy, HC-AC – accessing healthcare-related information, HC-U – understanding healthcare-related information, HC-AP – appraising healthcare-related information, HC-APPL – applying healthcare-related information, DP-AC – accessing information related to disease prevention, DP-U – understanding information related to disease prevention, DP-AP – appraising information related to disease prevention, HP-APPL – applying information related to disease prevention, HP-AC – accessing information related to health promotion, HP-AP – appraising information related to health promotion, HP-U – understanding information related to health promotion, HP-APPL – applying information related to health promotion

The associations between age and total HL and PL scores are presented in Figure 1. No significant correlation was found between participants' age and their HL (Figure 1A) or between age and PL (Figure 1B) (Pearson's R=0.15 and 0.09, respectively).

Figure 2 presents the correlations between age and different facets of HL and PL. For total scores, none of the HL subscores or HL-sob scores were significantly correlated with participants' age, with correlation coefficients ranging from

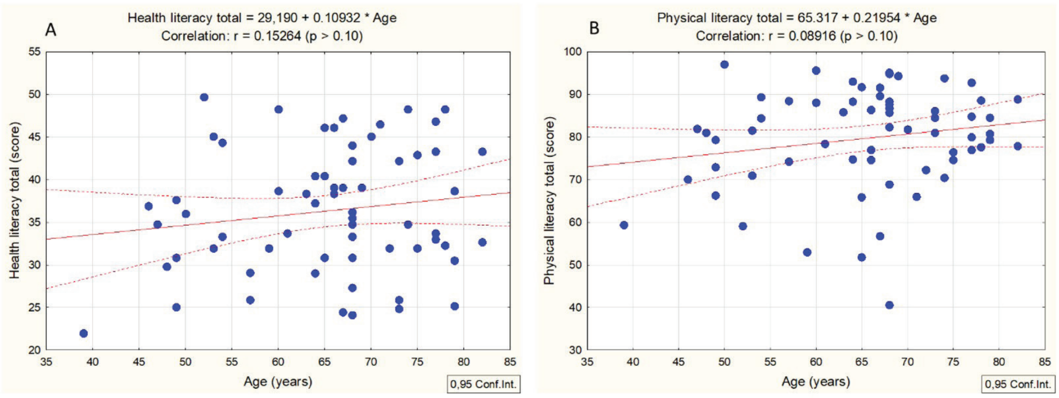

FIGURE 1. Correlations between age and health literacy total score (1A) and physical literacy total score (1B)

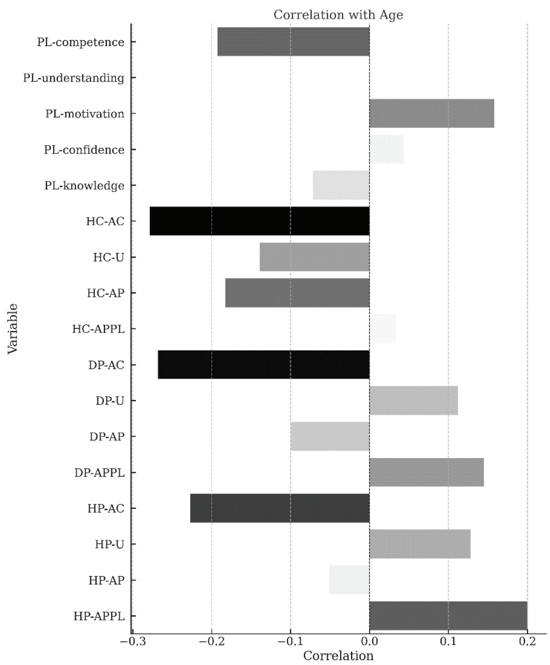

FIGURE 2. Correlations between age and physical literacy subscores and health literacy subdomains (for abbreviations, please see Table legends)

<0.02 (for correlation between age and PL understanding) to 0.27 (for correlation between age and HC-AC).

The differences among groups in terms of educational level were significant for HP-U (F test=3.34, p<0.05), highlighting the specific level of association between educational level and the level of understanding information related to health promotion, with the highest level of this HL subscore in women who were better educated (significant post hoc differences between college/university level and elementary school) (Table 2).

Table 2. Differences in educational level for health literacy and physical literacy variables (analysis of variance – ANOVA)

	Elementary school (n = 9)		High school (n = 28)		College/University Level (n = 8)		ANOVA	
	Mean	SD	Mean	SD	Mean	SD	F test	p-level
PL-competence (score)	63.29	24.82	67.50	31.29	70.31	17.46	0.07	0.98
PL-understanding (score)	96.95	6.73	98.67	2.81	92.08	10.67	1.46	0.24
PL-motivation (score)	87.71	22.39	81.00	30.87	77.92	22.77	1.23	0.31
PL-confidence (score)	75.29	22.19	59.50	35.31	65.00	31.14	2.35	0.09
PL-knowledge (score)	81.27	14.70	81.11	17.41	79.86	23.73	0.84	0.48
PL-total (score)	80.90	9.58	77.56	14.49	77.03	14.63	1.58	0.21
HC-AC (score)	36.19	10.68	37.50	10.39	36.46	9.92	0.22	0.88
HC-U (score)	38.21	9.29	38.75	7.36	38.02	11.57	0.44	0.72
HC-AP (score)	32.26	9.44	31.67	5.62	30.47	10.29	0.11	0.95
HC-APPL (score)	39.40	7.38	39.17	8.38	38.02	8.32	0.19	0.91
DP-AC (score)	39.05	10.89	40.42	9.22	38.37	8.32	0.52	0.67
DP-U (score)	41.83	8.49	40.56	10.16	39.24	8.23	0.21	0.89
DP-AP (score)	36.19	8.25	37.00	7.93	33.33	8.61	0.24	0.87
DP-APPL (score)	32.54	10.62	28.89	9.73	27.43	12.58	1.16	0.34
HP-AC (score)	34.10	11.18	35.00	6.33	33.13	8.73	0.75	0.53
HP-U (score)	31.11	12.29	34.17	10.54	39.17	11.98	3.34	0.03
HP-AP (score)	41.43	8.45	39.44	9.24	39.81	9.13	0.98	0.41
HP-APPL (score)	37.62	9.67	36.25	11.29	33.61	8.40	0.65	0.58
HL-total (score)	36.73	7.20	36.99	7.35	34.68	7.39	0.32	0.81

Legend: PL – physical literacy, HC-AC – accessing healthcare-related information, HC-U – understanding healthcare-related information, HC-AP – appraising healthcare-related information, HC-APPL – applying healthcare-related information, DP-AC – accessing information related to disease prevention, DP-U – understanding information related to disease prevention, DP-AP – appraising information related to disease prevention, HP-APPL – applying information related to disease prevention, HP-AC – accessing information related to health promotion, HP-AP – appraising information related to health promotion, HP-U – understanding information related to health promotion, HP-APPL – applying information related to health promotion

Table 3 presents the differences between groups formed on the basis of the self-declared socioeconomic status in the HL- and PL-derived variables. A significant difference among groups was found solely for PL competence (F test=4.19, p<0.05). In general, the highest level of PL competence was detected in participants who self-declared above-average socioeconomic status (significantly different from participants who declared below-average socioeconomic status).

Table 3. Differences in socioeconomic status for health literacy and physical literacy variables (analysis of variance – ANOVA)

	Below average (n = 6)		Average (n = 31)		Above average (n = 10)		ANOVA	
	Mean	SD	Mean	SD	Mean	SD	F test	p-level
PL-competence (score)	38.75	20.16	67.18	23.53	78.33	12.58	4.19	0.04
PL-understanding (score)	100.00	0.00	95.88	7.86	91.11	10.18	0.84	0.36
PL-motivation (score)	96.67	6.67	83.76	24.75	77.78	20.37	0.65	0.42
PL-confidence (score)	88.75	13.15	70.00	27.61	53.33	29.30	1.38	0.25
PL-knowledge (score)	91.67	10.64	81.41	17.51	62.96	16.97	1.19	0.28
PL-total (score)	83.17	5.28	79.65	12.29	72.70	8.18	0.16	0.69
HC-AC (score)	34.38	7.89	38.79	9.82	37.50	7.22	1.26	0.27
HC-U (score)	36.46	7.89	31.67	9.20	27.78	6.36	0.94	0.34
HC-AP (score)	40.63	10.96	39.32	7.30	31.94	8.67	0.00	0.95

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Table 3. Differences in socioeconomic status for health literacy and physical literacy variables (analysis of variance – ANOVA)

	Below average (n = 6)		Average (n = 31)		Above average (n = 10)		ANOVA	
	Mean	SD	Mean	SD	Mean	SD	F test	p-level
HC-APPL (score)	40.63	11.97	39.04	10.01	34.72	4.81	0.04	0.85
DP-AC (score)	47.22	3.21	40.86	8.53	33.33	9.62	1.43	0.24
DP-U (score)	36.67	7.20	35.58	8.14	33.33	13.33	0.03	0.85
DP-AP (score)	34.72	2.78	30.20	11.70	27.78	5.56	0.51	0.48
DP-APPL (score)	27.50	14.24	34.42	9.49	30.00	11.55	1.76	0.19
HP-AC (score)	35.42	12.95	33.87	12.12	29.17	7.22	0.06	0.81
HP-U (score)	41.67	9.62	40.48	8.79	38.89	9.62	0.00	0.99
HP-AP (score)	41.67	5.89	36.19	9.71	30.56	10.49	0.96	0.33
HP-APPL (score)	37.15	8.49	36.29	7.20	32.21	6.33	0.01	0.94

Legend: PL – physical literacy, HC-AC – accessing healthcare-related information, HC-U – understanding healthcare-related information, HC-AP – appraising healthcare-related information, HC-APPL – applying healthcare-related information, DP-AC – accessing information related to disease prevention, DP-U – understanding information related to disease prevention, DP-AP – appraising information related to disease prevention, HP-APPL – applying information related to disease prevention, HP-AC – accessing information related to health promotion, HP-AP – appraising information related to health promotion, HP-U – understanding information related to health promotion, HP-APPL – applying information related to health promotion

Discussion

Although some aspects of HL and PL were associated with educational level (higher HP-U in better educated participants) and socioeconomic status (higher PL-competence in participants with better socioeconomic status), associations between sociodemographic factors and PL and HL were generally nonsignificant and practically negligible. Therefore, our initial study hypothesis cannot be accepted. In the future, we will specifically discuss the possible reasons for such findings.

Age, health literacy and physical literacy

The absence of a significant correlation between age and PL among older women in our study may reflect the enduring nature of PL once it has been established earlier in life. The PL is grounded in the development of fundamental movement skills, confidence, and positive attitudes toward physical activity—attributes typically shaped during childhood and adolescence. Studies suggest that individuals who acquire these competencies early on are more likely to preserve them well into older adulthood, even in the face of age-related physical decline (Aarts, Paulussen, & Schaalma, 1997; Waller et al., 2018). In this context, women who were previously active or who had participated in organized physical education or sports may retain their movement competence and motivation regardless of their current age. This may buffer the expected decline often attributed to aging alone.

Similarly, the lack of an association between age and HL in our sample could be due to the stability of health-related knowledge and behaviors acquired earlier in life. Older women who have consistently engaged with healthcare systems, managed chronic conditions, or sought out health information over time may maintain their level of HL despite aging. Thus, women who develop strong health self-management practices earlier may demonstrate resilience in maintaining their literacy levels. These findings support the life-course perspective, emphasizing the cumulative effects of early-life experiences on health behaviors in older individuals (Sørensen et al., 2012).

Indeed, the connection between age and HL is not simple because two opposite things can occur as people grow older. On the one hand, aging is often linked with changes in thinking abilities—such as slower memory and difficulty understanding information—which can lower HL (Deary et al., 2009). On this basis, we might expect a negative correlation between HL and participants' age. However, at the same time, older people often deal with more health problems and visit doctors more often. This can make them more interested in health information and more active in learning about their conditions. This increased interest in and experience with the health system can actually improve HL, resulting in a positive correlation between age and HL. These two effects—declining thinking skills and growing interest in health—may cancel each other out, which could explain why we did not find a clear link between age and HL in our results.

Educational level, health literacy and physical literacy

The lack of a significant correlation between educational level and both HL and PL in our study is somewhat unexpected. Education is commonly viewed as a strong predictor of literacy in general, and many studies have shown that higher educational attainment is linked to better health-related knowledge and behaviors (Van Der Heide et al., 2013). However, our findings suggest a more nuanced relationship, likely shaped by generational and contextual factors.

The lack of a significant correlation between educational status and PL suggests that PL is not solely determined by formal schooling. While education can provide some opportunities for physical activity, especially during early years, it is the habits and experiences built throughout life that play a stronger role. The PL includes not only movement skills but also confidence, motivation, and the value placed on physical activity—all of which can develop outside of the classroom and through formal schooling (Blažević et al., 2024; Geets-Kesić et al., 2023). For example, women who have engaged in regular walking, gardening, or recreational activities for many years may maintain a high level of physical literacy regardless of their educational background. Personal lifestyle choices, family routines, and cultural norms often shape these habits more than school-based instruction does. Therefore, physical literacy appears to reflect a broader life context rather than academic achievement alone.

Another reason for the lack of association between education level and physical literacy in our sample may lie in the shared early-life experiences of women born in the 1950s and 1960s. During his period, access to sports and physical activity was largely equal, as out-of-school sports programs were publicly funded and free for all children (Petrov, 2018). In addition, physical education in schools followed a standardized national curriculum, meaning that most women in this generation received similar exposure to structured physical activity regardless of their formal educational achievements. These early experiences are known to have a strong and lasting impact on physical literacy, often more so than later educational or professional paths do (Dlugonski, Gadd, McKay, Kleis, & Hoch, 2022). As a result, educational differences in adulthood may not reflect meaningful differences in foundational physical literacy developed among youth in this age group.

Similarly, HL is not developed through formal education alone but often grows through everyday experiences and social interactions (Geboers, Reijneveld, Jansen, & de Winter, 2016). Managing personal or family health conditions, visiting doctors, talking with pharmacists, or caring for others all contribute to a practical understanding of health-related information. Older women who have regularly engaged with the healthcare system—regardless of their education level—may build strong HL over time. In many cases, social networks also play a key role, as information is shared and discussed among family, friends, or community groups (Pitt et al., 2019). This type of experiential learning can be just as influential as formal schooling in shaping health-related decision-making skills. Therefore, it is possible that women with lower levels of formal education in our study still achieved similar HL levels through lived experience and social support. This may help explain why no clear link was found between education and HL.

Socioeconomic status, health literacy and physical literacy

The absence of a significant correlation between current socioeconomic status and PL in our sample can be (once again) better understood within the historical and cultural context of the participants. Women born in the 1950s and 1960s in Croatia and the former Yugoslavia experienced a relatively uniform lifestyle during their youth, regardless of their family's economic position. State-supported education, equal access to physical education, and free participation in sports and recreational activities ensured that most girls had similar opportunities to develop movement skills and positive attitudes toward physical activity (Petrov, 2018). Since PL is shaped primarily in early life, these shared early experiences likely had a lasting impact, independent of changes in socioeconomic status later in adulthood. As a result, women who may now differ in income or occupation still have similar physical competencies and confidence developed in their youth.

Likewise, the observed lack of correlation between socioeconomic status and HL may also be influenced by generational similarities among the women studied. In brief, women born in the 1950s and 1960s were exposed to a relatively unified system of healthcare and public health messaging, which was state-driven and widely accessible regardless of social class. These common early-life experiences likely contributed to the development of similar HL and PL levels, regardless of their current differences in education or socioeconomic status. Importantly, this generation grew up in a social context that placed strong trust in institutions and public authorities. Health-related information disseminated through schools, workplaces, and national media is widely accepted and rarely questioned, which likely reinforces consistent attitudes and behaviors toward health management from an early age (Kunitz, 2004). This early trust in public health systems may have shaped a stable foundation of HL that persisted into older adulthood. Additionally, the relatively narrow age range of the sample (60 years and older) may have further reduced age-related variation in literacy outcomes. Together, these factors suggest that long-standing societal structures and generational beliefs may play a key role in shaping HL and PL trajectories.

The fact that all participants in our study were urban-living women may also help explain the lack of significant correlation between socioeconomic status and both health and PL. Urban settings generally provide more consistent access to healthcare services, organized physical activities, and public health information, which can reduce the influence of income or education on individual literacy levels (Aljassim & Ostini, 2020). In such environments, people from different socioeconomic backgrounds often benefit from similar infrastructure, such as local clinics, recreational spaces, and community programs. This shared environment may lead to more comparable experiences in health management and physical activity across the socioeconomic spectrum. Urban residents also tend to have broader access to transportation and social networks, which can further support engagement in health-promoting behaviors. As a result, the influence of current socioeconomic differences may be less pronounced in urban contexts, contributing to the uniform literacy levels observed in our sample.

Limitations and strengths

This study has several limitations that should be acknowledged. First, the sample included only urban-dwelling females over the age of 60, which limits the generalizability of the findings to rural populations, males, or younger age groups. Second, all the data were collected through self-report questionnaires, which may introduce bias due to overestimation, misunderstanding of questions, or social desirability effects. Self-perception of health and PL may not always align with objective measures. These limitations should be considered when interpreting the results and planning future research.

Despite its limitations, this study has several notable strengths. This study is among the first to simultaneously examine the associations between sociodemographic factors and both HL and PL in older adult women. This dual focus provides a more comprehensive understanding of how different aspects of literacy interact within the context of aging. Furthermore, to our knowledge, this is the first study of its kind conducted in southeastern Europe, offering valuable regional insights that are often underrepresented in the international literature. By focusing on a specific and well-defined population, the study also adds depth to the global discussion on aging, health promotion, and equity.

Conclusion

The findings revealed weak or nonsignificant correlations between the examined sociodemographic variables and both HL and PL. These results contrast with previous research that typically emphasizes the predictive role of such factors, suggesting that additional life-course or contextual influences may better explain literacy outcomes in this population.

A key consideration is the shared generational background of the participants, all born prior to the 1970s, who were exposed to a relatively standardized system of education, public health messaging, and access to physical activity through state-supported programs. These common early-life experiences may have contributed to the development of similar HL and PL levels, regardless of later-life differences in education or socioeconomic status. Additionally, the relatively narrow age range of the sample (60 years and older) may have limited the detection of age-related variability in literacy, further contributing to the lack of significant associations. This highlights the potential long-term impact of uniform early environments on health-related competencies in older adults.

These findings emphasize the importance of a life-course perspective in understanding the development and stability of HL and PL among aging populations. Rather than being shaped primarily by current demographic factors, these literacies may be more strongly influenced by lifelong habits, accumulated experience, and consistent exposure to health systems and information. Future studies should aim to include more diverse samples, particularly rural and socioeconomically heterogeneous groups, to further explore the determinants of HL and PL later in life.

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Conflict of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Effects of a Specific Six-Week Intensive Training Program on the Biomechanical Parameters of Futsal Players

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Abstract

Futsal is a high-intensity sport characterized by significant physical, technical, and tactical demands. Performance is influenced by various biomechanical and physiological factors, including speed, strength, and movement efficiency. Injury prevention has become a key component in maximizing performance and ensuring athlete longevity. This study aimed to evaluate the effects of a six-week, sport-specific training program on the biomechanical and motor performance parameters of futsal players, with an emphasis on injury prevention and performance enhancement. A total of 40 futsal players were divided into an experimental group (n=21) and a control group (n=19). The experimental group underwent a targeted training intervention consisting of exercises to develop strength, speed, agility, coordination, balance, and specific motor skills. The control group continued their standard training routine. Motor and functional tests were conducted pre- and post-intervention. Following the six-week intervention, the experimental group demonstrated statistically significant improvements in 12 out of 13 measured parameters compared to the control group. Notable enhancements were observed in aerobic capacity, vertical jump, sprint performance, agility, step frequency, and step length. The findings underscore the effectiveness of targeted conditioning programs in futsal, particularly those integrating strength, plyometrics, agility, balance, and dynamic stretching. Such interventions contribute to improved athletic performance and play a crucial role in injury prevention. These results highlight the need for evidence-based, sport-specific conditioning protocols in futsal training.

Keywords: *biomechanics, futsal, conditioning, injury prevention, performance enhancement*

Introduction

In recent years, the physical demands of sports have significantly increased, requiring athletes to perform more explosive movements, cover greater distances at higher speeds, and execute frequent changes in direction and intensity (Bradley et al., 2009). Futsal, as a high-intensity, fast-paced sport, differs substantially from traditional football—not only in terms of pitch dimensions and rules, but also in match dynamics. One of the most distinctive features is that the match clock stops during interruptions, extending the actual playing time by approximately 75–85% beyond the scheduled 40 minutes (Barbero et al., 2008).

During a typical match, futsal players cover 3–5 kilometers with alternating intensities, maintaining a work-to-rest ratio of about 1:1. Nearly half of the work phase consists of high-intensity efforts, including over 700 directional changes, frequent sprints, and jumps (Akenhead et al., 2013). These high-demand phases often occur during critical game moments, such as transitions, ball recoveries, and scoring opportunities (Di Salvo et al., 2009). Performance in futsal

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is influenced by a variety of factors, including linear speed, running technique, muscle strength, and leg power (Saryono et al., 2018).

In this context, understanding the principles of heterochrony and training periodization is crucial for optimizing athlete development and minimizing injury risk (Kiely, 2012; Molnar et al., 2007). Previous studies have highlighted that inadequate physical preparation, muscle imbalances, anatomical anomalies, and insufficient motor control may contribute to higher injury incidence, especially in younger players (Junge et al., 2010; Stanić et al., 2013). Notably, Jeffreys (2002) demonstrated that stability-focused exercises not only reduce injury risk but also enhance overall match performance throughout the season.

Based on the principle of training specificity, futsal coaches continuously seek effective training models to improve both performance and injury prevention (Sarmento et al., 2016). Sprint training with external load has shown benefits in improving change-of-direction speed in young athletes (Carlos-Vivas et al., 2020). Additionally, research into goal-scoring sequences in elite-level futsal confirms the importance of sport-specific conditioning for enhancing both physical and technical capabilities (Sarmento et al., 2016).

Recent studies have demonstrated that structured plyometric and high-intensity interval training (HIIT) programs significantly enhance key motor abilities in futsal players. For example, a six-week plyometric training intervention in sub-elite adult male futsal athletes produced substantial improvements in 20 m sprint performance (Δ≈-12.7%, d=2.08), moderate enhancements in agility (Δ≈-6.5%, d=0.85), and small to moderate gains in countermovement jump (CMJ) height (d=0.38) (Ishak & Abdul Halim, 2024; Silva et al., 2022). Similarly, combined high-load resistance and HIIT protocols over an 11-week period yielded significant improvements in Yo-Yo Intermittent Recovery Level 2 (IR2) test results and match performance indicators (Melo et al., 2023). While related conditioning programs in soccer have also proven effective in enhancing both aerobic and anaerobic capacity (Belegišanin, 2017), there is currently a lack of empirical evidence on the effects of such interventions in professional futsal players in Serbia.

Despite the increasing global popularity of futsal, it remains underrepresented in the scientific literature. Existing research primarily focuses on match analysis and physiological demands, leaving a notable gap in studies related to performance development, biomechanics, and the effects of specific training interventions (Naser et al., 2017). Given this context, comparative and longitudinal studies evaluating the outcomes of structured conditioning programs are essential to establish evidence-based training guidelines for coaches and practitioners.

The primary aim of this study is to examine the effects of a six-week high-intensity training program on motor and functional performance in professional futsal players. The intervention is designed to improve strength, speed, agility, coordination, balance, flexibility, and futsal-specific motor skills. Additionally, the program incorporates preventive strategies to reduce injury risk—an integral aspect of sustaining high-level athletic performance. This research addresses a significant gap in the current literature and offers practical insights for conditioning practices in futsal, particularly within the Serbian professional context.

Method

Participants

The participants in this study were 40 elite futsal players with an average sports experience of 7.68±3.12 years in the sport. The experimental group consisted of 21 senior elite futsal players from the first league (age 27.04±5.03 years, height 179.82±5.32 cm, weight 81.70±11.44 kg) who followed a specific six-week intensive training program during the preparation period, while the control group consisted of 19 senior futsal players from the second league (age 26.63±4.64 years, height 180.40±6.27 cm, weight 83.10±9.80 kg) who followed a standard pre-season training routine.

All participants were informed about the study procedures and provided written informed consent prior to participation. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Novi Sad (Approval No. 49-0204/2023-1).

Procedure

All participants were informed about the complete testing procedure prior to the start of the research. The testing was conducted between January and March 2024 in the small hall of the Sports and Business Center Vojvodina (SPENS), located in Novi Sad, Serbia. All assessments took place in the evening hours on a futsal court with a parquet surface.

Before the testing sessions, athletes performed a standardized warm-up protocol lasting approximately 15 minutes. The warm-up included both general and specific components. It began with 5 minutes of low-intensity jogging aimed at raising core body temperature, followed by dynamic stretching exercises. The specific part of the warm-up consisted of progressive running, changes of direction, sudden stops, and plyometric drills to ensure optimal readiness for testing.

Testing conditions were consistent across all sessions, with an indoor temperature maintained at approximately 20–22°C and relative humidity between 40–50%. All measurements were conducted by certified strength and conditioning professionals, while the experimental training program was implemented and supervised by licensed coaches with experience in working with elite futsal players.

Tests

Vertical Jump test - Kistler force plate (Kistler, Winterthur, Switzerland) was used to assess lower limb explosive power with these tests: squat jump, counter-movement jump, single leg jump, and counter-movement jump with arm swing.

5, 10 and 20m Sprint Test - Assessment of speed ability was performed with a 20-meter maximal sprint test (high start) which is measured with a wireless photocell system (Witty-Gate, Microgate, Bolzano, Italy). Within this test, variables like movement speed and starting acceleration were monitored, i.e. the time required to run the first 5 and 10 meters as well as the time required to run the second 10 meters. The system of photocells was placed at approximately hip height for all participants to assure that the gates were passed through with only one part of the body (Yeadon et al., 1999). Participants assumed a standing starting position 50 cm from the starting line and were instructed to cross the finish line as fast as possible.

Balsom Agility Test is an agility test designed for football players, which requires from participants to run around a series of cones, making several changes of direction and two sharp

180-degree turns. The test was developed by (Balsom, 1994).

RAT test (Reactive Agility Test), in addition to the ability to quickly change of direction, also includes the motor-cognitive domain of sports with visual signals during running. The reactive agility test (RAT) was performed according to the protocol described previously by Trecroci et al. (2019). Running time was recorded using photocell gates (Microgate Witty – Gate).

30-15 IFT test (Intermittent Fitness Test) - is an endurance test with a progressive gradual increase in the intensity of intermittent running. The mentioned test was used to evaluate the aerobic capacity as well as to program training for the development of endurance, which was conceived through medium and high-intensity sprint training. The test was performed according to the (Buchheit, 2008) protocol.

Sit and Reach test - test to assess mobility and flexibility of the hamstrings and lower back muscles on a specially designed bench.

Biomechanical analysis included kinematic parameters such as acceleration, maximum speed, step frequency, and step length. Data were recorded using a stationary high-speed digital camera (Sony HDR-CX405, Sony Corporation, Tokyo, Japan) positioned laterally to the sprinting lane. The recorded footage was analyzed using motion analysis software (Kinovea, version 0.9.5, Kinovea Open Source Project, Bordeaux, France).

Protocol

Before the tests, the players had a warm-up consisting of a general and a specific part, lasting about 15 minutes. The warm-up started with running at a lower intensity for 5 minutes, followed by dynamic stretching as well as a specific part in the form of progressive running, changing the direction of movement, micro-dosing of lending exercise and plyometrics.

The tests were conducted in the following order: body composition, vertical jump, speed test, agility test, 30-15 test, and flexibility assessment test.

Experimental treatment

During the preparation period for the season, players participated in a six-week experimental training program, conducted three to five times per week as part of regular team sessions. The experimental group followed a high-intensity, sport-specific program designed to develop muscular strength, speed, agility, coordination, mobility, balance, and futsal-specific motor skills. Special emphasis was placed on injury prevention through targeted neuromuscular and stabilization exercises. The structure and rationale of this training protocol are based on previous findings highlighting the effectiveness of integrated conditioning in team sports (Hammami et al., 2018; Silva et al., 2022; Slimani et al., 2016). The detailed training schedule and specific exercise descriptions are presented in the tables below.

Table 1. Detailed description and schedule of the specific six-week intensive program

‹	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK
M O N	Initial testing: tests of speed, explosive strength, agility, IFT test.	Sprint (acceleration), 6x20 m Extensive plyometrics, 6x20 m Circuit strength training 3x6 exercises (W:R=40”:20”)	Anaerobic circuit polygon with a ball 4x80 m (8 obstacles) Core exercises, SMG exercises (Prevention) 3x6 exercises (8-12 reps) PM - Te/ Ta - FUTSAL	DAY OFF	RSA 3x8 sprint , (W:R = 5”:10”) Te/ Ta - FUTSAL Strength exercises SMG (W:R=30”:15”)	Flying sprints (4x30 m), R=1’ Plyometrics micro dose 2x(4x7 m) Te/ Ta - FUTSAL
T U E	LSD running 2x4000 m (65%-70% MAS) Mobility flow 2x4 exercise (W=30”)	Core stability exercises with resistance band (paired) 3x6 exercises (W:R=30”:15”) Te/ Ta - FUTSAL	Active recovery Walk, bike, pool, foot tennis (1h) PM- Te/ Ta - FUTSAL	Strength training (whole body) 3x6 exercises (2-4 reps) Te/ Ta - FUTSAL	Proprioception activation Strength power based training (whole body) 2x6 exercise (3-6 reps (60-80% 1RM) Te/ Ta - FUTSAL	Strength training (power based) 2x6 exercises (2-4 reps,) Te/ Ta - FUTSAL
W E D	CNS activations Sprint micro doses 4x15 m Strength training (whole body) 2x6 excersice (12-15 rep) Te/ Ta - FUTSAL	LSD running 3x3000 m (70% MAS) Mobility exercises (foot, ankle, pelvic, spine, shoulder) 2x6 exercises (W=30-45”)	Isolated sprint (prolonged accelerations) 4x(4x60 m) W:R=1:3 Circuit strength training (lower body) 3x6 exercises, W:R=30”:15” PM - Te/ Ta - FUTSAL	"Lending skills" 4x8 repetitions Tempo running with COD 5x3 min (W:R = 2’:1’) Te/ Ta - FUTSAL Mobility exercises 2x4 exercises (W:R=45”:15”)	FUTSAL PRESEASON GAME Strength training (lower body) 2x6 exercise	CNS activation, Explosive jumps 4x4 reps Sprint micro doses 4x10 m Te/ Ta - FUTSAL Mobility exercises 2x3 exercises (W:R=30”:15”)

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Table 1. Detailed description and schedule of the specific six-week intensive program

‹	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK
THU	Isometric activation Extensive running 4x10 min (70%-75% MAS)	Plyometrics 3x(6x4 rep) R=1' Isometric 2x4 exercises (W:R=1':30") Te/ Ta - FUTSAL	Tempo running with progression and CoD, 4x8 min (W:R=15":45", 130% MAS) Foam roller (self-massage), Mobility exercises 2x5 exercises, W:R=30":15" PM - Te/ Ta - FUTSAL	Curvilinear sprints 8x20 m (R:1') Intensive plyometrics 6x4 reps (R:1') Te/ Ta - FUTSAL SMG (prevention) Cal Dietz 3x4 exercises (8 repetitions)	Boyle warm up „Lending skills"4x6 exercises Anaerobic circuit ball polygon 3x4 min (4 obstacles) Te/ Ta - FUTSAL	Isometric activation, Prevention core + SMG strength. 2x4 exercises (8 reps)
FRI	Hill sprint 2x (4x20 m) W:R=1:4 Hill plyometrics 2x (4x10 repetitions) Prevention, SMG 3x4 exercises (8-12 reps)	Altitude preparation Active recovery (after the trip) Foot tennis+ Mobility 3x6 exercises (W:R=45":15")	Isometric activation, Core + proprioception exercises 2x6 exercises (8 reps) PM - Te/ Ta - FUTSAL	CNS activation 4x5 m Landings exercise + COD 2x(4x10 m) Te/ Ta - FUTSAL	RSA 4x6 sprint, (W:R = 5":10") FUTSAL Mobility prevention 2x4 exercises (W:R=30":15")	CNS activation, "Lending skills" 4x6 repetitions 2x(4x10 m) SAQ, COD
SAT	Dynamic proprioception excersice 3x4 excersice (W:R = 30":30") Te/ Ta - FUTSAL	Aerobic tempo running 4x8 min (120% MAS) Strength exercises, Cal Dietz (prevention) 3x6 exercises (10/12 reps) PM - Te/ Ta - FUTSAL	Intensive plyometrics (microdoses) 4x5 repetitions Sprint with resistance 4x20 m Strength training 3x6 exercises (3-5 rep) PM - Te/ Ta - FUTSAL	PREPARARATION MATCH Strength training 3x6 exercises (6-10 reps 60%-80% of 1RM)	PRESEASON GAME Strength training 2x4 exercises (6-10 reps 60%-80% of 1RM)	FIRST ROUND GAME Tempo running after the game (who didn't play) 4x6 min (W:R=15":30", 130% of MAS)
SUN	DAY OFF	Extensive plyometrics 2x(4x20 m) W:R=1:3 Sprint with load (band in pairs) 2x(4x20 m) W:R=1:3 Circuit strength training 2x6 exercises (W:R=30":15")	Bilat running 30"-30" 3x7 min (100% of MAS) Mobility exercises 2x3 exercises (W:R=45":15") DEPARTURE FOR THE Novi Sad	DAY OFF	Intensive plyometrics 2x4 exercises (4 repetitions) SAQ + COD, 2x (4x10 m) Extensive intervals (85-90% of MAS) 10x2 min, W:R=2':1'	DAY OFF

Legend. W:R – Work: Rest; R – Rest; PM – Post meridiem; MAS – Maximal aerobic speed; Cal Dietz – strength exercises for pelvic muscles; LSD – long slow distance running; SMG – strengthening of small muscle groups; SAQ – Speed, Agility, Quickness training; Te/Ta – Technical/Tactical training.

Statistical Analyses

All statistical analyzes were performed using SPSS V. 20 (IBM Corporation; Armonk, NY, USA). Descriptive statistics were calculated for all the previously mentioned data. Paired sample T-test and Analysis of covariance were used for data analysis. Paired sample T-test showed differences between the initial and final testing in both groups and determined whether there was a statistically significant effect of the experimental treatment. After determining the conditions that there are no differences in the initial measurement between the groups and that there is no regression homogeneity, Analysis of Covariance (ANCOVA) was used where the initial measurement was taken as a covariate, the group variable was a fixed factor and the final measurement was taken as a dependent variable. The level of statistical significance was set at $p<0.05$.

Results

Table 2 shows the pre- and post-intervention comparisons within the experimental group, indicating statistically significant improvements across all measured variables, with the exception of the Reactive Agility Test (RAT), where the observed change did not reach statistical significance ($p=0.716$).

Table 2. Differences between the initial and final measurements of the experimental group

	Experimental group (N=21)		t	p
	AM	SD		
5m sprint (s) 1	1.171	.195	2.310	.032
5m sprint (s) 2	1.128	.178		
10m sprint (s) 1	1.903	.187	6.400	.000
10m sprint (s) 2	1.795	.133		
20m sprint (s) 1	3.180	.256	2.435	.024
20m sprint (s) 2	3.068	.141		
SJ (cm) 1	45.416	5.438	-5.341	.000
SJ (cm) 2	48.504	5.235		
CMJ (cm) 1	49.585	5.032	-5.805	.000
CMJ (cm) 2	51.125	4.825		
VJ (cm) 1	55.213	6.316	-10.386	.000
VJ (cm) 2	58.430	5.948		
Balsom test (s) 1	11.873	.654	6.572	.000
Balsom test (s) 2	11.501	.583		
RAT (s) 1	2.429	.126	5.031	.716
RAT (s) 2	2.315	.092		
IFT 1	17.452	1.731	-11.649	.000
IFT 2	19.024	1.528		
Sit&Reach (cm) 1	30.642	4.604	-5.187	.000
Sit&Reach (cm) 2	32.690	5.211		
Step frequency (f) 1	5.515	0.958	-1.459	.038
Step frequency (f) 2	5.374	0.097		
Stride length (cm) 1	181.48	23.852	2.175	0.28
Stride length (cm) 2	186.02	21.567		

N – number of respondents; AM – arithmetic mean; SD – standard deviation; t - value; p – statistical significance; SJ – squat jump; CMJ - countermovement jump; VJ – vertical jump; RAT – reactive agility test; IFT – intermittent fitness test.

Table 3 presents the differences in the control group. No statistically significant differences were found between pre- and post-testing in most variables, except in the squat jump (SJ, p=0.001) and the reactive agility test (RAT, p=0.031), where modest improvements were observed. These findings suggest that the six-week specific high-intensity training program in the experimental group led to significant improvements in most performance variables, unlike the control group, which showed limited progress.

Table 4 presents the results of the differences in variables at

Table 3. Differences between initial and final measurements of the control group

	Control group (N=19)		t	p
	AM	SD		
5m sprint (s) 1	1.224	.107	1.837	.083
5m sprint (s) 2	1.206	.092		
10m sprint (s) 1	1.941	.152	.516	.612
10m sprint (s) 2	1.936	.148		
20m sprint (s) 1	3.262	.212	.152	.881
20m sprint (s) 2	3.260	.183		
SJ (cm) 1	47.486	4.953	-4.112	.001
SJ (cm) 2	46.940	4.760		
CMJ (cm) 1	49.933	6.046	.609	.551
CMJ (cm) 2	48.211	13.684		

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Table 3. Differences between initial and final measurements of the control group

	Control group (N=19)		t	p
	AM	SD		
VJ (cm) 1	55.733	5.645	1.216	.242
VJ (cm) 2	50.300	19.742		
Balsom test (s) 1	12.302	.493	-.801	.434
Balsom test (s) 2	12.329	.510		
RAT (s) 1	2.576	.253	2.333	.031
RAT (s) 2	2.354	.255		
IFT 1	16.55	.414	-2.005	.060
IFT 2	18.36	.813		
Sit&Reach (cm) 1	32.578	7.832	1.372	.187
Sit&Reach (cm) 2	32.894	7.210		
Step frequency (f) 1	5.841	0.997	.872	.622
Step frequency (f) 2	5.720	0.112		
Stride length (cm) 1	171.41	19.184	1.457	.247
Stride length (cm) 2	174.81	17.462		

Legend. N – number of respondents; AM – arithmetic mean; SD – standard deviation; t - value; p – statistical significance; SJ – squat jump; CMJ –counter – movement jump; VJ – vertical jump; RAT – reactive agility test; IFT – intermittent fitness test.

the final test with the control of the initial test. Univariate analysis of covariance (ANCOVA) was used to test the existence of differences and determine the effects of the experimental program. Statistically significant differences were observed in all variables in favor of the subjects of the experimental group at the level of statistical significance p<0.05, only in the variable for reactive agility (RAT test) no statistically significant differences were observed.

Table 4. Significance of differences in variables at the final test with control of the results from the initial test (covariate)

	Experimental group N=21		Control group N=19		ANCOVA	p	Partial Eta Squared
	AM	SD	AM	SD	F		
5m sprint (s)	1.128	0.178	1.206	0.092	3.144	0.084	0.078
10m sprint (s)	1.795	0.133	1.936	0.148	51.979	0.000	0.583
20m sprint (s)	3.068	0.141	3.260	0.183	17.314	0.001	0.318
Sit & Reach (cm)	32.690	5.211	31.894	7.210	16.977	0.024	0.314
SJ (cm)	48.504	5.235	46.940	4.760	0.947	0.037	0.026
CMJ (cm)	51.125	4.825	48.211	13.684	1.614	0.022	0.044
VJ (cm)	58.430	5.948	50.300	19.742	4.526	0.040	0.114
RAT (s)	2.315	0.092	2.354	0.255	18.111	0.116	0.328
Balsom test (s)	11.501	0.583	12.329	0.510	42.837	0.000	0.536
IFT 30-15 (vift)	20.024	1.528	18.368	0.813	1.871	0.049	0.048
Step frequency (f)	5.374	0.097	5.720	0.112	28.712	0.003	0.274
Stride length (cm)	186.02	21.567	174.81	17.462	50.298	0.001	0.322

Legend. N – number of respondents; AM – arithmetic mean; SD – standard deviation; p – statistical significance; F - test value; ANCOVA - analysis of covariance; SJ – squat jump; CMJ –counter – movement jump; VJ – vertical jump; RAT – reactive agility test; IFT – intermittent fitness test.

Discussion

The findings of this study indicate that the implemented six-week high-intensity training program significantly improved motor and functional abilities in professional futsal players. Improvements were observed in 12 out of 13 measured variables (Table 2), suggesting the efficacy of this multimodal training approach in enhancing physical preparedness and supporting injury prevention.

These results are consistent with previous studies emphasizing the unique physiological demands of futsal, characterized by repeated high-intensity efforts, accelerations, decelerations, and multidirectional changes (Castagna et al., 2009). Statistically significant gains were observed in aerobic capacity (VIFT 30-15, p<0.049), vertical jump (p<0.040), sprint speed (10 m: p<0.000; 20 m: p<0.001), agility (p<0.000), flexibility (p<0.024), step frequency (p<0.003), and step length (p<0.001).

These results align with findings from Loturco et al. (2015), who reported strong associations between vertical jump performance and sprint speed in elite athletes, highlighting the importance of neuromuscular power. Similarly, Torres-Torrelo et al. (2018) demonstrated that both resistance training alone and combined training programs positively influenced repeated sprint ability in futsal players. Although the current study employed a more comprehensive training model—including strength, agility, coordination, balance, and flexibility components—the similarities in performance gains suggest that multifactorial training programs may offer broader benefits across multiple physical domains in futsal athletes.

Mechanistically, the observed improvements likely stem from neuromuscular adaptations facilitated by plyometric and high-intensity interval training, including increased motor unit recruitment, enhanced intermuscular coordination, and greater eccentric strength (Markovic & Mikulic, 2010). In addition, improvements in aerobic capacity may result from peripheral and central cardiovascular adaptations induced by high-intensity efforts performed near 90–95% of individual VIFT, as noted by Buchheit et al. (2008). Such adaptations are further influenced by the interplay between training intensity, duration, and recovery strategies, as demonstrated in studies on football players (Dupont et al., 2004; Iaia et al., 2009; Impellizzeri et al., 2005).

Nonetheless, comparisons with earlier studies should be interpreted cautiously due to differences in methodology, training volume, and sample characteristics (Viana-Santasmarinas et al., 2018). Unlike previous designs that matched training volume between groups, this study included variability in workload, which may have affected adaptation responses.

A notable limitation of this study is the use of a generalized training program that incorporated multiple training elements simultaneously, without isolating specific training modalities (e.g., resistance vs. plyometric vs. HIIT). As a result, it is not possible to determine which component contributed most significantly to specific performance improvements. Future research should investigate the isolated effects of individual training types to identify the most efficient methods for targeting particular motor abilities in futsal players. Moreover, long-term monitoring of training load and injury rates would be valuable for evaluating the sustainability and safety of such interventions.

In conclusion, the integrated high-intensity training program implemented in this study led to significant improvements in multiple domains of physical performance in professional futsal players. These findings reinforce the value of multifaceted conditioning approaches and provide practical guidance for coaches aiming to enhance sport-specific fitness in futsal.

Conclusion

This study demonstrated that futsal players who participated in a six-week high-intensity training program focused on developing muscle strength, speed, agility, coordination, balance, and sport-specific motor skills, with a strong emphasis on injury prevention achieved significantly better results in the final testing compared to the control group. These players showed greater improvements in key physical performance indicators and, notably, reported no injuries or discomfort during the preparatory period that would have limited their participation. These results underscore the importance of evidence-based, sport-specific conditioning protocols in optimizing athletic performance and minimizing injury risk. In conclusion, the integrated high-intensity training program implemented in this study proved to be effective in enhancing multiple domains of physical performance in professional futsal players. These findings highlight the practical value of multifaceted conditioning approaches and may assist coaches and practitioners in designing more efficient and targeted training strategies tailored to the specific demands of futsal.

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Conflict of interest
The authors declare no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Test-Retest Reliability of the EUFITMOS Battery for Assessing Health-Related Physical Fitness in Low-Income Young People

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Abstract

Assessing the reliability of physical fitness measures in middle- and low-income contexts is considered a research priority. This study aimed to analyse the test-retest reliability of field-based physical fitness tests in low-income young people from Amazonas, Brazil. Participants were 152 adolescents (75 boys) aged 11 to 16, living in Jutaí, Amazonas. Physical fitness, including cardiorespiratory fitness, upper- and lower-body strength, flexibility, and speed, was assessed using the EUFITMOS battery across two trials conducted one week apart. Test-retest reliability was assessed using the intra-class correlation coefficient (ICC). The agreement was estimated using the Bland-Altman approach with a 95% confidence interval (CI). Every physical fitness test showed good to excellent reproducibility with ICC ranging from 0.81 to 1.00 between trials 1 and 2. Agreement analysis presented limited evidence of systematic bias with mean difference lines close to 0 and without any specific positive or negative trend. In each physical fitness test, most observations were within the 95%CI limits, except for the standing broad jump in boys. The EUFITMOS battery is appropriate for use in low-income contexts such as the Amazonas, providing field-based physical fitness measures that can be used to collect important data and inform decision-making on young people's health from low-income contexts.

Keywords: *fitness testing, public health, reproducibility, surveillance*

Introduction

Physical fitness translates the combined result of genetic and biological characteristics with the influence of the social environment in which young people live (Burgos-Postigo et al., 2021; Caspersen et al., 1985). Body composition, cardiorespiratory fitness, and muscular fitness are the main components of physical fitness, where attributes such as height, body weight, waist circumference, lean mass, fat mass, VO2 peak, flexibility, agility, upper, middle and lower body strength are often assessed (Campbell et al., 2013). It is widely recognized that physical fitness is a biomarker of health, used not only in epidemiological studies but also in different types of scientific studies (e.g. clinical, experimental) (García-Hermoso et al., 2022; Murphy et al., 2016; Ortega et al., 2023). Thus, assessing physical fitness in youth is important for monitoring health and well-being, and can contribute to a better understanding of young people's health status and to developing tailored physical activity-promoting strategies.

Physical fitness tests are properly structured protocols designed to stimulate certain biological systems. The response of biological systems to these specific stimuli varies according to individual characteristics and adolescents' exposure to physical activity, exercise, or sports participation (Henriques-Neto et al., 2021; Ibáñez et al., 2023). Therefore, different batteries of physical fitness tests have been developed worldwide, mainly to monitor young people's health (Marques, Henriques-Neto, et al., 2021). The EUFITMOS battery is a field-based physi-

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cal fitness battery developed using scientifically validated test protocols for young people between 10 and 18 years old with minimal instrument requirements. It was designed to assess and monitor the health of young people in Europe at the lowest possible cost and with a high level of validity and reproducibility (Marques, Peralta et al., 2021).

A recent twin-panel Delphi study defined the top 10 international priorities for physical fitness research and surveillance (Lang et al., 2022). Priority 7 assesses the reliability and validity of fitness measures, with a special focus on middle- and low-income countries, as research in these contexts is scarce. Young people from Amazonas in Brazil are considered a low-income population with difficulties in accessing health monitoring services. Given the needs of young people from Amazonas and the research gap among low-income countries, it can be beneficial to assess the adequacy of the EUFITMOS battery in this population, allowing for the use of physical fitness as a health indicator and providing reliable fitness data. Therefore, this study aimed to analyse the test-retest reliability of the different physical fitness test protocols composing the EUFITMOS battery in low-income young people from Amazonas.

Methods

Participants, study design and procedures

This test-retest study comprises 152 adolescents aged between 11 and 16 (75 boys and 77 girls) living in the municipality of Jutaí (Amazonas). Participants were recruited between September and October 2023 in public schools. All participants were informed about the project's aim and written consent was obtained from their legal guardians before participating in the research. The authors did not have access to information that could identify participants during or after data collection. This study was approved by the Ethics and Research Committee of the Amazonas State University - Manaus following the Declaration of Helsinki (WMA, 2013) and Resolution 466/12 of the National Health Council and is part of the research project:"EFEJU - Educação Física nas Escolas de Jutaí, Amazonas" (CAAE 56791822.8.0000.5016 / opinion 5.621.338).

Physical fitness assessment was carried out in schools by trained staff. Each participant performed eight physical fitness tests from the EUFITMOS battery in four different sessions with a 48-hour interval in between (trial 1). Researchers repeated assessments following week with a 7-day interval (trial 2). Each session lasted approximately 60 minutes. Before performing the physical fitness tests, the participants underwent a standardised 10-minute warm-up. To minimise the effects of circadian rhythm variability, all the tests were carried out in the same order and at the same time of day.

Measures

Physical fitness was assessed using the EUFITMOS fitness battery (Marques et al., 2023). The manual and videos of the physical fitness tests, including procedures and protocols, are available on the EUFITMOS website (https://eufitmos.eu/fitness-testing-protocol/). Eight fitness tests were performed including body mass index (BMI), grip strength, push-up test, standing broad jump (SBJ), back-saver sit and reach, 20m run, Progressive Aerobic Cardiovascular Endurance Run (PACER), and 1-mile run.

Body mass index. Weight (kg) and height (cm) were determined using a mechanical scale with an attached stadiometer (Welmy, São Paulo City, Brazil) to the nearest decimal place. Participants were wearing shorts and a T-shirt but without shoes. BMI was calculated as weight (kg)/height2(m). Anthropometric assessments were only carried out in trial 1.

Grip strength. Grip strength (kg) was assessed using a JAMAR® hydraulic dynamometer. Participants were instructed to stand upright, feet shoulder-width apart, hold the dynamometer with the elbow in full extension and the arm slightly abducted, and then squeeze as hard as possible for at least two seconds. This procedure was carried out twice on each hand with 1-minute rest between attempts. The best result was recorded.

Push-up test. Upper-body strength (muscular endurance) was assessed with the push-up test. The number of push-ups performed (until the arm and forearm formed a 90º angle) was recorded at a cadence of 20 push-ups per minute.

Standing broad jump. Lower-body strength (power) was assessed with the SBJ. Participants stood with their feet parallel, shoulder-width apart and immediately behind a line. Then, they were instructed to slightly bend their knees, swing their arms and jump forward as far as possible, landing in a standing position with both feet simultaneously. The distance (cm) covered in the jump, considering the heel of the rear foot, was measured using a measuring tape. The best result from two attempts was recorded.

Back-saver sit and reach. It is used to assess the flexibility of the lower back and posterior thigh. Participants flexed their torso with both arms outstretched, one hand on top of the other with the palms facing downwards, one leg stretched out with the sole touching the measuring box and the other bent with the foot on the floor. The best score (in cm) of the two attempts was recorded.

20m run. The 20-meter run was used to assess speed. Time (s) was recorded using a stopwatch. Two attempts, with a minimum rest period of 3 minutes, were performed, and the best time was recorded.

Progressive Aerobic Cardiovascular Endurance Run. PACER examines cardiorespiratory fitness. Participants run back and forth between two parallel lines 20m apart at a pre-defined increasing cadence (starting at 8.5 km/h and increasing by 0.5 km/h each minute). The number of laps performed before exhaustion or two fouls (e.g. not reaching the line on time) is recorded. An audible signal was used to help participants control their running speed during the test.

1-mile run. The 1-mile run is also used to assess cardiorespiratory fitness. Participants must complete a 1-mile course on a flat surface (e.g. running track) at a steady running pace (walking at a fast pace is allowed) and time is recorded.

Sociodemographic

Sex and age were self-reported. Decimal age was calculated as the difference between the date of birth and the date of data collection in months. Socioeconomic status was assessed with a questionnaire from the Brazilian Association of Research Companies (ABEP, 2021). This questionnaire allows us to identify five social classes, ranging from class A (highest purchasing power) to class E (lowest purchasing power), based on the possession of certain consumer goods, the education level of the head of the family and access to public services.

Statistical Analyses

Descriptive statistics (including mean, standard deviation and frequencies) were calculated for anthropometric and sociodemographic variables. Differences between sexes were examined using the independent sample t-test and chi-square. For each physical fitness test, differences between trials (one week apart) were assessed using paired sample t-tests. Test-retest reliability was assessed using the intra-class correlation coefficient (ICC) by one-way random effects, absolute agreement, multiple measurements and categorised as ICC<0.50 - poor; 0.50≤ICC<0.75 - moderate; 0.75≤ICC<0.90- good; and ICC ≥0.90– excellent (Koo & Li, 2016). The 95% confidence interval (CI) for the ICC was calculated. The agreement was estimated using the Bland-Altman approach on the between-trial difference for each test (T2-T1). Data analysis was performed using IBM SPSS Statistics version 28.0 (SPSS Inc., an IBM Company, Chicago, Illinois, USA). Statistical significance was set at p≤0.05.

Results

Anthropometric and socioeconomic characteristics are presented in Table 1. Notably, most participants (90.1%) had a low socioeconomic status.

Test-retest reliability analysis showed that every physical fitness test had a good or excellent ICC (ranging from 0.81 to

Table 1. Anthropometric and sociodemographic characteristics

	Mean±SD or n (%)			p-value
	Total (n=152)	Boys (n=75)	Girls (n=77)	
Age, years	13.29±1.00	13.32±1.07	13.25±0.94	0.344
Weight, kg	47.96±10.78	49.49±11.50	46.48±9.88	0.043
Height, m	1.53±0.08	1.55±0.09	1.50±0.06	<0.001
BMI, kg/m2	20.34±3.56	20.31±3.51	20.37±3.63	0.460
Socioeconomic status				0.290
Low	137 (90.1)	65 (86.7)	72 (93.5)	
Average	14 (9.2)	9 (12)	5 (6.5)	
High	1 (0.7)	1 (1.3)	0	

Legend: BMI - Body mass index; SD - Standard deviation.

Table 2. Test-retest reliability of each physical fitness test for the total sample and by sex.

	Mean±SD		p-value	T2-T1 (%T1)	ICC	ICC 95%CI
	T1	T2				
Total (n=152)						
Grip strength (kg)	25.9±7.5	26.5±7.5	<0.001	0.64 (2.5)	0.99	0.96, 0.99
Push-up test (reps)	3.8±5.1	4.3±5.3	<0.001	0.43 (11.3)	0.98	0.96, 0.99
Back-saver sit and reach (cm)	26.7±6.6	27.5±6.3	<0.001	0.82 (3.1)	0.86	0.80, 0.90
SBJ (cm)	133.8±26.8	134.6±26.6	<0.001	0.84 (0.6)	0.99	0.99, 1.00
The 20m run (s)	4.6±2.5	4.6±2.5	<0.001	-0.05 (1.1)	0.99	0.99, 0.99
PACER (VO2Peak – ml/Kg/min)	37.8±4.5	37.8±4.5	0.082	0.01 (0.0)	1.00	1.00, 1.00
1-mile run (minutes)	12.0±2.5	12.0±2.5	<0.001	-0.05 (0.4)	0.99	0.99, 0.99
Boys (n=75)						
Grip strength (kg)	28.3±8.9	28.8±8.9	<0.001	0.02 (0.1)	0.99	0.98, 0.99
Push-up test (reps)	6.3±6.0	7.0±6.2	<0.001	0.68 (10.8)	0.98	0.94, 0.99
Back-saver sit and reach (cm)	25.1±6.7	26.5±6.6	0.001	1.39 (5.5)	0.81	0.70, 0.88
SBJ (cm)	144.6±26.8	145.1±26.7	<0.001	0.44 (0.3)	0.99	0.99, 1.00
The 20m run (s)	4.6±3.5	4.5±3.5	<0.001	-0.05 (1.1)	1.00	0.99, 1.00
PACER (VO2Peak – ml/Kg/min)	39.4±5.1	39.5±5.1	0.057	0.02 (0.1)	1.00	1.00, 1.00
1-mile run (minutes)	11.3±2.9	11.2±2.9	<0.001	-0.09 (0.8)	0.99	0.99, 0.99
Girls (n=77)						
Grip strength (kg)	23.5±4.7	24.2±4.8	<0.001	0.67 (2.9)	0.97	0.83, 0.99
Push-up test (reps)	1.4±2.1	1.6±2.3	0.017	0.18 (12.9)	0.94	0.91, 0.96
Back-saver sit and reach (cm)	28.2±6.0	28.5±6.0	0.192	0.27 (1.0)	0.90	0.84, 0.93
SBJ (cm)	123.2±22.2	124.5±22.3	<0.001	1.22 (1.0)	0.99	0.94, 0.99
The 20m run (s)	4.6±0.6	4.6±0.6	<0.001	-0.05 (1.1)	0.98	0.96, 0.99
PACER (VO2Peak – ml/Kg/min)	36.2±3.0	36.2±2.9	0.396	0.01 (0.0)	0.99	0.99, 1.00
1-mile run (minutes)	12.6±1.8	12.6±1.8	<0.001	-0.03 (0.2)	1.00	0.99, 1.00

Legend: CI, confidence interval; ICC, intraclass correlation coefficient; PACER, Progressive Aerobic Cardiovascular Endurance Run; SBJ, standing broad jump; SD, standard deviation; T1, trial 1; T2, trial 2. P-value is for paired sample t-test.

1.00) between trials 1 and 2 for the whole sample, boys and girls (Table 2). Mean differences between trials (T2-T1) were minimal. However, a slight but statistically significant improvement in the physical fitness tests' results was observed for all tests, except the PACER and the back-saver sit and reach (only for girls). The total sample relative improvements (compared to trial 1) ranged from a 0.4% decrease in the 1-mile run time to an 11.3% increase in repetitions for the push-ups test. Apart from the push-ups test, all tests presented a single-digit relative improvement from trial 1 to trial 2.

Bland-Altman plots for the difference between trials 1 and 2 for each physical fitness test are presented in Figures 1 (boys) and 2 (girls). All tests presented a mean difference line close to 0 without any specific positive or negative trend, suggesting low systematic bias. Furthermore, most differences were within the 95%CI limits of agreement for all tests except for the SBJ for boys.

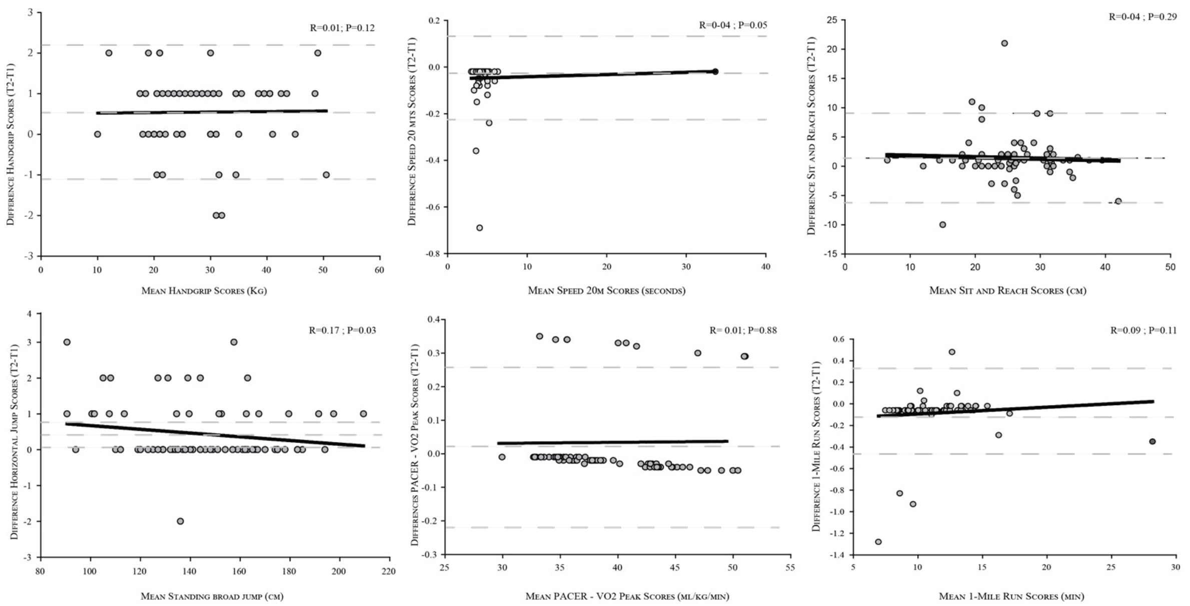

FIGURE 1. Bland-Altman of the difference between trials 1 and 2 for each physical fitness test with 95% confidence interval lines among boys.

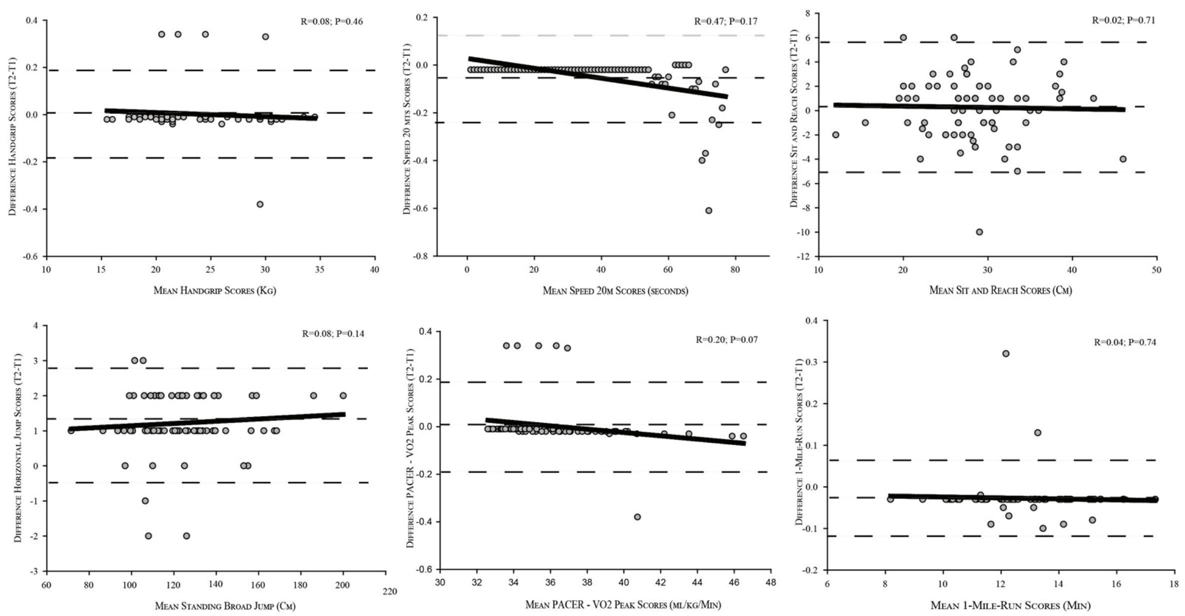

FIGURE 1. Bland-Altman of the difference between trials 1 and 2 for each physical fitness test with 95% confidence interval lines among girls.

Discussion

This investigation examined the test-retest reliability of the physical fitness tests composing the EUFITMOS battery in low-income young people from Amazonas. Every physical fitness test, including grip strength, push-up test, SBJ, back-saver sit and reach, 20m run, PACER and 1-mile run, presented good to excellent reproducibility between two trials one week apart. Moreover, agreement analysis showed no risk of serious systematic bias. These findings suggest that the EUFITMOS battery is appropriate for use in low-income contexts such as the Amazonas when assessing physical fitness.

Physical fitness is intimately associated with present and future health in youth. For example, cardiorespiratory fitness is an indicator and predictor of cardiovascular, metabolic and mental health (Altermann & Gröpel, 2024; Roldão da Silva et al., 2020; Sánchez-Delgado et al., 2022; Wheatley et al., 2020). Muscular fitness attributes such as speed and upper- and lower-body strength are associated with better bone mineral density (Henriques-Neto et al., 2020). Therefore, field-based physical fitness assessment is a non-invasive, easy-to-apply and inexpensive methodology that allows to monitoring of young people's health and plans tailored health promotion strategies focused on physical activity. While physical fitness laboratory protocols are more precise, they are more expensive and require specific technical support (e.g. instrumental and personal) (Tabacchi et al., 2019). When considering low-income contexts, having an inexpensive but reliable tool is key (Brazo-Sayavera et al., 2024). In this sense, the EUFITMOS battery provides field-based physical fitness measures that can be used to collect important data and inform decision-making on young people's health from low-income contexts.

Assessing the reliability and validity of physical fitness tests, especially among school-aged young people from low- and middle-income countries, is considered a research and surveillance priority (Lang et al., 2022). To the best of our knowledge, this is the first study examining the test-retest reliability of physical fitness tests in young people from Amazonas. On the one hand, the EUFITMOS battery comprises field-based physical fitness tests that showed good to excellent test-retest reliability (with ICC ranging from 0.81 to 1.00) and no evidence of systematic bias. On the other hand, physical fitness measurements slightly improved from trial 1 to trial 2. Notwithstanding, these improvements were small and can be attributed to a learning effect since this was the first time performing the tests. Previous research in middle- and low-income countries has found similar results. For example, in the FUPRECOL study from Colombia, several filed-based physical fitness tests, including some that are also used in the EUFITMOS battery such as grip strength, SBJ, sit-and-reach and PACER, were reliable for measuring health-related components of fitness (Ruiz et al., 2015). These findings support the use of field-based physical fitness assessments, such as those comprising the EUFITMOS battery, as reliable measures to monitor health in young people from low- and middle-income contexts.

Strengths and limitations

The conceptualization and results of this research were developed based on the three main objectives of the European Union Global Health Strategy (Plasència et al., 2024), namely, strengthening health systems to prevent disease and promote well-being, with special attention to populations with low economic resources and a geographical location known as tropical.

There is extensive evidence on the reliability of different physical fitness tests in young people. However, very few studies have been conducted in middle- and low-income settings (Lang et al., 2022). Thus, to the best of our knowledge, the major strength of this study is the first to examine the test-retest reliability of a field-based physical fitness battery in Amazonas, a low-income context and with a mostly low-income population (90.1%). Despite recent strides in this direction, future research should still be focused on providing data on the validity and reliability of field-based physical fitness measurements in different middle- and low-income countries. Other strengths include using already validated physical fitness tests incorporated in a standardised fitness battery (EUFITMOS battery) implemented in different European countries. Some limitations must also be acknowledged, such as the relatively small and non-representative sample and the lack of confounding variables that could influence physical fitness levels (e.g. regular physical activity, diet, maturation), and the tests were not familiarized before the first assessment.

Conclusion

The EUFITMOS battery comprises scientifically validated field-based physical fitness tests that are simple to apply and low-cost. For the first time, these tests were reliable for assessing physical fitness among young people from a low-income context in Amazonas. In addition, the EUFITMOS online platform allows education, sport and health professionals to learn all the protocols through educational resources (e.g. video tutorials, images, descriptions of the protocols and scientific articles). These resources have been developed to reduce errors between assessors. Thus, the EUFITMOS battery can be useful for monitoring health-related fitness and inform decision-making on creating health promotion strategies focused on physical activity tailored to low-income young people.

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Conflict of interest
The authors declare that there is no conflict of interest.

Declaration of funding
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ORIGINAL SCIENTIFIC PAPER

Effects of a Short-Term Aquatic Training Program on In-Water Vertical Jump Performance and Neuromuscular Output in Water Polo Players

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Abstract

The dynamic nature of water polo imposes high physiological demands, requiring players to produce rapid, high-force lower limbs actions, while maintaining body control in a fluid medium. Vertical body elevation is essential for actions such as blocking and shooting, depends heavily on lower limb strength and coordination. Despite this, limited research exist on the effectiveness of aquatic-based strength intervention in enhancing such capabilities. This study aimed to evaluate the effects of a 21-day aquatic training program on vertical jump performance and neuromuscular output in competitive water polo players. Fourteen male athletes underwent targeted training focusing on explosive leg strength and maximal elevation of the body from the water. Employing a quasi-experimental, one-group pretest–posttest design, the study assessed performance using two portable systems: an adapted EasyForce dynamometer to measure, in water, peak force (PF), average force (AF), and time to peak force (TTPF); and a Kinect-based motion capture system to assess vertical displacement in water (H). The best of three vertical jump attempts was used for analysis. Due to non-normal data distribution, non-parametric statistical tests were applied. Within-group changes, assessed using the Wilcoxon signed-rank test, revealed significant improvements in H (p=0.027, r=0.59), TTPF (p=0.004, r=0.77), PF (p=0.001, r=0.88), and AF (p=0.001, r=0.88). These findings suggest that short-term aquatic training can improve neuromuscular coordination and explosive power in water polo athletes. Our study highlights the value of portable motion and force technologies in monitoring aquatic-specific performance changes. Future applications may consider extending such protocols for broader performance enhancement and integration into elite training routines.

Keywords: *water polo, vertical jump, training intervention, explosive power, EasyForce dynamometer, Kinect motion capture, aquatic performance assessment*

Introduction

Water polo is a high-intensity intermittent sport characterized by frequent explosive actions such as vertical jumps, rapid changes in direction, and overhead throwing, all performed in an aquatic environment (Kovačević et al., 2024; Spittler & Keeling, 2016; Uljević et al., 2013a). Performance in water polo relies on a complex interaction of multi-directional movements, including fast swimming with abrupt speed changes, transitions between horizontal and vertical positions, and high-intensity efforts like shooting, blocking, and grappling for position (Croteau et al., 2024; Melchiorri et al., 2010).

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One of the most critical abilities in these scenarios is the capacity to execute an effective in-water vertical jump, which allows athletes to perform technical actions such as shot blocking, pressured passing, or aerial contests with greater effectiveness (Perazzetti et al., 2023). This jump is typically initiated from a vertical floating position and involves a rapid upward propulsion using explosive leg strength.

Two main lower-limb techniques contribute to this movement: the eggbeater kick, which maintains vertical stability through a continuous alternating motion (Homma & Homma, 2005; Melchiorri et al., 2015; Sanders, 1999; Stirn et al., 2014), and the breaststroke kick, which is more commonly used for explosive upward elevation required during passes, shots, or goalkeeper saves (Tsunokawa et al., 2015). The latter requires high levels of muscular power and precise inter-limb coordination to achieve maximum vertical displacement under competitive conditions.

While vertical jump performance has been extensively studied in land-based sports (Cormie, McGuigan, & Newton, 2011; Komi, 2003), aquatic-specific training and testing methods remain relatively underdeveloped. In contrast to the broad body of literature addressing general conditioning in water polo (Botonis et al., 2015, 2018, 2019), few studies have explored the transfer of explosive strength training to water-based actions or assessed vertical jump ability under ecologically valid conditions. Some exceptions include research comparing dry-land and in-water training modalities, which has shown that both can enhance water polo-specific performance, particularly when combined (de Villarreal et al., 2014, 2015).

Some recent efforts have validated sport-specific in-water jump tests (Uljević et al., 2013b; Uljević, Esco, & Sekulić, 2014) and investigated the force–velocity and power–velocity relationships involved in aquatic jumping (Annino et al., 2021). However, these approaches often rely on expensive laboratory equipment and lack accessibility for field implementation.

To address these limitations, the present study implemented a novel, portable dual-assessment protocol using a Kinect-based motion capture system to assess jump height and a customized EasyForce dynamometer to measure neuromuscular force parameters. These tools provide a practical, low-cost solution for field-based monitoring of aquatic performance.

The aim of this study was to examine the effects of a 21-day aquatic training program on in-water vertical jump performance and neuromuscular output in competitive water polo players. We hypothesized that athletes would demonstrate significant improvements in vertical jump height, time to peak force, and force output following the intervention.

Materials and Methods

Research Design

This study employed a quasi-experimental, one-group pretest–posttest design with repeated measures to investigate the effects of a targeted aquatic training program on vertical jump performance in competitive water polo athletes. Owing to logistical constraints and the structure of team-based participation, neither randomization nor a control group was implemented. Instead, a single cohort underwent a 21-day specialized aquatic intervention. All outcome variables were assessed under standardized testing conditions at both baseline and post-intervention time points. This design permitted the examination of within-subject changes over time attributable to the applied training protocol.

Participants

Fourteen male competitive water polo players voluntarily participated in the study. All athletes were medically cleared for unrestricted physical activity and had a minimum of three years of structured training experience. Participants completed a structured aquatic training program specifically designed to enhance vertical jump performance. All procedures were reviewed and approved by the institutional ethics committee (Protocol No.282/16.05.2025) and were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to the start of the study.

Procedure and Assessments

Two primary aquatic performance parameters were evaluated before and after the intervention: vertical jump height and vertical force output. Vertical jump height was assessed using a Microsoft Xbox Kinect (Microsoft, Redmond, USA; Zhang, 2012) camera integrated with TouchDesigner software (Derivative, Vancouver, BC, Canada). The sensor system was calibrated to capture vertical displacement along the Y-axis by tracking a standardized anatomical landmark at the base of the neck. Each athlete performed maximal vertical jumps from a stationary position in water under two distinct arm conditions: both arms submerged and one arm raised above the water. Among the three attempts, the best performance regardless of arm position was selected for analysis, as no significant differences were observed between the two arm positions.

Vertical force output was measured using an EasyForce dynamometer (Meloq, Stockholm, Sweden; Meloq Devices, 2025), mounted on a custom-built telescopic rig positioned at the edge of the pool. Athletes were secured in a harness connected to a guiding pulley system that enabled vertical force application during simulated jump efforts. The device recorded peak force (PF), average force (AF), and time to peak force (TTPF). All testing procedures were standardized and supervised, and the best attempt from each condition was retained for subsequent analysis.

Pre- and post-intervention testing took place under standardized conditions using validated equipment: a Kinect video system for measuring maximal elevation of the body from the water and the EasyForce dynamometer for vertical force assessment. Testing protocols isolated lower limb contribution by instructing athletes to perform a vertical jump with submerged arms in a static position.

Intervention Protocol

The athletes underwent a 21-day specific aquatic training program aimed at enhancing vertical jump performance in water polo through targeted neuromuscular and biomechanical adaptations. Training sessions were conducted three times per week, each lasting approximately 60 minutes, and were supervised by a certified aquatic coach to ensure proper technique and adherence to the prescribed intensity.

Exercise selection focused on activating lower limb musculature under conditions of instability and resistance, employing tools such as elastic bands and medicine balls to simulate game-like scenarios. The protocol alternated between high-intensity efforts and short active rest intervals to stimulate neuromuscular adaptations while maintaining technical control. Asymmetrical exercises, such as holding a medicine ball with one arm, were included to enhance trunk musculature activation and dynamic balance. Forward and backward movements under load aimed to reproduce the demands of in-game maximal elevation of the body from the water. Training intensity was progressively adjusted based on athlete feedback and performance progression to ensure sustained neuromuscular overload without excessive fatigue.

Our intervention program was not directly adapted from a single published protocol. Its design was conceptually informed by a range of studies focusing on water polo-specific strength development, neuromuscular adaptation, and in water-vertical jump. Key findings from Annino et al. (2021) and Keiner et al. (2020) supported the use of force-velocity profiling in water while de Villareal et al. (2014) and Veliz et al. (2015) highlighted the efficacy of in season aquatic and resistance training in improving performance indicators such as jump height, throwing velocity, and sprint swim capacity. Additional evidence from Marrin and Bampouras (2008) and Platanou (2006) contributed to our exercise selection by emphasizing year-round physiological adaptation and sport-specific testing methods. Based on these insights, we created a novel, short-term intervention specifically tailored to the biomechanical and neuromotor requirements of vertical jump performance in water polo, while maintaining practical applicability under field conditions.

A detailed overview of the aquatic training protocol, including exercise descriptions, activity durations, rest intervals, and repetitions, is provided in Table 1.

Table 1. Aquatic Training Program Protocol Over 21 Days

Phase	Exercise Description	Activity Duration	Rest Period	Repetitions
Warm-up	General lower limb warm-up performed in water	5 minutes	–	–
Exercise 1	Athlete treads water while extending an elastic band to 70% of maximal length for 20 seconds, followed by a 10-second maximal stretch on coach's whistle	30 seconds	60 seconds	4
Active Rest	Short active rest	–	2 minutes	–
Exercise 2	Athlete holds a 5 kg medicine ball above the forehead with shoulders out of the water for 20 seconds, followed by 10 seconds of vertical breaststroke kicks	30 seconds	60 seconds	4
Active Rest	Short active rest	–	2 minutes	–
Exercise 3	Athlete treads water while holding a 2 kg ball above the head with one arm for 40 seconds; after 20 seconds of rest, the movement is repeated with the other arm	40 seconds × 2 arms	20 seconds between arms	4
Active Rest	Short active rest	-	2 minutes	–
Exercise 4	Athlete holds a 2 kg medicine ball overhead while moving forward for 40 seconds, then backward on the coach's whistle using eggbeater kicking	40 seconds × 2 (forward/back)	40 seconds	6
Recovery	Four 25 m low-intensity front crawl kick laps using a kickboard	5 minutes	-	4

Note. The training protocol was applied across a 21-day intervention period. All sessions were supervised by a certified aquatic coach. Exercise intensity was progressively adjusted to ensure neuromuscular overload while maintaining technical control.

Statistical Analysis

Descriptive statistics were used to characterize the sample and summarize baseline demographic and performance variables. The Shapiro–Wilk test was performed to assess the normality of the data distribution. As the assumptions for parametric analysis were not met, the Wilcoxon signed-rank test was applied to assess within-group changes from pre- to post-intervention. Effect sizes for non-parametric tests were calculated using the formula $r=Z/\sqrt{N}$ and interpreted according to Cohen's (2013) guidelines as small (≥0.10), medium (≥0.30), or large (≥0.50). All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p<0.05$.

Results

Descriptive statistics were calculated for all measured variables at both the pretest and posttest stages for the experimental group (see Table 2 and Table 3).

According to Table 2, at baseline, the experimental group demonstrated a mean vertical jump height (Hi) of 0.24 m (SD=0.09), peak force (pre_PF) of 290.14 N (SD=56.81), average force (pre_AF) of 127.21 N (SD=17.83), and time to peak force (pre_TTPF) of 0.52 s (SD=0.11).

Table 2. Pretest Descriptive Statistics for Experimental Group

Group	Variable	Mean	SD
Experimental group	H_i (m)	0.24	0.09
	pre_TTPF (s)	0.55	0.08
	pre_PF (N)	290.14	56.81
	pre_AF (N)	127.21	17.83

Note. H_i=initial stage height; pre_TTPF=time to peak force (pre-test); pre_PF=peak force (pre-test); pre_AF=average force (pre-test); SD=standard deviation. Measurements for force are expressed in Newtons (N), height in meters (m), and time in seconds (s).

Following the 21-day aquatic training protocol, the experimental group showed improvements across all performance metrics (Table 3). Final height (Hf) increased to 0.29 m (SD=0.08), post_TTPF decreased to 0.44 s (SD=0.10), and both post_PF and post_AF increased to 348.14 N (SD=55.48) and 145.00 N (SD=22.58), respectively.

Table 3. Posttest Descriptive Statistics for Experimental Group

Group	Variable	Mean	SD
Experimental group	H_f (m)	0.29	0.08
	post_TTPF (s)	0.44	0.10
	post_PF (N)	348.14	55.48
	post_AF (N)	145.00	22.58

Note. H_f=final stage height; post_TTPF=time to peak force (post-test); post_PF=peak force (post-test); post_AF=average force (post-test); SD=standard deviation. Measurements for force are expressed in Newtons (N), height in meters (m), and time in seconds (s).

The observed differences in neuromuscular performance between the initial and final assessments in the experimental group are presented in Figure 1.

Subsequently, a Wilcoxon signed-rank test was applied to examine within-group changes in the experimental group, assessing whether the intervention led to significant improvements in the measured parameters (see Table 4).

As shown in Table 4, the Wilcoxon signed-rank test was conducted to assess within-subject changes in the experimental group (N = 14) before and after the 21-day aquatic training program. The results revealed statistically significant improvements across all measured variables: final height (Z=-2.21, p=0.027, r=0.59), time to peak force (TTPF; Z=-2.89, p=0.004, r=0.77), peak force (PF; Z=-3.30,

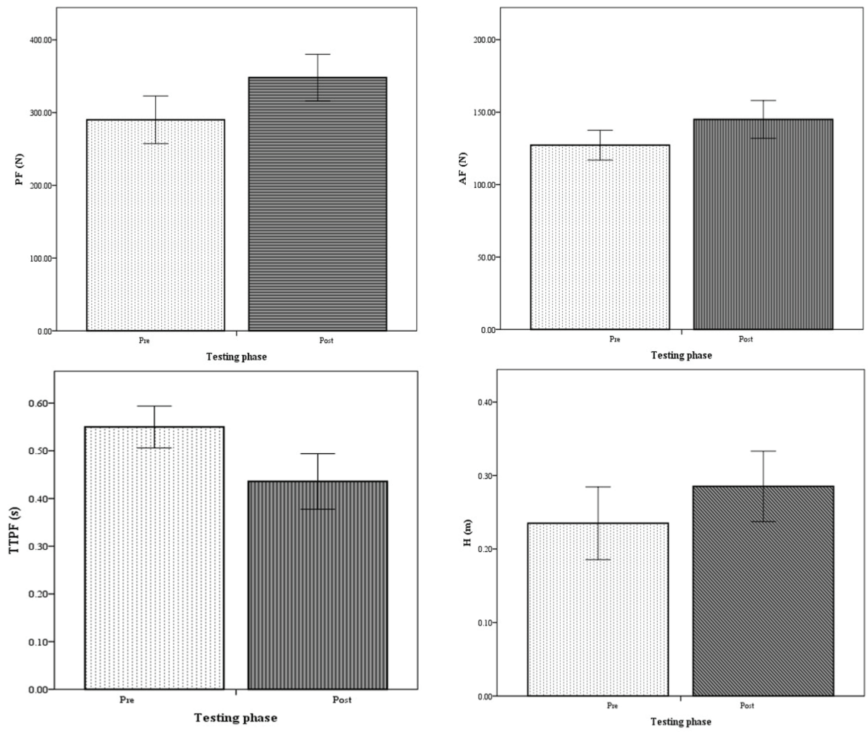

FIGURE 1. Changes in neuromuscular performance variables between pre- and post-training assessments in the experimental group
Note. Values are presented as means ± standard errors for peak force (PF), average force (AF), time to peak force (TTPF), and vertical displacement (H) during in-water vertical jump tests. All comparisons reflect within-subject differences across testing phases (Pre vs. Post).

Table 4. Wilcoxon Signed-Rank Test Results for Within Experimental Group Differences

Variable	Z	P	r
Height (m)	-2.21	0.027	0.59
TTPF (s)	-2.89	0.004	0.77
PF (N)	-3.30	0.001	0.88
AF (N)	-3.30	0.001	0.88

Note. Z=standardized test statistic; p=exact significance (2-tailed); r=effect size, calculated as Z/√N. Differences were considered statistically significant at p<0.05.

p=0.001, r=0.88), and average force (AF; Z=-3.30, p=0.001, r=0.88). These large effect sizes indicate that the aquatic training program had a substantial impact on both neuromuscular coordination and strength development, effectively enhancing explosive and maximal force capabilities in the participants.

Discussion

The aim of the study was to examine the effects of a 21-day aquatic training program on in-water vertical jump performance and neuromuscular parameters in competitive water polo athletes. The results demonstrated significant within-group improvements in all measured variables: jump height (H), time to peak force (TTPF), peak force (PF), and average force (AF), with large effect sizes. This indicates that even a short-term, water based intervention can trigger meaningful neuromuscular adaptations in competitive athletes.

Such outcomes highlight the value of biomechanically relevant training stimuli tailored to the aquatic environment, aligning with prior literature that emphasizes specificity and contextual relevance in conditioning programs (Botonis et al., 2018; de Villareal et al., 2015). Our observed increase in jump height (from 0.24 m to 0.29 m; M=0.05 m, or +20.8%) aligns with the findings of de Villarreal et al. (2014), who reported significant CMJ improvements (2.6 cm; +7.6%) in their in-water strength group (WSG) following a six-week training period. Although their intervention was longer in duration, our aquatic-only protocol yielded comparable or superior relative gains, particularly in PF and H, reinforcing the efficacy of water-based strength training conducted independently of dry-land components. In contrast, Heywood et al. (2022), in their systematic review, noted that several studies employing aquatic-only plyometric interventions reported more modest performance gains, likely due to lower training intensity, shorter protocol durations, or suboptimal specificity. Our findings contrast with these limitations, likely because our protocol emphasized high-effort, game-relevant movements such as resistance vertical thrust and asymmetrical loads, enhancing both neuromuscular activation and specificity.

Water-based propulsion requires distinct neuromuscular coordination strategies compared to dry-land movements due to water resistance and buoyancy forces (Sanders, 1999; Stirn et al., 2014). The significant decrease in TTPF suggests improved neuromuscular efficiency, a critical factor in the rapid execution of explosive actions in water polo, such as shot blocking or aerial ball contests (Perazzetti et al., 2023).

Mechanistically, early-phase neuromuscular adaptations likely underpin the observed performance improvements. These include enhanced motor unit synchronization, increased recruitment of high-threshold units, and better intermuscular coordination, as supported by prior findings (Aagaard et al., 2022; Bobbert & van Ingen Schenau, 1988). Moreover, the repeated exposure to resisted aquatic movement patterns may promote a faster rate of force development and proprioceptive refinement, crucial aspects for vertical elevation under unstable water dynamics. A comprehensive understanding of aquatic sport-specific motor actions requires the examination of the entire integrated psycho–neuro–motor continuum ranging from cortical command initiation to peripheral muscular execution and the reciprocal feedback mechanisms involved in movement regulation and neuromuscular adaptation (Geantă & de Hillerin, 2023). This integrated framework highlights the importance of assessing not only mechanical outputs but also the neuromotor coordination strategies that underpin explosive actions in water polo and potentially other aquatic sports.

The consistent within-group gains in strength metrics observed in this study suggest positive neuromuscular adaptations, consistent with early-phase training responses described in the literature (Aagaard et al., 2002; Bobbert & van Ingen Schenau, 1988). It is also worth noting that improvements in coordination and speed of force development may precede increases in absolute strength, particularly in aquatic contexts where technical execution plays a dominant role.

A methodological strength of the study lies in the use of portable, field-based technologies namely the EasyForce Dynamometer and Xbox Kinect which enabled ecologically valid testing in sport-specific settings. Prior validation studies (Bonnechère et al., 2014; Gray et al., 2017; Karl et al., 2024; Pfister et al., 2014) support the reliability and applied value of these tools in sport science. Importantly, all performance assessments and training were conducted exclusively in the aquatic environment, enhancing transferability to actual competitive contexts. To the best of our knowledge, this is the first investigation conducted in Romania involving competitive water polo players and employing such portable neuromuscular assessment technologies representing a novel methodological contribution to the national context of aquatic performance research. This study's strengths also include the ecological validity of the intervention, the use of sport-specific movements, and the deployment of accessible measurement tools. Limitations include the absence of a control group, small sample size, and lack of biomechanical markers such as electromyography.

From an applied standpoint, the intervention demonstrates high practical scalability, requiring minimal equipment and allowing for seamless integration into existing training framework. The training components including asymmetrical loading, maximal elevation overload, and active rest alternation, proved effective in eliciting targeted neuromuscular adaptations aligned with the physiological and tactical demands of competitive water polo. This make the protocol particularly useful in settings where dry-land training may be limited or contraindicated (e.g. injury, rehabilitation, or in-season management). The approach has attracted institutional interest, with formal discussions in progress to incorporate the findings into national performance monitoring protocols under the guidance of the Romanian Water Polo Federation. This highlights the translational value of the research and its relevance in shaping evidence-based, sport-specific conditioning strategies.

Future studies should incorporate longer intervention periods, female athletes, and transfer assessments to in-game performance. Despite these limitations, the 21-day aquatic program proved scalable and effective, with strong translational relevance. Our results align with recent systematic reviews confirming the utility of aquatic plyometric in enhancing strength, power, and jump ability (Heywood et al., 2022; Ramirez-Campillo et al., 2022).

Conclusion

The 21-day aquatic training intervention led to significant improvements in vertical jump height and neuromuscular performance in competitive water polo athletes. These findings highlight the effectiveness of targeted, sport-specific training conducted in water and support the integration of aquatic-based strength and power exercises in elite water polo preparation. The use of portable and accessible tools highlights the feasibility of monitoring performance in real-world, sport-specific environments.

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Conflict of Interest
The authors declare no conflict of interest related to this study. The research was conducted independently, and no financial or personal relationships influenced the design, execution, or reporting of the findings.

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ORIGINAL SCIENTIFIC PAPER

Kinematic Analysis of Basketball Free Throw Trajectory

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Abstract

Free throw shooting is a fundamental skill in basketball that requires a combination of technique, consistency, mental focus, and the ability to perform under pressure. The purpose of this study was to analyze the kinematic parameters of the ball trajectory during a successful free throw. The study involved 20 players from the Kosovo Basketball League during the 2020 season. Ten kinematic variables were selected for analysis. Three Canon cameras (Canon Inc., Tokyo, Japan), recording at 60 frames per second, were used to capture the free throw motion. The recorded videos were analyzed using the Ariel Performance Analysis System (APAS) to extract kinematic data. Significant correlations were found between kinematic variables in the ball trajectory during a successful free throw between: Initial distance between the ball and the center of gravity and height of release (r=0.68), Final distance between the ball and the center of gravity and height of release (r=0.61), Height of release and vertical displacement of the ball's trajectory (r=-0.72), Release angle and entry angle of the ball (r=0.65). The results of this research enrich the scientific knowledge of the kinematic analysis of the ball trajectory in basketball free throws, contributing to the development of more accurate methodologies for evaluating and improving performance in the sport of basketball. These findings contribute to a deeper understanding of the kinematic principles underlying successful free throw shooting and provide valuable information for coaches and athletes seeking to enhance performance.

Keywords: *basketball, kinematic, ball trajectory, free throw shoot, Pearson's correlation*

Introduction

Basketball is considered one of the most popular sports worldwide. This beautiful game is played by more than 450 million people worldwide (Kachanathu, Dhamija, & Malhotra, 2013). Previous research has shown that free throw performance is one of the key factors in determining whether a team wins or loses at some of the highest levels of basketball competition (Sampaio & Janeira, 2003). The biomechanical parameters of the player determine the accuracy of free throws in basketball during the performance (Fontanella, 2006). When discussing the kinematic parameters of the shot, authors Miller and Bartlett (1993) believe that an optimal combination of kinematic parameters is important for a successful shot in the game of basketball. Ibana and Saenzy (2003) showed that the factors determining a successful shot include arm action, foot movement, body position, height, and distance of the shot. Malone (1999) stated that for a successful shot in basketball, the force used by the flexion of the arms must be consistent with the angle of release of the ball. One of the kinematic parameters of the shot is the trajectory of the ball in the sport of basketball (Satti, 2004). The analysis of the trajectory of the ball in basketball has been an interesting topic, but also important for many researchers around the world (Brancazio, 1981; Satern, 1988; Southard & Miracle, 1993). At the moment when the player is released from the ball, the elements that he performs are: the height of the ball release, the trajectory of the ball movement, the horizontal and vertical displacement, the angle of the ball release, the speed of the ball and the angle of entry of the ball. The path followed by a projectile is called its trajectory (Changjan & Mueanply, 2015). The study of ball

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trajectory in basketball has been a topic of great interest to researchers worldwide (Brancazio, 1981; Satern, 1988; Southard & Miracle, 1993). Once the ball leaves the player's hand, becomes a projectile subject to the laws of gravity, air resistance, and spin. According to Perse et. al. (2009), the ball trajectory in basketball provides valuable information for developing effective training tactics and strategies.

The research on the ball trajectory by the authors (Miller & Bartlett, 1996) has identified several key components of a successful free throw: angle of entry, velocity, and height of release. The angle of entry for the ball is determined by three ball factors: vertical displacement, horizontal displacement, and velocity (Okazaki et al., 2015). According to Perse et al. (2009), analysis of the ball trajectory in basketball provides valuable information for the development of effective training tactics and strategies. The values of kinematic indicators are a reference point for the level of technique realization. The evaluation of the main kinematic indicators in quality basketball players provides accurate information for the level of technique and the possibilities for improving technique. The aim of this study is to analyze the kinematic variables of the ball trajectory that influence the success of a free throw in basketball.

Materials and methods

Participants

This study involved twenty professional male players (n=20) from the top two basketball clubs in the Kosovo Basketball League during the 2020 season. All participants took part voluntarily and with the written permission of their clubs. The participants' anthropometric characteristics and experience were as follows: average weight of 84.90±7.86 kg, average height of 192.10±6.62 cm, and an average of 13±3 years of basketball experience, with ages ranging from 18 to 25 years.

Procedure

The free throw was executed from the regulation free-throw line at a distance of 4.57 meters. Prior to testing, participants completed a 15-minute warm-up followed by 10 trial shots. Each participant then performed a single shot during the actual test, which was used for further analysis. In total, 20 shots were analyzed in this study.

The ball release phase was defined as the moment the ball leaves the shooter's hands, including its subsequent trajectory and entry into the hoop. This phase was analyzed to evaluate key kinematic parameters that influence shot accuracy.

Analyzed Variables

For the purposes of this study, ten kinematic variables (n=10) were analyzed and are presented in Table 1: initial distance between the ball and the center of gravity, final distance between the ball and the center of gravity, height of the ball's release, horizontal displacement of the ball's trajectory, vertical displacement of the ball's trajectory, angle of the ball's release, angle of the ball's entrance, ball movement speed, ball movement time, and total time. Figure 1 illustrates the basketball shot and the trajectory of the ball as it moves toward the hoop.

Table 1. Description of parameters used in analysis

Abbreviation	Variable
IDCG (cm)	Initial distance between the ball and the center of gravity
FDCG (cm)	Final distance between the ball and the center of gravity
HBR (°)	Height of the ball's release
HDT (°)	Horizontal displacement of the ball's trajectory
VDT (°)	Vertical displacement of the ball's trajectory
ABR (°)	Angle of the ball's release
ABE (m/s)	Angle of the ball's entrance
BMS (m/s)	Ball movement speed
BMT (sec)	Ball movement time
TT (sec)	Total time

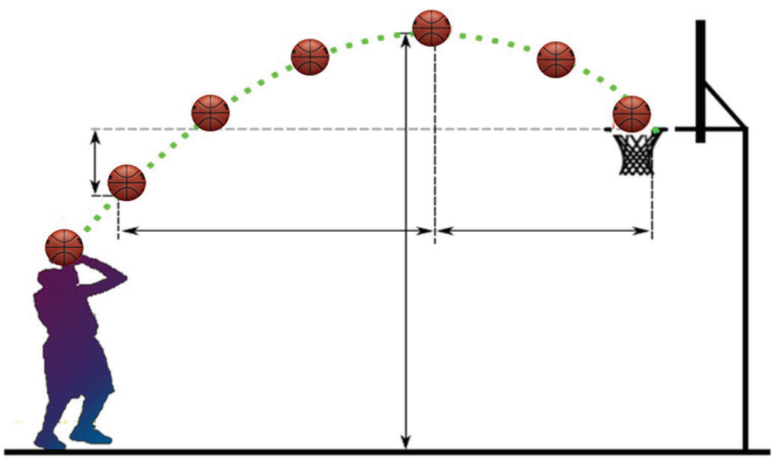

FIGURE 1. The moment the ball is released from the hands, its trajectory during flight, and the point at which it enters the basket are all crucial elements of a successful shot.

Data collection and processing methods

Ariel Performance Analysis System (APAS) is a video-based 3D motion analysis system from the producer Ariel Dynamics Inc. (Trabuco Canyon, CA 92679 USA), that accurately quantifies and provides objective data, which professionals can use to assess and enhance treatment. The successful applications of the APAS system include evaluating human (athlete) movement performance, assessing movements during the rehabilitation process, equipment evaluation, product testing, and development, and identifying potential or actual risks associated with products (equipment) and related activities.

This system accurately quantifies and provides objective data that can be used to evaluate and improve treatment, enhance athletic performance, assess rehabilitation progress, and test and develop products. It also aids in determining potential or actual risks associated with equipment. For this study, the basketball shooting techniques were filmed using three Canon digital cameras (Canon Inc., Tokyo, Japan) positioned approximately 120 degrees apart. The cameras were placed at a distance of about seven meters from the performance area.

After fixing the cameras, a 200x200x200 cm calibration frame was recorded and subsequently removed. The camera arrangement was designed to ensure that all reference points (markers that were attached to the body) of the athletes' bodies were within the camera's field of view and visible. The filming of the basketball shooting techniques was then conducted, capturing images at a rate of 60 Hz, ensuring optimal reproduction (Tang & Shung, 2005).

Statistical Processing Methods

The collected data were processed using IBM SPSS Statistics 20 software, and statistical parameters were determined using the following methods: Arithmetic Mean, Standard Deviation, Minimum Value, Maximum Value, Skewness, and Kurtosis. The significance of the mutual influence between the variables was verified using Pearson's Correlation Method. Correlation Method, which measures the strength and direction of the linear relationship between two variables. If the calculated correlation coefficient (r) and associated p-value (a measure of statistical significance) indicate a non-zero correlation, it suggests that a linear relationship exists between the variables. In accordance with Cohen's (1988) guidelines, the strength of the correlation was interpreted as follows: values of r between 0.10 and 0.29 indicate a weak relationship, values from 0.30 to 0.49 reflect a moderate relationship, while values of r equal to or greater than 0.50 signify a strong correlation. Statistical significance was set at $p<0.05$.

Results

Table 2 shows the descriptive statistics for 10 kinematic variables related to the ball trajectory during successful free throws in basketball. The values for the arithmetic mean (Mean), standard deviation (Std. Deviation), minimum (Minimum), and maximum (Maximum) fall within the expected ranges.

The average initial distance between the ball and the center of gravity (IDCG) was 65.95 cm with a standard deviation (SD) of 9.99 cm, ranging from 51.00 to 98.00 cm. The final distance between the ball and the center of gravity (FDCG) had a mean value of 129.05 cm (SD=12.15), with a minimum of 113.00 cm and a maximum of 155.00 cm.

The height of the ball's release (HBR) averaged 248.05° (SD=15.08), while horizontal displacement of the ball trajectory (HDT) was on average 415.85° (SD=24.83). Vertical displacement (VDT) had a mean of 149.25° with a standard deviation of 19.55.

The average release angle (ABR) was 32.65° (SD=5.60). The ball entry speed (ABE) averaged 36.35 m/s (SD=6.43), and the ball movement speed (BMS) was 8.90 m/s with a standard deviation of 1.51. Regarding time variables, ball movement time (BMT) averaged 1.11 seconds (SD=0.17), and total shot time (TT) was 1.48 seconds (SD=0.20). Overall, the results indicate consistent and expected variability in the kinematic parameters of successful free throws, reflecting stable and repeatable movement patterns across participants.

The majority of kinematic parameters demonstrated skewness and kurtosis values within the normal distribution range, indicating the stability and reliability of the obtained results.

Table 2. The results of the basic statistical parameters for the analysis of 10 kinematic variables related to the ball trajectory during a basketball free throw are presented.

Kinematic variables	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
IDCG (cm)	65.95	9.99	51.00	98.00	1.58	4.81
FDCG (cm)	129.05	12.15	113.00	155.00	0.49	-0.54
HBR (°)	248.05	15.08	221.00	279.00	-0.03	-0.11
HDT (°)	415.85	24.83	367.00	468.00	0.39	0.32
VDT (°)	149.25	19.55	112.00	188.00	0.13	-0.41
ABR (°)	32.65	5.60	20.00	44.00	-0.27	0.46
ABE (m/s)	36.35	6.43	25.00	55.00	0.98	2.81
BMS (m/s)	8.90	1.51	6.48	13.83	1.67	5.36
BMT (sec)	1.11	0.17	0.91	1.55	1.64	2.01
TT (sec)	1.48	0.20	1.02	1.85	-0.86	1.52

Legend: IDCG – Initial distance between the ball and the center of gravity; FDCG – Final distance between the ball and the center of gravity; HBR – Height of the ball's release; HDT – Horizontal displacement of the ball's trajectory; VDT – Vertical displacement of the ball's trajectory; ABR – Angle of the ball's release; ABE – Angle of the ball's entrance; BMS – Ball movement speed; BMT – Ball movement time; TT – Total time.

Table 3 presents the Pearson correlation coefficients for the kinematic indicators of the ball trajectory during a basketball free throw. Variables that showed strong statistically significant correlations at the p=0.01 level included: Initial distance between the ball and the center of gravity (IDCG) and the height of the ball's release (HBR), with a correlation coefficient of 0.68; Final distance between the ball and the center of gravity (FDCG) and the height of the ball's release (HBR), with a correlation coefficient of 0.61; Height of the ball's release (HBR) and vertical displacement of the ball's trajectory (VDT), with a correlation coefficient of -0.72; and angle of the ball's entrance (ABE) and angle of the ball's release (ABR), with a correlation coefficient of 0.65. Statistically significant correlations at the p=0.05 level were found between: Initial distance between the ball and the center of gravity (IDCG) and horizontal displacement of the ball's trajectory (HDT), with a correlation coefficient of 0.48; and horizontal displacement of the ball's trajectory (HDT) and total time (TT), with a correlation coefficient of 0.44.

Figure 2 illustrates the trajectory of vertical displacement, showing the changes in the height of the body's center of gravity from the ground during a subject's free throw.

Table 3. Presents the results of the Pearson coefficient correlation of the kinematic indicators for the ball trajectory for the free throw in basketball.

Kinematic variables	IDCG (cm)	FDCG (cm)	HBR (°)	HDT (°)	VDT (°)	ABR (°)	ABE (m/s)	BMS (m/s)	BMT (sec)
FDCG (cm)	0.30								
HBR (°)	0.68**	0.61**							
HDT (°)	0.48*	0.09	0.18						
VDT (°)	-0.24	-0.31	-0.72**	0.01					
ABR (°)	0.08	0.27	0.16	-0.08	-0.32				
ABE (m/s)	0.18	0.13	0.25	-0.05	-0.28	0.65**			
BMS (m/s)	0.26	0.27	0.18	0.30	0.04	0.21	0.08		
BMT (sec)	-0.19	0.16	-0.09	-0.30	0.10	0.35	0.40	0.09	
TT (sec)	0.09	-0.25	-0.35	0.44*	0.59**	-0.27	-0.35	-0.17	-0.34

Legend: IDCG – Initial distance between the ball and the center of gravity; FDCG – Final distance between the ball and the center of gravity; HBR – Height of the ball's release; HDT – Horizontal displacement of the ball's trajectory; VDT – Vertical displacement of the ball's trajectory; ABR – Angle of the ball's release; ABE – Angle of the ball's entrance; BMS – Ball movement speed; BMT – Ball movement time; TT – Total time.

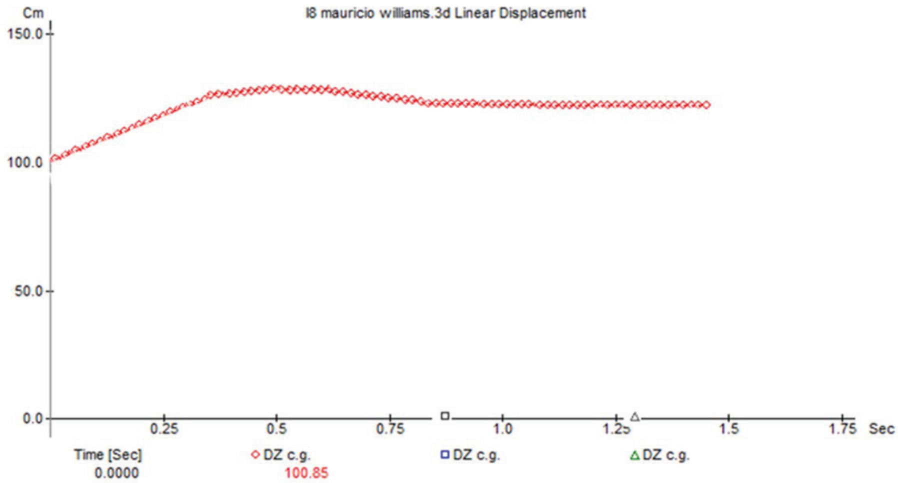

FIGURE 2. The curve of the change in the height of the center of gravity of the body from the ground, (displacement in the vertical axis - z), during the free throw of a subject.

Discussion

This research aimed to analyze the kinematic parameters of the ball trajectory during a successful free throw. In the results of the Pearson correlation coefficients, of the Kosovo elite basketball players, for the analysis of the ball trajectory, the variables that have shown high correlations with statistical significance at the level (p=0.01) are: the height of the ball release (HBR) turned out to be one of the most important variables, as it showed strong correlations with the distances between the center of gravity and the ball, both in the initial position (IDCG) and in the final position (FDCG). This shows that correct body positioning during the moment of release directly affects the height of the ball throw and consequently the accuracy of the shot. In this study, a negative correlation was found in these variables between the height of the ball release (HBR) and the trajectory of the ball movement (vertical displacement) (VDT). This result suggests that the higher the release point is, the ball reaches its greatest height along its trajectory, which helps create a more stable and more suitable arc to enter the basket.

Also, other variables that have shown a strong correlation are the ball release angle (ABR) and the ball entry angle into the basket (ABE), indicating that the release angle directly affects how the ball ends up in the basket, as a key factor for the successful shot.

Variables that have shown high correlations with statistical significance at the p=0.05 level are: the distance between the center of gravity and the ball in the initial position (DQPF) and the horizontal trajectory of the ball's movement (TLZH); as well as between the horizontal trajectory of the ball (TLZH) and the total time (KT). These relationships show that the horizontal distance the ball travels and the time it spends in the air are closely related and affect shooting efficiency, in accordance with the laws of physics that imply that a greater distance requires more travel time.

The results of this study are consistent with previous findings by various authors, who have emphasized the importance of kinematic parameters in free throw success. Radenković et al. (2018) and Malone (1999) emphasize the role of the height of the center of mass at the moment of release as a key factor, as is also observed in this research.

Similarly, Malone et al. (2002), and Hamilton and Reinschmidt (1997) show that a higher release height allows the use of a smaller angle and lower speed, helping with the accuracy of the throws. A clear correlation was also observed with the findings of Hara et al. (2006), Yogi et al. (2006), and Okazaki & Rodacki (2012), who identify the relationship between the release angle and the entry angle, both of which are key factors in the effectiveness of a free throw. There is a direct correlation between release angle and entry angle, both of which are key factors in the effectiveness of a free throw (Hara et al., 2006; Yogi et al., 2006). Blazevich (2010) also confirms that the trajectory is influenced by the speed, angle and height of the projection.

Increasing the height of release of the ball permits the player to use a smaller release angle, thereby reducing the need for high movement velocity to execute a successful shot (Malone et al., 2002). Therefore, obtaining appropriate movement techniques of the body segments during the learning process may contribute to the development of a shooting technique that results in a successful shot.

The results of this research enrich the scientific knowledge of the kinematic analysis of the ball trajectory in free throws, contributing to the development of more accurate methodologies for evaluating and improving performance in the sport of basketball. We recommend that future research include a larger sample size and also consider analyzing unsuccessful shots.

Conclusions

This study analyzed the kinematic factors influencing trajectory of free throw success in basketball, offering valuable insights for performance enhancement. Kinematic indicator values provide a crucial benchmark for evaluating and refining shooting technique. The precise measurement of these parameters, including release height, the distance between the center of gravity and the ball (both initially and at release), and release and entry angles, offers players, coaches, and basketball experts a practical guide for improvement. The results of this research revealed significant relationships between these indicators and ball trajectory. Notably, strong correlations were found between release height and both vertical and horizontal ball displacement, underscoring the importance of release height for optimizing trajectory and maximizing shot accuracy. These findings contribute to a deeper understanding of the kinematic principles underlying successful free throw shooting and provide valuable information for coaches and athletes seeking to enhance performance.

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Conflict of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Impact of COVID-19 Lockdown on Physical Activity and Lifestyles of Male and Female Athletes Varying in Discipline, Level and Nationality

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Abstract

The COVID-19 pandemic has significantly reduced physical activity levels in the general population. This study seeks to examine the impact of pandemic-related lockdowns on physical activity among athletes, comparing individuals across different performance levels and countries. A cross-sectional study was employed. Between 5 and 15 April 2020, they were administered the International Physical Activity Questionnaire (IPAQ) and the Short-Form General Health Questionnaire (SF-12) (including SF-12 Physical and Mental Component Summary subscores [PCS and MCS respectively]). Before the lockdown, women had higher energy expenditure (AEE) and physical component scores (PCS) compared to men, while mental component scores MCS were higher for men than for women. During a lockdown, total activity time (TAT) and AEE decreased significantly for all athletes, sitting time increased, and quality of life worsened. TAT, AEE, and PCS became similar between sexes during lockdown, but women had lower MCS at low activity levels, except for high-level female athletes, who showed similar MCS to males. In conclusion, the COVID-19 lockdown negatively impacted athletes' Total activity time, activity energy expenditure, and quality of life were greater among low-level athletes, particularly females.

Keywords: *health, athletes, pandemic, IPAQ, SF-12*

Introduction

As a preventive measure, more than a third of the world's population found themselves under full or partial lockdown for several weeks during the COVID-19 pandemic.

Polero et al. (2020) conducted a study on physical activity (PA) recommendations during the pandemic, including data from 29 articles that discussed PA patterns. Though they noted that there was a lack of consensus and that recommendations made were not suitable for all people, the authors found that PA in the form of aerobic, strength, flexibility, and balance exercises was widely recommended.

Various studies have considered different groups, in-

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cluding youth, older individuals, and people with certain diseases. For example, Tornaghi et al. (2021) considered PA levels during the pandemic among youth in northwestern Lombardy. Their results show that, in general, the lockdown had a clearly negative impact on physical activity among the young population, which was already inactive to moderately active. Only highly active students (>2.520 MET-min/wk) increased PA during (3467.48±55.85 MET-min/wk) and after (3515.73±65.75 MET-min/wk) lockdown, relative to their baseline (3151.43±42.41 MET-min/wk). Physical activity helps protect against age-related decline in physical performance and boosts biological functions while aging has no impact (Cefis et al., 2025).

Among recreational athletes, Martin et al. (2021) found that the negative impact of COVID-19 restrictions on PA was greater for females, those engaged in winter or team sports, individuals aged 18 to 39, and low-resilient copers. Yet the number of days of exercise per week increased, as did recourse to online workouts, home gym exercise, and fitness apps.

Others have studied the effects on higher-level athletes. Fikenzer et al. (2021) considered the impact of lockdowns on endurance capacity among elite handball players. They observed a reduction in this capacity in the absence of team training, despite a home-based strength and endurance program. Font et al. (2021), who also studied elite handball players, detected moderate blood lactate increases post-lockdown right after submaximal shuttle run tests, but no changes in jump performance.

Lockdown effects on youth soccer players were investigated by Pucsok et al. (2021). They found that agility, speed, and explosive power did not change under home-based conditions, but it was challenging for participants to increase endurance capacities relative to their pre-pandemic baseline. However, Rampinini et al. (2021) concluded that home-based training was effective in improving aerobic fitness among soccer players, but did not allow players to maintain the levels of power exhibited during their competitive period.

Certain international studies, relying on surveys, conducted in larger populations of athletes playing various sports. Izzicupo et al. (2021) gathered data on 467 high-school (21.9%) and university (78.1%) student athletes (57% males, 43% females) from 11 countries, competing in 49 different sports at regional (17.5%), national (43.3%), and international (39.2%) levels. Respondents reduced their time spent on sports and academics but continued to lead active lifestyles during the lockdown (Izzicupo et al., 2021). Students who participated in sports in nations that experienced widespread outbreaks were more likely to train at home, devote time to their studies, and receive encouragement from their coaches but were less likely to receive it from their teachers. They find individual sports athletes trained more and were more likely to have their coaches back them up, athletes at an international level trained the most and were the most supported by their coaches. While college students were more inclined to explore multiple vocations (i.e., athletics and higher education) to cope with the COVID-19 situation, high school students got greater support from their coaches and teachers (Izzicupo et al., 2021).

Pillay et al. (2020) examined the effects of lockdowns on 692 elite and semi-elite athletes and found they preferred sedentary to active behavior during their leisure time. They also noted altered sleep patterns (79%; p<0.0001), excessive consumption of carbohydrates (76% [males, 73%; females, 80%]; p<0.0001), feelings of depression (52%), and a need for motivation to remain active (55%). The authors concluded that COVID-19 had physical, nutritional, and psychological consequences that may have compromised general health and the safe resumption of athletics.

As most of the studies of the impact of COVID-19 lockdowns on athletes have only considered small populations and particular regions, sports, skills, and athletic levels, we chose to focus on male and female athletes, and at various levels of activity intensity. Therefore, the present study reports on the impact of COVID-19 lockdown on physical activity and quality of life of male and female athletes varying in discipline, level, and nationality from 10 countries.

Methods

Population

A total of 941 athletes (682 men 29±10 years, 259 women 25±9 years), all under lockdown at home (March to May 2020), responded to our survey. They hailed from 10 countries: Jordan (30%), Saudi Arabia (19%), Oman (12%), Palestine (10%), Kuwait (7%), France (7%), Algeria (6%), Thailand (5%), Bahrain (3%), and Iraq (1%). Athletes participating at different levels and in various sports were studied: "low-level" athletes practiced in clubs, at a local or regional level (n=727, 242 women 25±9, 485 men 29±10 years) while "high-level" athletes practiced at the national or international level (n=214, 155 men 28±11 years, 59 women 23±9). All agreed to participate and were informed that their data would remain confidential. All athletes included did not present any pathology.

During the confinement period, all athletes have received an e-mail link allowing them to access questionnaires. These allowed us to evaluate the status of each athlete before confinement and also the effect of confinement on the parameters monitored.

This study was reviewed and approved by the Research Ethics Committee (REC) of the Department of Physical and Health Education at Al-Ahliyya Amman University (Decision No. 1/11-2019/2020). All participants provided written informed consent to participate in the study and to allow their anonymized data to be used for research and publication purposes. The study complied with the institutional committee's ethical standards and followed the principles outlined in the Declaration of Helsinki.

Study design

We administered the International Physical Activity Questionnaire (IPAQ) and 12-Item Short Form Survey (SF-12) to study participants - from sports clubs, federations, and universities in 10 countries - before and during COVID-19 lockdown.

IPAQ

The International Physical Activity Questionnaire (IPAQ) is designed for international use, to provide comparable PA estimates (Craig et al. 2003). We selected the short version, which considers PA over the preceding week (Craig et al., 2003). Participants independently completed online versions in Arabic, English, French, or Thai. The unit used to score the IPAQ was the metabolic equivalent of task (MET), where 1 MET is the amount of energy expended at rest. Walking corresponded to 3.3 METs, moderate intensity exercise is equivalent to 4 METs, and intensity vigorous exercise amounts to 8 METs.

SF-12

The Short-Form General Health Questionnaire (SF-12) (Ware et al., 1996) is a 12-item subset of the 36-item SF-36 survey (Ware & Sherbourne, 1992). As for the IPAQ, online versions in Arabic, English, French, and Thai were independently completed by participants. The SF-12 yields Physical Component Summary (PCS) and Mental Component Summary (MCS) sub-scores, while the total score is a measure of quality of life.

Data analysis

We used R statistical software (version 4.2; R Foundation for Statistical Computing, Vienna, Austria) to analyze our data, which are presented as means with standard deviations. For all statistical analyses, the significance level was $p<0.05$.

A linear mixed-models approach (R nlme package) with repeated-measures ANOVAs was applied to evaluate correlations between lockdown (before vs. during), sex, and athletes' levels (low vs. high). Post-hoc analyses were performed using simultaneous tests for general linear hypotheses (R emmeans package) with Bonferroni corrections.

Results

Effect of lockdown on body weight and BMI

There was no observable effect on weight or BMI (Figure 1) in male or female athletes, regardless of their levels.

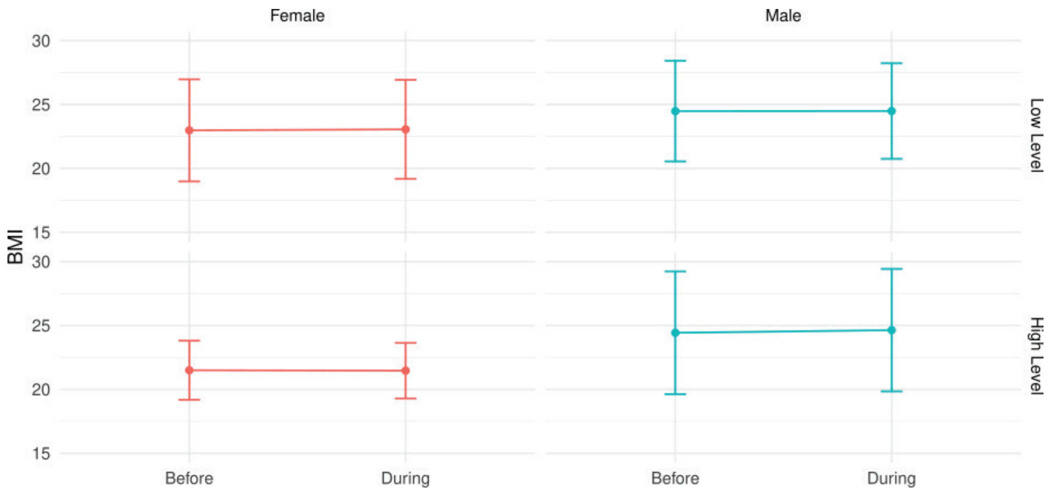

FIGURE 1. Effect of lockdown on athletes' BMI.

Note. Data for 941 athletes (682 men and 259 women), presented as means and standard deviations, and analyzed through repeated-measures ANOVA with 3 factors: period (before or during lockdown), sex, and level (low-level: athletes practicing in clubs at a local or regional level; high-level: athletes practicing at a national or international level). Regardless of sex or athletic level, no difference was detected between periods.

Total activity time (TAT) decreased for all athletes (205±228 vs. 160±251 min/wk). Before lockdown, TAT was longer for women than men ($p<0.01$) though this difference only concerned low-level athletes—while it was similar for both sexes during lockdown (Figure 2A). There was no significant differences between women and men for high level athletes though.

Before lockdown, in the male population, low-level athletes trained less than high-level ones ($p<0.001$), but no such difference was detected during lockdown. TAT for female athletes did not differ across levels either before or during lockdown.

AEE also diminished (from 4,537±3,718 MET-min/wk to 3,181±2,875 MET-min/wk), for both men and women. Before lockdown, there was again a difference between sexes that only concerned low-level athletes, with women expending more energy ($p<0.001$). Among males, before lockdown, EE was higher for high-level athletes than for low-level ones ($p<0.001$). During lockdown, however, EE was similar between levels (Figure 2B).

Sitting Time

Time spent sitting increased for both men and women during lockdown reaching 5.53±3,43 vs. 8.11±4.20 and 4.92±3,24 vs. 7.22±3.63 hours/day for men and women, respectively, but was higher for men compared with women before ($p<0.05$) as well as during ($p<0.01$) lockdown. This difference between sexes only concerned low-level athletes: sitting time did not differ between sexes before or during lockdown within the high-level population (Figure 2C).

Quality of Life Score

Total SF-12 scores, measuring quality of life, fell during lockdown (from 38.96±4.86 to 35.17±5.72, $p<0.001$) for both men and women. However, during lockdown, though only among low-level athletes, these scores were lower for women than men (34.6±5.9 vs. 35.4±5.6, $p<0.01$). High-level athletic activity among women thus tended to preserve quality of life.

Physical Component Summary (PCS) sub-scores

For low- and high-level athletes combined, women's pre-lockdown SF-12 PCSs were slightly higher than men's (+3.5%, $p<0.001$). These sub-scores fell during lockdown (from 17.1±2.4 to 15.6±2.7). Among high-level athletes alone, women's PCSs surpassed men's before (+6.5%, $p<0.01$), it was also the case among low level athletes ($p<0.05$), during lockdown there are no significant difference between men and women anymore for both levels (Figure 3B).

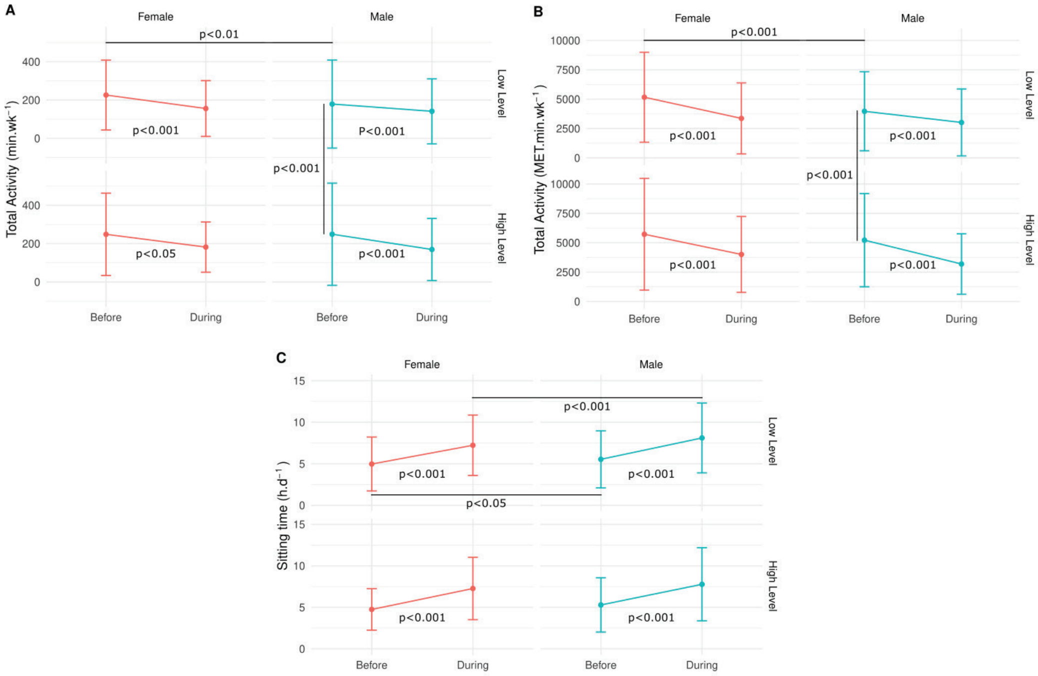

FIGURE 2. Effects of lockdown on (A) Total Activity Time (TAT), (B) Activity Energy Expenditure (AEE) and (C) Sitting Time, stratified by athletic level.
Note. Data for 941 athletes (682 men, of which 155 were high-level athletes; and 259 women, of which 59 were high-level athletes) collected using International Physical Activity Questionnaire, presented as means and standard deviations, and analyzed through repeated-measures ANOVA with 3 factors: period (before or during lockdown), sex, and level (low-level: athletes practicing in clubs at a local or regional level; high-level: athletes practicing at a national or international level).

Mental Component Summary (MCS) subscores

Overall, SF-12 MCSs dropped during lockdown (from 21.9±3.3 to 19.6±3.9, $p<0.001$), for all participants. MCSs among low-level athletes alone, during lockdown, were higher for men than for women ($p<0.001$). For women, high-level activity buoyed MCSs ($p<0.05$), just as was noted for quality of life (Figure 3C).

Apart from what is described above, we found no other

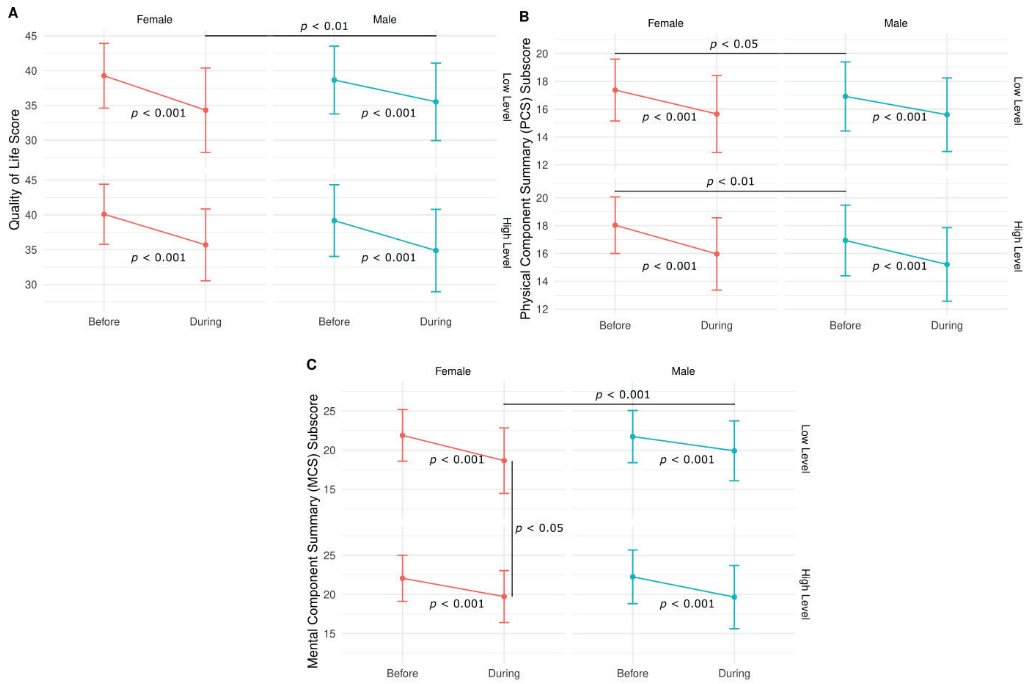

FIGURE 3. Effect of lockdown on (A) Quality of Life Score, (B) Physical Component Summary (PCS) subscore, and (C) Mental Component Summary (MCS) subscore, stratified by athletic level.
Note. Data for 941 athletes (682 men, of which 155 were high-level athletes; and 259 women, of which 59 were high-level athletes) collected using 12-Item Short Form Survey (SF-12), presented as means and standard deviations, and analyzed through repeated-measures ANOVA with 3 factors: period (before or during lockdown), sex, and level (low-level: athletes practicing in clubs at a local or regional level; high-level: athletes practicing at a national or international level).

differences when varying the groups studied (e.g. Female/Male, ...), and no correlation was found between the parameters studied except a correlation between height and mass (data not shown).

Discussion

The aim of this study was to determine the effects of COVID-19 lockdowns on physical activity and quality of life among athletes of different levels from 10 countries. There were no observed effects on body weight, regardless of athlete sex or level. Before lockdown, among low-level athletes, TAT and AEE was higher for women than for men, though there was no longer any difference during lockdown. During lockdown, TAT and AEE decreased for all athletes but did not differ between sexes at either athletic level. In general, PCSs fell during lockdown, with women scoring slightly higher than males before lockdown in both the low-level and high-level athlete subpopulations, but not anymore during lockdown.

Sitting time increased for low-level athletes during lockdown. Within this low-level athlete subpopulation, men spent more time seated than women did, both before and during lockdown. For high-level athletes, however, there was no difference in sitting time between the sexes.

Quality of life and MCSs were impacted during the lockdown in all subgroups, especially low-level female athletes. However, these variables were less severely affected among high-level female athletes.

Most studies focus on athletes practicing the same sport, or even on the same team of athletes; others have included larger populations (Pillay et al., 2020; Rampinini et al., 2021); but none have considered athletic levels of activity as did the present study. Yet results often differ by the level of activity or the sex of the athlete.

We did not observe any effect of the lockdown on BMI or body weight in either male or female athletes. Other studies have reported weight gain, as among Egyptian soccer players (Nassar et al., 2021). Needless to say that many studies have observed gains in body weight during the pandemic among the general population (Bonfanti et al., 2023; Chang et al., 2021).

In the current study, TAT was shortened for all athletes during the lockdown. Other authors have reported the similar finding. In Martin et al. (2021) study, when training frequency increased among recreational athletes, overall activity time did not. Considering student athletes, Izzicupo et al. (2021) noted a reduction in the time dedicated to sport and academics, although subjects still maintained active lifestyles. Additionally, Bourdas and Zacharakis (2020) observed a negative impact on overall PA during lockdown.

Among the low-level athletes in the present study, pre-lockdown TAT was longer for women than for men, though the gap was closed during lockdown. On the contrary, Martin et al. (2021) found that lockdown was negatively impacted women activity more than men, at the recreational level. In our study, low-level male athletes trained less than high-level male athletes before lockdown, but this difference did not carry over into the lockdown period as women's TAT was similar between low and high athletic levels.

AEE (MET-min/wk) also decreased for all athletes in our study. Washif et al. (2022) stated that "during lockdown, more than 50% of the athletes were unable to maintain prelockdown intensity during strength, endurance, speed, and/or plyometric training, change-of-direction, and technical training. The number of athletes who trained at the same frequency during lockdown was reduced by ~20% to 30%". Furthermore, just as reported by Gjaka et al. (2021), women expended more than men prior to the lockdown. Such findings were observed among our subgroup of low-level athletes. Also, before lockdown AEE was greater among high-level male athletes compared with low-level male athletes, though there was no difference during lockdown period.

Like Gjaka et al. (2021), we found that sitting time increased during lockdown. This was true for both men and women in our study. Additionally, within the low-level athlete subgroup, men spent more time sitting than women both before and during lockdown.

Quality of life score worsened during lockdown for athletes of both sexes. Ferreira et al. (2021) reported lower quality of life for women, relative to men, during lockdown. In the present study, quality of life score under lockdown was lower for women only within the subgroup of low-level male and female athletes. High-level athletic practice apparently conferred an advantage to women in terms of quality of life.

MCSs also fell during lockdown for our subjects. Baumann et al. (2021) state that "impaired mental health," defined by an MCS below the first quartile, was more common among women in their study. However, women's MCSs in our study were only lower than men's within the low-level athlete population and solely during lockdown. In addition, high-level female athletes had higher lockdown MCSs than low-level female athletes. As with quality of life, high-level athletic activity appeared to lessen the decline in MCSs.

It is interesting to note that most participants in the current study came from Jordan, as there were over twice as many men as women, and only 23% of the subjects were high-level athletes. Most studies of the impact that COVID-19 lockdowns used surveys similar to what we used in our current study, but McCarthy et al. (2021) employed a smartphone tracking app to compare exercise before, during, and after lockdown. Through this approach, the authors were able to collect data from a large number of people (5,395 individuals). Such an app may be of value for ensuring study data are more representative of the wider population.

This study relied on self-reported data and a cross-sectional design, limiting the accuracy and generalizability of the findings. Sport-specific impacts were not analyzed, and subgroup sizes were small. Future research should use longitudinal data, analyze sport-specific responses, examine sex differences, and evaluate the long-term effectiveness of the online and home-based training programs. Additionally, it's essential to consider the lockdown health impacts, especially in master athletes/aging population such as hospitalized individuals.

Conclusions

As revealed in previous studies, COVID-19 lockdown negatively impacted athletes' Total activity time, activity energy expenditure, and quality of life. This impact was apparently greater among low-level athletes, particularly females. High-level athletes of either sex were more likely to pursue high-intensity training at a high frequency. Among women, being a high-level athlete appeared to lessen the decline in one's MCS and quality of life.

In addition, to pursue training during lockdown and maintain activity levels, some athletes resort to online workouts, fitness apps, and home-gym exercise (Baumann et al., 2021; Djemai et al., 2022). Pucsok et al. (2021) observed that a home-based exercise program effectively preserved speed, agility, and explosive power. Font et al. (2021) reported that a structured home-based training program for top-level handball players, during lockdown, preserved lower-limb explosive strength but not aerobic capacity. With autonomous practice becoming ever more common among athletes, further investigation into the efficacy of home-based programs, mobile apps, distance coaching, and other solutions would be of interest.

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Conflict of interest

The authors report no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Association Between Body Composition Metrics and Heart Rate Recovery in Female Cricketers: A Cross-Sectional Study

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Abstract

Heart rate recovery (HRR) is a recognized non-invasive marker of cardiovascular fitness and autonomic nervous system function. This study aimed to investigate the association between HRR and anthropometrically derived indicators of body composition in female cricket players, and to identify the most reliable adiposity-related predictor of HRR during field-based fitness screening. A total of 100 female cricketers (aged 16–26 years) were recruited from eight divisions of the Bangladesh National Women's Cricket League (2021–2022). Participants underwent a modified Harvard Step Test, and HRR was recorded at 1 and 2 minutes post-exercise. Anthropometric measures included body mass index (BMI) z-score, waist circumference (WC), waist-to-height ratio (WHtR), and body fat percentage (estimated via skinfolds). Data were analysed using Pearson's correlation and multiple linear regression (SPSS v26). The results revealed that all indicators were negatively correlated with HRR at 1 minute ($r=-0.159$ to -0.223, $p<0.001$), and to a lesser extent with HRR at 2 minutes ($r=-0.098$ to -0.138, $p<0.05$). Body fat percentage emerged as the only significant predictor of HRR at 2 minutes in regression analysis ($\beta=-0.318$, $p=0.009$). In summary, the study reveals a inverse association between body composition indicators (BMI, body fat percentage, waist circumference, and WHtR) and heart rate recovery in female cricketers, with body fat percentage being a key predictor of post-exercise HRR. These findings emphasize the relevance of body composition in evaluating cardiovascular fitness and highlight the value of the Harvard Step Test as a practical assessment tool. Further research is needed to clarify the physiological mechanisms behind these associations and to inform individualized training strategies for female athletes.

Keywords: *heart rate recovery, body composition, female cricketers, cardiovascular fitness, Harvard step test*

Introduction

Cardiovascular fitness and body composition are two interrelated dimensions that influence both athletic performance and health outcomes in sport (Abu Hanifah et al., 2013; Carnethon et al., 2005). In cricket, where intermittent bursts of activity require a balance between endurance and explosive power, these factors are particularly relevant, especially among female players whose physiological responses are understudied (Azam et al., 2022).

Body composition refers to the proportion of fat, lean tissue, bone, and water in the human body (Chao et al., 2008). In applied field settings, anthropometric measurements such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and skinfold-derived body fat percentage are commonly used to estimate adiposity (Pelegrini et al., 2015). Although true body composition is best assessed using advanced laboratory methods such as DEXA, the use of indirect anthropometric estimates is widely accepted and practi-

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cal for large-scale or field-based studies (Duren et al., 2008; Katanic et al., 2023).

In female cricketers, body composition is pivotal in determining agility, strength, and power (Herridge et al., 2020; Koley et al., 2012). Athletes with a higher lean body mass-to-fat mass ratio often exhibit enhanced athletic performance due to increased muscle power and reduced body fat, which contribute to better endurance and faster recovery (Aikawa et al., 2020).

Heart rate recovery (HRR) is a valuable indicator of cardiovascular fitness and the body's ability to return to a resting state after physical exertion (Faria & Drummond, 1982; Römer & Wolfarth, 2022). Rapid HRR has been consistently associated with favorable cardiovascular outcomes and better endurance performance (Mahon et al., 2003; Radaković et al., 2024; Singh et al., 2007, 2008; Watanabe et al., 2001). For cricketers, especially during prolonged or high-intensity matches, efficient HRR may serve as a critical performance asset (David & Ian, 2017).

Physical fitness is a crucial aspect of performance in any sport, and cricket is no exception (Williams, 1965). As the popularity of women's cricket continues to grow, understanding the relationship between various physiological factors and performance becomes essential. One such factor is the body composition of female cricketers, which can significantly impact their cardiovascular health and overall athletic abilities. Previous research has explored the relationship between heart rate recovery (HRR) and various cardio-metabolic factors, particularly in pediatric and adolescent populations (Laguna et al., 2013; Lin et al., 2008; Singh et al., 2008). According to one study, 39% of the diversity in HRR can be attributed to chronological age, sex, blood pressure, and Body Mass Index (Singh et al., 2008). However, these studies rarely included elite female athletes, and there remains a lack of data on the predictive value of specific anthropometric indicators of body composition on HRR in adult female cricketers.

According to a recent study, boys but not girls showed an unfavorable connection between maximum heart rate, homeostatic model evaluation, waist circumference, and skinfold thickness (Laguna et al., 2013). These findings suggest that HRR is consistently correlated with body composition factors. Optimizing athletic performance and ensuring cardiovascular health are critical priorities in competitive sports (Bermon & Adami, 2019). This quest for excellence often involves the meticulous examination of various physiological and biomechanical factors that contribute to an athlete's capabilities. Within this context, cricket has risen to prominence as a fiercely competitive and physically demanding sport, capturing the hearts of millions around the globe. In Bangladesh, where cricket holds a special place in the national psyche, the commitment to nurturing talent and improving performance among female cricketers has never been more pronounced.

The success and prowess of female cricketers extend beyond the boundaries of skill and technique. To unravel the full potential of these athletes, it is essential to delve into the intricacies of their physiological makeup (Mandoli et al., 2021). One such aspect that has gained increasing attention in sports science is heart rate recovery (HRR), a powerful indicator of cardiovascular fitness and an essential component of an athlete's overall well-being.

This study addresses a gap in the current literature by focusing on female cricketers in Bangladesh a population underrepresented in prior HRR research. While some studies have explored the association between HRR and generalized adiposity indicators, specific anthropometric predictors such as WHtR and field-derived body fat percentage have not been thoroughly examined in this group. Given that impaired autonomic regulation has been linked to adolescent obesity (Baum et al., 2013; Yakinci et al., 2000), a deeper understanding of these relationships in adult female athletes is warranted.

Therefore, the present investigation aimed to examine the relationship between anthropometrically derived indicators of body composition and heart rate recovery following submaximal exercise in female cricket players. It also sought to determine which of these indicators particularly adiposity-related measures exert the strongest predictive influence on HRR performance.

We hypothesized that female cricketers with higher body fat percentage would exhibit slower heart rate recovery, while those with greater lean mass and lower adiposity would recover more efficiently due to superior cardiovascular adaptation.

Methods

Study Design and Participants

A cross-sectional design was employed. A total of 100 female cricketers (mean age =21.8±0.3 years) were randomly selected from participants in the Bangladesh National Women's Cricket League (2021–2022). These athletes represented eight regional divisions and were aged between 16 and 25 years. Prior to enrolment, all participants received a verbal and written explanation of the study's purpose, procedures, and potential risks. Informed written consent was obtained from each participant in accordance with ethical guidelines.

Ethical Consideration

This study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and approved by the Research Ethics Committee of the Faculty of Health and Life Science, Daffodil International University (Ref: FHLS-REC/DIU/2024/0013, dated May 6, 2024). All participants provided written informed consent prior to data collection. Anonymity and confidentiality were maintained throughout the research process.

Blood Pressure

With both feet flat on the floor, each participant was seated upright with her right upper arm positioned at heart level. Prior to measuring blood pressure and heart rate, participants were instructed to rest for five minutes. Systolic (SBP) and diastolic (DBP) blood pressure were measured using a stethoscope and a mercurial sphygmomanometer (ALPK2 Blood Pressure Monitor, Tokyo, Japan). Three readings were taken at two-minute intervals, and the average values of SBP and DBP were used for analysis.

Anthropometric Data

Body height was recorded with a portable stadiometer (Seca 213, Seca, Hamburg, Germany), and body weight measured while wearing lightweight clothing was assessed using a digital scale (Equinox Ltd., Gurgaon, Haryana, India). Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. The BMI z-score is a statistical measure of how an individual's BMI compares to the average BMI for their age and gender. Body fat percentage was estimated using a skinfold caliper. Waist circumference (WC) was measured with a non-elastic tape (Seca 201, UK), positioned halfway between the lowest rib margin and the hip. The waist-to-height ratio (WHtR) was calculated by dividing each participant's waist circumference (WC) by her body height (BH). These anthropometric indicators have been applied and thoroughly described in numerous previous studies involving athletes (Bjelica et al., 2025; Górnicka et al., 2022; Osayande, Azekhumen, & Obuzor, 2018).

Hart Rate Data

The Harvard Step Test began with each participant stepping on and off a standardized step box for 5 minutes, following a rhythm of 30 cycles per minute, synchronized with a metronome set at 120 beats per minute (bpm; Bunn et al., 2017). A fingertip pulse oximeter (Dr Trust USA Professional Series, Nureca Limited, Mumbai, India) was attached to one of the participant's fingers to continuously monitor heart rate throughout the exercise. Maximum heart rate was recorded during the final minute of the step test. Participants who reached a heart rate exceeding 200 bpm, exhibited respiratory distress, or were unable to continue were immediately withdrawn from the test. Upon completion or early termination, individuals were instructed to sit and rest. The total exercise duration (in seconds) and heart rates at 1 and 2 minutes post-exercise were recorded. Heart rate recovery at 1 minute (HRR1min) and 2 minutes (HRR2min) was calculated as the difference between peak heart rate during exercise and heart rate at each respective recovery time point.

UP UP Down Down

FIGURE 1. Harvard Step Test Method

Statistical Analysis

The collected data were analyzed using descriptive statistics and inferential statistics. The mean and standard deviation were calculated for each group, and the Pearson correlation test was used to determine the correlation between each HRR parameters (HRR1min and HRR2min) with body composition measures (BMI z-score, body fat percentage, WC and WHtR). A p-value of less than 0.05 was considered statistically significant. The data were analyzed using statistical software SPSS version 26 (IBM Corp., Armonk, NY, USA).

Results

Table 1 presents the descriptive statistics for a sample of 100 female cricket players. According to the data analysis, the mean age of the participants was 21.8±0.3 years. On average, the players were 150.6±6.2 cm tall and weighed 48.7±4.5 kg. The average body mass index (BMI) was 20.01±2.4 kg/m², while the mean body fat percentage was 19.7±14.6%.

Table 1. Participants' initial traits and workout specifications.

Variables	Mean	SD
SBP (mmHg)	112.9	10.5
DBP (mmHg)	64.9	10.6
Pulse rate (beats/min)	83.3	11.1
Height (cm)	150.6	6.2
Weight (kg)	48.7	4.5
BMI (kg/m²)	20.0	2.4
BMI z-score	0.2	1.6
Body fat (%)	19.7	14.6
WC(cm)	78.6	12.9
WHtR	0.47	0.1
Peak heart rate (beats/min)	177.6	14.5
Heart rate at 1 min rest (beats/min)	144.7	15.5
Heart Rate at 2 min rest (beats/min)	131.3	14.6
HRR 1 min	41.0	11.9
HRR 2 min	54.5	11.9

The average systolic blood pressure (SBP) was 112.9±10.5 mmHg, and the average diastolic blood pressure (DBP) was 64.9±10.6 mmHg. The resting heart rate was 83.3±11.1 beats per minute (bpm), while the mean maximum heart rate was 177.6±14.5 bpm.

According to the results of the correlation analysis (Table 2), the BMI z-score, body fat %, WC, and WHtR all had a negative connection with HRR 1 min (r=-0.159, -0.195, -0.223, and -0.199 respectively). The table also showed that all body composition measurements were adversely connected with HRR2 min in female crickets (r=-0.113, -0.138, -0.130, and -0.098, respectively).

Table 2. Pearson correlation analysis between HRR parameters and body composition.

Body Composition	HRR 1 min		HRR 2 min	
	r	p	r	p
BMI z-score	-0.159	<0.001	-0.113	0.042
Body Fat (%)	-0.195	<0.001	-0.138	0.012
WC (cm)	-0.223	<0.001	-0.130	0.006
WHtR	-0.199	<0.001	-0.098	0.021

Note. NS—Not significant, BMI—Body mass index, HRR—Heart rate recovery, WC—Waist circumference, WHtR—Waist height ratio.

According to the results of the multiple regression analysis (Table 3), only body fat percentage was found to be adversely correlated with females' HRR 2 min (p=0.009). For BMI z-score, none of the correlations at 1 minute or 2 minutes post-exercise are statistically significant. Waist Circumference and Waist-to-Height Ratio do not show statistically significant correlations with HRR at either 1 minute or 2 minutes post-exercise

Table 3. Standardized coefficients (β) between HRR and body composition (multiple linear regression)

Body Composition	HRR 1 min		HRR 2 min	
	β	p	β	p
BMI z-score	-0.113	NS	-0.008	NS
Body Fat (%)	-0.225	NS	-0.318	0.009
WC (cm)	0.197	NS	0.081	NS
WHtR	-0.071	NS	0.137	NS

Note. NS—Not significant, BMI—Body mass index, HRR—Heart rate recovery, WC—Waist circumference, WHtR—Waist height ratio

Discussion

Heart rate recovery (HRR) after exercise serves as a well-established physiological marker of cardiovascular health, reflecting the body's ability to restore autonomic balance and cardiac efficiency following exertion (Huang et al., 2005).

The present study investigated the relationship between HRR and several anthropometric indicators commonly used to estimate body composition metrics in field settings. It is important to distinguish between body composition as a physiological construct referring to the relative proportions of fat, lean mass, bone, and water in the human body (Chao et al., 2008) and the proxy measures employed to estimate it, such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and skinfold-derived body fat percentage (Pelegrini et al., 2015). These metrics, though indirect, offer practical value in large-scale assessments of adiposity and cardiometabolic risk.

Our findings revealed an inverse association between body composition metrics and HRR, suggesting that increased adiposity may impair autonomic recovery. Body fat percentage emerged as the strongest predictor of HRR at 2 minutes post-exercise in female cricketers. Statistically significant negative correlations were observed between HRR (at both 1 and 2 minutes) and multiple anthropometric measures including BMI z-score, body fat percentage, WC, and WHtR indicating that individuals with higher adiposity values experienced slower recovery. These findings are consistent with previous research emphasizing the detrimental impact of excess fat mass and central obesity on cardiovascular function and recovery capacity (Baruah Hazra, 2023).

At 1 minute post-exercise, all body composition metrics exhibited negative correlations with HRR, indicating that individuals with higher BMI z-scores, greater body fat percentages, larger waist circumferences, or higher WHtR values experienced delayed initial recovery. However, at the 2-minute recovery mark, while body fat percentage and WC maintained negative associations with HRR, the correlations weakened for BMI z-score and WHtR. These nuanced variations in correlations across recovery times suggest potential distinctions in the mechanisms governing immediate and delayed cardiovascular recovery dynamics.

The analysis of beta coefficients provided nuanced insights into the specific predictive capacities of body composition metrics on HRR. Notably, body fat percentage emerged as a significant predictor of delayed HRR, displaying a robust negative association specifically with 2-minute recovery. This distinctive influence of body fat percentage on delayed recovery aligns with established literature emphasizing the pivotal role of adiposity in cardiovascular health outcomes (Heymsfield et al., 2005; Söğüt et al., 2018). However, the non-significant beta coefficients for BMI z-score, WC, and WHtR in predicting HRR suggest potential limitations in their contributions to cardiovascular recovery dynamics.

Our research was contrasted with previously released findings. The European Youth Heart Study evaluated HRR 1 min, HRR 3 min, and HRR 5 min, and found that WC was linked with HRR 3 min in boys but not HRR characteristics in girls (Laguna et al., 2013). The researchers looked at the relationship between HRR and a number of cardio-metabolic risk factors, including measurements of body composition (Laguna et al., 2013; Lin et al., 2008; Singh et al., 2008). Results that were different from ours would have resulted from these factors and the various HRR values used. The HRR 1 min and HRR 2 min were examined in our study. Both HRR parameters have been shown to be accurate and reliable indicators of HRR (Shetler et al., 2001). The different exercise regimes could be another factor. While other investigations, which were carried out in controlled laboratory settings, used active resting periods for treadmills (Lin et al., 2008; Singh et al., 2008) or cycle ergometers (Laguna et al., 2013), this study used mass screening step tests and passive resting recovery. Numerous workout regimes have been proven to affect the results of HRR (Buchheit et al., 2009; Crisafulli et al., 2003). Girls' body fat deposits under the skin and in the total body fat both accumulate (Staiano & Katzmarzyk, 2012). When exercising, the heart rate (HR) increases because the parasympathetic nervous system stops working, and further increases in HR are mediated by the sympathetic nervous system (Buchheit et al., 2007; Drott et al., 1994; Falcone et al., 2005; Hunt, 2001). The first minute of HRR during recovery is caused by vagal reactivation, while the second minute and beyond is caused by a combination of vagal drive, a decrease in the sympathetic pathway, and metabolite clearance (Buchheit et al., 2007; Imai et al., 1994; Laguna et al., 2013; Ohuchi et al., 2000). It has been demonstrated that decreased vagal activity is a predictor of all-cause mortality in both healthy adults and post-myocardial infarction (MI) patients, which has sparked greater interest in HRR in adults and its link with mortality (Cheng et al., 2003; Cole et al., 2000; Nishime et al., 2000; Schwandt et al., 2010; Watanabe et al., 2001). According to a study, there is less parasympathetic drive among MI patients when the sympathetic route is dominant (Rothschild et al., 1988). An increased risk of cardiovascular mortality is indicated by HRRs of less than 12 bpm or 18 bpm during active rest, and less than 43 bpm for HRRs of 1 and 2 minutes, respectively (Cole et al., 2000).

The huge sample size used in this study is its main strength. The modified Harvard Step Test may be utilized as an alternate fitness evaluation tool, according to the research population who used it as a tool. The step test is simple, affordable, portable, and generally safe (Kizilbash et al., 2006; Watanabe et al., 2001b). Due to its portability and need for little equipment, the activity in this study may be completed by five students at once. Furthermore, because it is not a laboratory setting, the atmosphere is more easygoing and requires little specialized training. Each test often took less than 10 minutes to complete, and this short time frame is perfect for on-site mass testing.

The intricate interplay between body composition metrics and HRR holds substantial clinical implications. The significant association between body fat percentage and delayed HRR underscores the importance of integrating adiposity assessments into risk stratification for cardiovascular health post-exercise. Incorporating body fat percentage evaluations in cardiovascular fitness assessments may refine risk assessment strategies and guide targeted interventions aimed at optimizing recovery dynamics (Dewi et al., 2017; Djaafar et al., 2019; Karunasena et al., 2014). However, further research endeavors are imperative to elucidate the underlying mechanisms driving these associations. Exploring potential mediators, such as autonomic nervous system function, inflammatory markers, or hormonal responses, could provide deeper insights into the physiological pathways linking body composition metrics to HRR. Additionally, longitudinal studies encompassing diverse populations, accounting for lifestyle factors, comorbidities, and physical activity levels, are crucial to validate these findings and enhance the generalizability and applicability of results to broader populations.

Limitations and Considerations

This study is subject to several limitations that warrant careful consideration. The cross-sectional nature of the study impedes establishing causality or inferring temporal relationships between body composition metrics and HRR. Additionally, unmeasured confounders, such as fitness levels, medications, or hormonal variations, might influence the observed associations. Thus, cautious interpretation and careful consideration of these limitations are essential when translating these findings into clinical practice or population-level interventions.

In summary, this study unravels the intricate relationship between body composition metrics and cardiovascular recovery dynamics post-exercise. While correlations elucidate associations between body composition and HRR, beta coefficients highlight body fat percentage as a key predictor of delayed recovery. Integrating body composition assessments into cardiovascular fitness evaluations may bolster risk assessment strategies, paving the way for tailored interventions to optimize cardiovascular recovery and promote better health outcomes.

Conclusion

In conclusion, this research highlights the inverse relationship between body composition metrics (such as BMI, body fat percentage, waist circumference, and waist-to-height ratio) and heart rate recovery (HRR) in female cricketers. Body fat percentage emerged as a significant predictor of HRR post-exercise. The study underscores the importance of considering body composition in assessing cardiovascular fitness among female athletes and suggests the practical utility of the Harvard Step Test in evaluating their health. However, further exploration is warranted to understand the complex interplay between body composition and cardiovascular parameters, especially in the context of tailored training and health interventions for women in cricket. Overall, this study provides valuable insights into enhancing performance and well-being among female cricketers.

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Conflicts of interest
The authors declare that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

The Effect of Fundamental Movement Skills Training Implemented with the Differential Learning Approach on the Attention Skills of Elementary School Students

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Abstract

Physical activity is essential for the healthy growth and development of children, supporting motor skills as well as cognitive and psychosocial abilities. Research has demonstrated that children who engage in regular physical activity show improvements in executive functions, memory, and attention. The Differential Learning approach promotes variability in movement experiences, minimizing explicit instructions and corrections, which encourages adaptability and cognitive-motor interactions crucial for attention development. This study aims to examine the impact of a fundamental movement skills training program based on the Differential Learning approach on the attention skills of elementary school students. The sample consisted of 24 students (13 male, 11 female, aged 8-9 years) from the 3rd grade of a school in Beykoz, Istanbul. The program, lasting 13 weeks with two hours of weekly sessions, utilized Yellow Cards from Physical Activity Cards and focused on fundamental movement skills. Attention was assessed using the D2 Test of Attention as both a pre-test and post-test. Descriptive statistics and a Paired Sample T-test were used to analyze the data, revealing significant differences in psychomotor speed, quality of work, and attention balance speed ($p<0.05$). The mean scores for psychomotor speed increased from 2.50 to 4.54, work quality from 2.17 to 3.33, and speed-attention balance from 2.04 to 4.54, indicating a statistically significant improvement in these subdimensions. These results suggest that the Differential Learning approach effectively contributes to the development of attention skills in 3rd grade students.

Keywords: *differential learning, motor development, attention, physical activity, cognitive skills*

Introduction

Physical activity is a key factor that plays a central role in the healthy growth and development of children. Regular physical activities not only support the development of motor skills but also positively contribute to cognitive and psychosocial abilities (Diamond, 2015; Lubans et al., 2016). Research has shown that children who regularly engage in physical activity show improvements in executive functions, memory, and attention processes (Best, 2010; Pesce, 2012). At the core of this effect are the positive impacts of physical activity on brain structure and function.

Regular exercise leads to structural and functional changes in brain areas responsible for cognitive functions, such as the prefrontal cortex and hippocampus, thereby enhancing attention skills (Erickson et al., 2011). Furthermore, physical activity has been shown to support neuroplasticity by increasing connections between nerve cells, which in turn makes cognitive functions more efficient (Hillman et al., 2014). In this context, regular participation in physical activity at an early age is emphasized as potentially having long-term effects on

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attention skills (Tomporowski et al., 2011).

Children in elementary school age go through a critical period in terms of both motor and cognitive development (Van der Fels et al., 2015). Acquiring fundamental movement skills at this age lays the foundation for lifelong physical activity habits, while also contributing to the development of cognitive functions (Gallahue & Donnelly, 2003). The development of children's fine and gross motor skills is directly related to cognitive processes such as executive functions, attention, memory, and problem-solving (Diamond & Lee, 2011).

The Ministry of National Education (MEB) has developed Physical Activity Cards under the International Inspiration Project as part of the Primary School Physical Education and Play course curriculum, which has been gradually implemented starting from the 1st grade since the 2012-2013 academic year (MEB, 2012a; MEB, 2012b). This program aims to contribute to the psychomotor, cognitive, and affective development of students through play and physical education. Through the cards, students are given the opportunity to develop their movement skills interactively, both individually and in group activities. İrez et al. (2013) also stated that Physical Activity Cards (PAC) are highly useful materials for skill development in physical education classes.

Physical education classes should not only be viewed as an activity domain that enhances children's physical fitness levels, but also as a holistic educational area that supports their cognitive and psychosocial development. Specifically, it has been noted that game-based and movement-focused activities strengthen children's problem-solving skills, creativity, and social interactions (Lakes & Hoyt, 2004). However, an important question arises regarding how much the teaching models applied in physical education classes support students' individual learning processes.

Traditional physical education approaches typically standardize teaching by offering the same methods to all students. However, this approach may not adequately address the individual differences of students and might include limited elements that support cognitive development (Rink, 2013). In traditional models, repetitive routine activities and teacher-centered guidance dominate, while there is a noticeable lack of personalized feedback for students and teaching methods adapted to individual learning paces (Kirk, 2010). On the other hand, contemporary educational approaches suggest that practices that encourage active student participation, stimulate cognitive processes, and enrich individual learning experiences could be more effective (Metzler, 2017).

At this point, the necessity of implementing the Differential Learning approach arises. Applying the Differential Learning approach in physical education classes could provide more benefits for students' motor skill and cognitive development. This approach aims to shape the teaching process by considering students' individual learning speeds, interests, and physical capabilities (Schempp & McCullick, 2010).

Differential Learning departs from traditional repetition-based teaching by offering a learning environment based on individual and variable experiences (Schöllhorn, 2016). In this approach, the natural variability of movements is supported with minimal repetition, and individual differences are prioritized in the learning process. In Differential Learning, instead of repeatedly practicing the same movement, students are encouraged to experience different variations continuously, creating more flexible, adaptable, and lasting learning processes (Henz & Schöllhorn, 2016). This method not only aims to develop individuals' motor skills but also actively encourages them to use cognitive processes (Schöllhorn et al., 2009).

Attention refers to the ability of individuals to focus on and respond to stimuli in their environment. Attention plays a critical role in educational and developmental processes, as efficient learning requires the individual to be able to focus on a specific subject. Attention can be studied in various types, and these types may influence individuals' learning processes in different ways (Posner & Petersen, 1990).

Recent studies have shown that the Differential Learning Approach (DL) can have positive effects not only on motor skills but also on cognitive functions and attention processes (Schöllhorn et al., 2009; Henz & Schöllhorn, 2016). One of the most important aspects of this approach is its encouragement of individuals to consciously plan their movements and continuously generate new solutions to changing stimuli (Wagner & Schöllhorn, 2014). Activating cognitive processes in this way can contribute to the development of executive functions, problem-solving skills, and attention processes (Henz & Schöllhorn, 2017).

Specifically, when examining attention skills, the Differential Learning approach has been noted to improve children's ability to focus, adapt to changing environmental factors, and sustain attention (Buszard et al., 2017). Individuals who are constantly exposed to variable stimuli must actively direct their attention during the learning process, which helps develop their attention control mechanisms (Henz, Wagner, & Schöllhorn, 2018). Furthermore, the constant variation and movement experiences brought by the Differential Learning approach contribute to the holistic development of attention and cognitive processes by strengthening problem-solving skills (Schöllhorn, 2016).

This study examines the effect of the Differential Learning approach-based movement skills training program on the development of attention characteristics in elementary school students. The research uses a pre-test/post-test model to evaluate changes in the students' attention levels. In this context, the study is expected to contribute to understanding the effects of different teaching approaches in physical education and sports on cognitive development. The aim of this study is to investigate the effects of a basic movement skills training program implemented with the Differential Learning approach on the development of attention characteristics in elementary school students.

Material and methods

The ethical approval for the study was obtained from the Ethics Committee of a state university (Ethics Committee Approval Date and Number: 31.08.2022 / 06-2). In addition, the necessary official permissions were obtained from the Provincial Directorate of National Education (Ethics Committee Protocol No: 359829) and the school administration where the study was conducted. The parents of the students participating in the study signed written consent forms. It was clearly stated to the participating students and their parents that their performance during the implementation process would not affect their grades in any way. All participants voluntarily participated in the study. The research was conducted in the fall semester of the 2022-2023 academic year, with the students in the sample group during class hours under the supervision of their classroom teacher.

Research Design

The research is designed based on a single-group pre-test/post-test model, which is one of the experimental approaches. Experimental research is used to examine the effect of the program applied by the researcher (independent variable – basic movement skills training with the differential learning approach) on the specified study group (dependent variable – attention characteristics) (Campbell & Stanley, 1963).

Participants

In this study, the sample group consists of 24 students (13 male students and 11 female students) from a 3rd-grade class of 9-year-olds at an elementary school in Beykoz district, Istanbul. The students' average age was 8.63±0.50 years, their average height was 136.21±5.20 cm, and their average weight was 35.17±6.31 kg.

D2 Test of Attention

The D2 Test of Attention was used to determine the attention characteristics of the students. The adaptation and norm studies of the D2 Test of Attention in Turkey were carried out by Toker (1993). The test's split-half reliability was found to be 0.94. In the validity study, a correlation of 0.44 was found between the total score and the WISC-R coding subtest (Kirici, 2008).

D2 Test of Attention, is a psychological test developed by Brickenkamp and Zillmer in 1982 (Brickenkamp & Zillmer, 1998). This test is used to assess individuals' selective attention and concentration abilities (Baysal, 2019). The test consists of a single-page form with 14 rows, each containing 47 figures, totaling 658 figures. The test uses the letters 'd' and 'p.' Some of the letters may have one, two, three, or four dots above or below them. The letters, which can appear in 16 different ways, vary based on the position and number of dots. The main task for the person taking the test is to identify the 'd' letter with exactly two dots. These letters can appear in three different forms in the test. The participant is given 20 seconds to complete the task in each row. The total administration time for the test is approximately eight minutes. In group applications, an additional 7-8 minutes may be required for preparation, ensuring the instructions are understood, and conducting a sample trial (Öcal & Aybek, 2023).

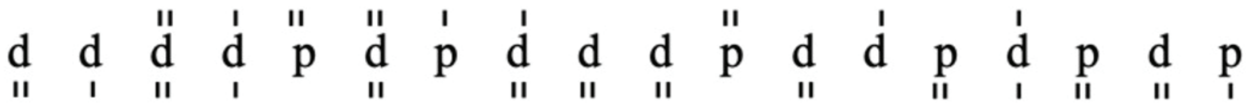

FIGURE 1. Examples of letters found in the D2 Test of Attention

Test scores are calculated using two separate scoring keys. Six different scores are obtained during the test. These are: TN (total number of figures marked), E1 (number of figures skipped), E2 (number of incorrectly marked figures), CP (number of correctly marked figures), TN-E (test performance), and E% (error rate).

Experimental treatment

The physical activity exercises and games based on fundamental movement skills included in the physical activity cards were implemented during the fall semester of the 2022-2023 academic year in physical education and play classes for 13 weeks, with two hours per week, totaling 26 class hours. During the implementation process, attendance was taken at the beginning of each lesson, and students who demonstrated regular participation throughout the 13-week period were identified. Students who missed three consecutive lessons were excluded from the study due to absenteeism and were not included in the groups.

The topics in the physical activity cards (displacement movements, balancing movements, object control movements, and combined movements) were implemented based on the Differential Learning approach, with no routine repetitions or corrective external feedback provided. The exercises were diversified through various activities, including different surfaces such as artificial turf, asphalt, and tiled floors, small and large spaces, various cognitive tasks, additional challenges, and the use of materials of various sizes and types (balls, jump ropes, markers, cones, hoops, etc.). These activities were performed under both indoor and outdoor skill conditions, in individual, pair, and group work formats.

The application process of the Differential Learning approach was based on varying the movements and presenting each movement in different variations, rather than repeating the same movements continuously. This approach accelerated students' learning processes and supported skill development. Additionally, changing the directions of the movements aimed to increase the flexibility of the children's motor skills; for example, movements originally performed forward were varied by performing them backward or sideways. Increasing the difficulty level by introducing more complex tasks stimulated students' development without overwhelming their skill levels. Applying the same movement with different technical variations allowed students to understand and apply different forms of the movement by making technical adjustments.

Each session was divided into warm-up, main, and cool-down phases and was applied in the form of games. The tests and game applications in the research were carried out by the researcher, a sports expert and physical education teacher.

Data Analysis

The data analysis was conducted using the SPSS Statistics 25.00 program (IBM Corp., Armonk, NY, USA). In determining the analysis techniques, the skewness and kurtosis values of the variables were considered to evaluate the normality distribution. It was assumed that variables with skewness and kurtosis values within the range of ±2 exhibited a normal distribution (George & Mallery, 2010).

Descriptive statistics, including the arithmetic mean (X), standard deviation (Ss), minimum (Min.), and maximum (Max.) values, were reported. The comparison of pre-test and post-test scores was performed using the Paired Sample t-test. The significance level was set at $p<0.05$.

Results

Table 1 presents the descriptive statistics of the physical characteristics of the participants in the study group.

It was observed that 45.8% of the 24 participants in the

Table 1. Demographic Information

N=24	Participants	
	n	%
Gender		
Female	11	45.8
Male	13	54.2
Handedness		
Right-handed	22	91.7
Left-handed	2	8.3
Age (years)		
Mean±SD		8.63±0.50
Min-Max		8.00-9.00
Height (cm)		
Mean±SD		136.21±5.20
Min-Max		125.00-147.00
Body Weight (kg)		
Mean±SD		35.17±6.31
Min-Max		25.00-47.80

Table 2. Descriptive Statistical Information of the Study Group's D2 Test of Attention Scores

Participants N=24	Pre-Test						Post-Test					
	Mean	SD	Min	Max	Skewness	Kurtosis	Mean	SD	Min	Max	Skewness	Kurtosis
D2 Attention Test												
TN (Psychomotor Speed)	2.50	1.10	1.00	5.00	0.11	-0.37	4.54	0.72	3.00	5.00	-1.30	0.34
E (Quality of Work)	2.17	1.17	1.00	5.00	0.72	-0.19	3.33	1.01	2.00	5.00	0.64	-0.59
TN-E (Speed-Attention Balance)	2.04	0.91	1.00	3.00	-0.09	-1.85	4.54	0.72	3.00	5.00	-1.30	0.34
FR (Sustained Attention Capacity)	2.63	0.97	1.00	4.00	-0.70	-0.49	2.46	0.93	1.00	5.00	0.66	1.23

study group were girls and 54.2% were boys; 91.7% were right-handed and 8.3% were left-handed; the average age was 8.63 years, with an average height of 136.21 cm and an average body weight of 35.17 kg.

Descriptive statistical information regarding the study group's D2 Test of Attention scores is provided in Table 2.

When we look at the pre-test mean scores of the D2 Test of Attention for the study group, the psychomotor speed mean score is 2.50, the work quality mean score is 2.17, the speed-attention balance mean score is 2.04, and the sustained attention power mean score is 2.63.

When we examine the post-test mean scores of the D2 Test of Attention for the study group, the psychomotor speed mean score is 4.54, the work quality mean score is 3.33, the speed-attention balance mean score is 4.54, and the sustained attention power mean score is 2.46.

The results of the comparison between the pre-test and post-test scores of the D2 Test of Attention for the study group are shown in Table 3.

There was no significant difference between the pre-test and post-test scores for attention span ($p>0.05$); however, a significant difference was found between the pre-test and post-test scores for psychomotor speed, work quality, and speed-attention balance ($p<0.05$).

Table 3. Comparison of Pre-Test and Post-Test Scores of the D2 Test of Attention for the Study Group

Participants N=24	Pre-Test		Post-Test		t	p
	Mean	SD	Mean	SD		
D2 Test of Attention						
TN (Psychomotor Speed)	2.50	1.10	4.54	0.72	-8.113	0.000*
E (Quality of Work)	2.17	1.17	3.33	1.01	-7.000	0.000*
TN-E (Speed-Attention Balance)	2.04	0.91	4.54	0.72	-11.519	0.000*
FR (Sustained Attention Capacity)	2.63	0.97	2.46	0.93	0.500	0.622

Note. T - Dependent Samples t-test, p<0.05: * - The relationship is significant.

It was found to be statistically significant that the post-test scores for psychomotor speed, work quality, and speed-attention balance of the research group were higher compared to the pre-test scores. These improvements indicate that the intervention had a positive effect on the participants' psychomotor abilities. This difference between the pre- and post-test is also shown in Figure 2.

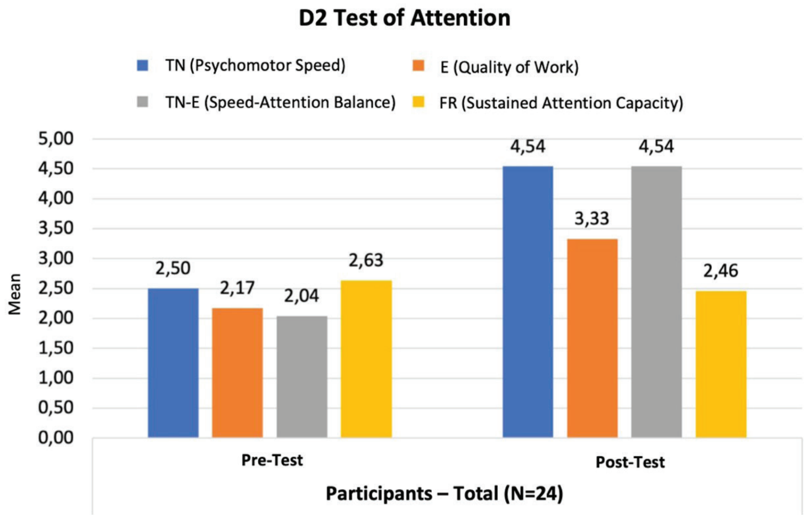

FIGURE 2. Research Group's D2 Test of Attention Scores

Discussion

In this study, the effects of a fundamental motor skills training program based on the Differential Learning approach on primary school students' attention characteristics were examined. As a result of the 13-week intervention, significant improvements were observed in the sub-dimensions of psychomotor speed, work quality, and speed-attention balance ($p<0.01$). These findings indicate that motor skill training positively contributes to children's attention processes.

First and foremost, the significant improvements found in our study can be explained by the neurologically coordinated development of movement and attention processes (Schöllhorn, 1999). The Differential Learning approach, which is based on continuous variability and change, enables children to use their attention processes more flexibly and efficiently, thereby supporting the development of skills such as psychomotor speed and attention balance. As Schöllhorn (2009) emphasizes, the brain is actively engaged in this process, integrating movement and attention functions, which enhances students' attentional performance.

In this regard, the findings of Topsakal et al. (2019) are consistent with our results. They also reported significant improvements in students' attention performance following a 10-week motor skill training program based on the Differential Learning approach. Similarly, Özdemir (2019) showed that physical activity cards and exergaming activities improved the attention levels of 10–11-year-old children, supporting the positive effects of motor skill-oriented programs on attention. These studies reveal that movement diversity and innovative methods stimulate students' attention processes.

Furthermore, a study by Yurdakul et al. (2012), which investigated the effects of movement training on attention and memory development in 8-year-old children, also supports our findings. Following a 12-week movement training program delivered twice a week, significant improvements were observed in attention performance. This suggests that movement is directly related to cognitive processes, and that regular, structured motor activities play a critical role in attention development. Additionally, Akcınlı (2005) reported that movement training had positive effects on attention and memory development in 8-year-old children. Similarly, Adsız (2010) found that primary school students who regularly participated in sports were 83% more attentive than their peers who did not. Göktepe et al. (2016) also reported that planned games based on fundamental movements and movement patterns made a significant contribution to attention and memory development in children participating in sports. These findings support the positive effects of movement and planned physical activities on children's cognitive development.

However, not all studies show consistent findings. For example, in the study by Yaşar et al. (2018) examining the effects of Life Kinetik training on attention and speed-attention balance, no significant changes were observed in some sub-dimensions, whereas our study identified significant improvements in psychomotor speed, work quality, and speed-attention balance. These differences may result from variations in methodology, duration of intervention, or participant age groups. In addition, the content and intensity of Yaşar et al.'s training program may have differed. In such cases, variables such as the quality and intensity of movement programs play a critical role in attention development. Moreover, a study conducted by Kanbir et al. (2024), which investigated the effects of complex motor activities and exergaming games on attention, timing, and hyperactivity, found significant improvements in the complex movement group. This supports the idea that diverse and complex motor activities have a positive effect on attention. The DL-based approach and physical activity cards used in our program may have created a similar stimulating effect by continuously varying and diversifying children's motor actions.

The positive effect of physical activity on attention is widely supported in the literature. Tine and Butler (2012) demonstrated that 12 minutes of aerobic exercise enhanced selective attention in 10–13-year-old children, while Chaddock-Heyman et al. (2013) reported that sports activities increased cognitive control in the prefrontal cortex of 8–9-year-old children. Alesi et al. (2016) emphasized the particularly positive effects of football on attention skills, and Bidzan-Bluma and Lipowska

(2018) showed that regular daily physical activity enhances cognitive functions. These studies provide neurological and psychological foundations for the mechanisms through which motor skill training supports attention development.

Motivational factors may also have played an important role in our findings. Borrego-Balsalobre et al. (2021) emphasized that innovative and constantly varying experiences increase student motivation, which in turn accelerates motor skill development. The DL-based approach applied in our study offered a dynamic learning environment far from monotony and appealing to children's interests, allowing students to maintain more focused and sustained attention.

On the other hand, our study has certain limitations. The most significant limitation is the absence of a control group, which makes it difficult to determine whether the observed effects are specific to the intervention group. In addition, the limited sample size and the fact that participants were selected from a single school restrict the generalizability of the findings. Future research is recommended to employ experimental designs with control groups for comparison with the DL approach. Increasing the sample size and including different age groups would also enhance generalizability. Moreover, examining more detailed sub-dimensions of attention and using different measurement tools could contribute to a deeper understanding of the findings.

In conclusion, this study demonstrates that the Differential Learning approach is effective in improving attention characteristics among primary school students. The underlying mechanism of this effect may be attributed to the incorporation of continuous variation and novelty in movements, balanced cognitive load, and increased motivation. Therefore, integrating the Differential Learning approach into the design of motor skill programs in education may significantly contribute to the attention and psychomotor development of children.

Conclusion

This study highlights the impact of a fundamental movement skills training program applied with the differential learning approach on the attention characteristics of 9-year-old students. The research findings indicate that variable and continuously renewed movement experiences contribute to students' ability to manage their attention processes more flexibly and effectively. Additionally, the reduction of cognitive load, increased motivation, and the integration of motor skills with attention processes are key factors that make this approach effective. In this context, the differential learning approach can be considered an innovative learning model that helps strengthen cognitive processes. Based on the results obtained, it is recommended that more comprehensive research be conducted on the application of this method in different age groups and educational settings.

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Conflict of interest

The authors declare that there is no conflict of interest.

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REVIEW PAPER

A Minimalistic Approach to Promote Health-Span via Bouts of Daily Physical Activity in Older Adults: A Review

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Abstract

While increasing human life expectancy is a significant societal achievement, it often contrasts with a shorter health-span, leading to a higher incidence of chronic diseases, particularly in older adults. Physical activity is crucial for mitigating age-related musculoskeletal decline, yet participation in structured and vigorous exercise among older adults is low. This review aims to provide an overview of the impact of biological aging on the musculoskeletal system and to highlight countermeasures, including viable exercise-related strategies. The review found that biological aging contributes to sarcopenia (age-related loss of muscle mass and quality), sarcopenic obesity (reduced muscle mass with elevated fat mass), dynapenia (age-related loss of muscle strength), and declines in aerobic capacity, alongside changes in appetite regulation and energy expenditure. Importantly, moderate-to-vigorous physical activity (MVPA) is crucial for maintaining muscle mass and preventing sarcopenia. Achieving daily step counts of approximately 6,000-8,000 for adults over 60, or specifically around 8,000 steps for men and 6,900 for women, and/or 15-20 minutes of MVPA daily, appears adequate for preventing sarcopenia. Replacing sedentary time with even small amounts of MVPA, such as 15 minutes daily, can reduce sarcopenia risk by about 15%, with greater benefits seen with longer durations like 60 minutes of MVPA. In conclusion, while structured resistance and endurance training are highly recommended, older adults who find adherence challenging can still enhance their health-span by aiming for daily step targets or incorporating approximately 30 minutes of daily MVPA. This minimalistic approach can help preserve muscle mass, limit fat accumulation, and counteract the detrimental effects of biological aging on the musculoskeletal system.

Keywords: *health span, sarcopenia, sarcopenic obesity, physical activity*

Introduction

Recent history has seen a notable rise in human life expectancy, a metric representing the average lifespan within a population. This trend has been consistent in developed nations for the last two centuries, yet it surpassed projected global limits of 71 years for males and 74 years for females, thereby maintaining its trajectory (Ismail et al., 2021; Oeppen et al., 2002). Although this sustained increase in life expectancy within developed countries was not anticipated, understanding the factors driving these aging demographic shifts is crucial. Indeed, enhancements in living standards, readily available resources like accessible clean drinking water, improved sanitation, medical progress (such as antibiotic use), and education correlate with reduced mortality rates in early and mid-life stages, thus contributing to the extension of life expectancy (Mitchell

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et al., 2020). Furthermore, advancements in socioeconomic conditions, healthcare accessibility and quality, public health initiatives, and social support systems have collectively improved the quality of life across the entire lifespan (Marzo et al., 2023). Consequently, projections indicate that by 2050, the populations aged over 65, 85, and 100 years will grow by 188%, 551%, and 1004%, respectively (Oksuzyan et al., 2020). In fact, the cohort aged 60 and above has already doubled over the past four decades, now numbering 810 million globally. This demographic trend is anticipated to continue, with the aging population expected to approach approximately 2 billion by the year 2050 (Oksuzyan et al., 2020). Global disparities in life expectancy, along with associated sex-based differences in mortality and morbidity risks, represent significant areas of focus for academia and policy, aiming to promote more equitable and healthy lives for everyone. While this significant extension of life expectancy among aging populations signifies societal progress, this increased longevity does not invariably translate to a proportionately extended health-span (Olshansky, 2018). The former denotes the total duration of life lived, whereas the latter refers to the period experienced free from significant disease. In reality, lifespan and health-span seldom align perfectly. For instance, Garmany and colleagues (2021), comparing 2020 median probabilistic projections for life expectancy and health-adjusted life expectancy, identified a 9.2-year gap between health-span and lifespan. This chronological discrepancy between health-span and lifespan often manifests as non-communicable diseases affecting various biological systems, including the cardiovascular, pulmonary, endocrine, and musculoskeletal systems, and ultimately arises from unhealthy biological aging processes (DiLoreto et al., 2015). For these reasons, the World Health Organization (WHO) has designated healthy biological aging as a research priority for the period between 2016 and 2030 (Keating, 2022). To enhance health-span and promote optimal body mass, the WHO advises a minimum of 300 minutes of physical activity (PA) per week for adults aged 18 to 64 (Bull et al., 2020). This recommendation stems from the fact that PA—any bodily movement generated by skeletal muscles—is the most significant regulator of skeletal muscle plasticity in both younger and older adult populations (Escriche-Escuder et al., 2021). However, for older adults (65+ years), the WHO places increased emphasis on more structured and vigorous forms of PA to prevent sarcopenia and sarcopenic obesity (Bull et al., 2020). Vigorous PA modalities can induce distinct physiological adaptations depending on the type of exercise (Escriche-Escuder et al., 2021). For example, resistance exercise training is considered the most effective non-pharmacological intervention for promoting skeletal muscle hypertrophy, a condition where muscle protein synthesis consistently surpasses muscle protein breakdown, leading to an increased cross-sectional area of the muscle (Damas et al., 2015). This form of training is associated with improvements in muscle pennation angle, neural rate coding, coordination, and increased bone mineral density (Kraemer et al., 2002). Conversely, endurance exercise training enhances muscle capillarization, mitochondrial density, and consequently, maximal oxygen uptake (VO2max) (Hughes et al., 2018). It is thus understandable that the WHO recommends combining resistance and endurance training modalities for older adults. Nevertheless, despite these clear health advantages, population-level participation in these recommended exercise forms among older adults (65+ years) worldwide remains low, at only 16% (Elgaddal et al., 2022). Therefore, the primary objective of this review is to provide an overview of the impact biological aging can have on the musculoskeletal system and to highlight countermeasures as well as viable exercise-related strategies

Hallmarks of Biological Ageing

From a biological perspective, aging can be described as senescence, signifying a progressive, cumulative decline in an organism's regenerative capacity and bioprotective functions (Hernandez-Segura et al., 2018). Key initiators of cellular damage, and consequently biological aging, include genomic instability, the shortening of telomeres, epigenetic modifications, and impaired proteostasis. These fundamental processes subsequently trigger various cellular responses, including disruptions in intracellular communication, depletion of stem cell populations, induction of cellular senescence, mitochondrial impairment, and aberrant nutrient sensing pathways (Aubert et al., 2008; Fafián-Labora et al., 2020; Roger et al., 2021). However, inflammation represents a standard physiological reaction to cellular damage, facilitating tissue repair following endogenous or exogenous insults (Weavers et al., 2020). While this acute inflammatory response is typically beneficial and aids healing, persistent low-grade inflammation frequently remains undetected yet can detrimentally affect specific tissues and organs, thereby contributing to the continuation of chronic diseases and debilitating conditions (Minihane et al., 2015). Both aging and obesity are linked to this state of chronic low-grade inflammation, a condition also recognized in various non-communicable diseases like arthritis, type 2 diabetes, and cancer (Adler, 2011). Notably, the elevation in pro-inflammatory markers (cytokines) driven by obesity originates from enlarged adipocytes and immune cells residing within adipose tissue, predominantly lymphocytes and macrophages (Moss et al., 2023). Nevertheless, even a modest body mass reduction of just 5% has demonstrated efficacy in mitigating obesity-associated chronic low-grade inflammation in both human and murine models (Ellulu et al., 2017). In this context, reducing fat mass (FM) is achievable through establishing a negative energy balance, a condition where energy expenditure surpasses energy intake over extended durations, leading to intentional weight reduction (Kim, 2021).

Although inflammation linked to obesity can be lessened via weight reduction, biological aging itself is an unavoidable process and is associated with a persistent age-related chronic low-grade inflammation, often termed 'inflamm-ageing' (Franceschi et al., 2000). Sustained and unresolved inflamm-ageing can subsequently diminish brain plasticity, degrade skeletal muscle quality and function, and promote the accumulation of visceral and ectopic fat deposits, which themselves are pro-inflammatory (Cianciulli et al., 2022). Collectively, these changes result in an elevated probability of physical disability, frailty, and metabolic disorders, ultimately impairing the quality of life for older adults (Figure 1) (Netuveli et al., 2008; Vanleerberghe et al., 2017).

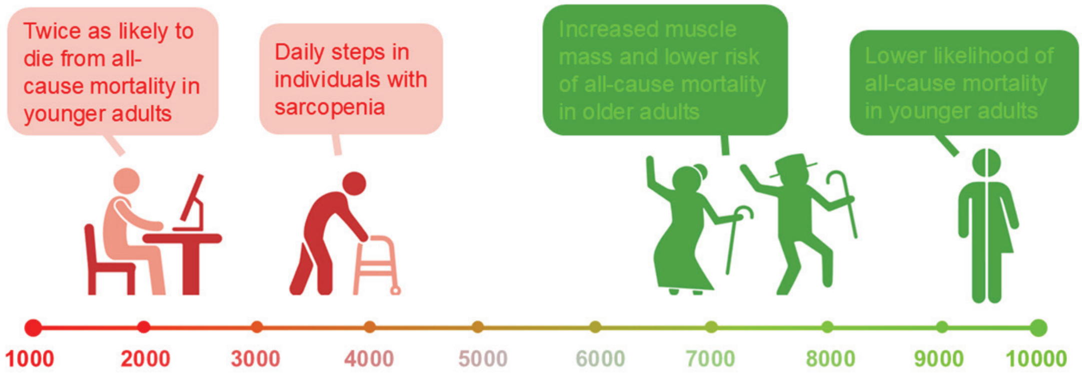

FIGURE 1. Markers of biological aging resulting in reduced health-span

Sarcopenia and Changes in Lean Body Mass

The adverse consequences of biological aging can manifest surprisingly early, potentially beginning in the second decade of life, and impacting various physiological systems such as the cardiovascular and neuromuscular systems, along with the brain (Netuveli et al., 2008; Vanleerberghe et al., 2017). A prime example is the age-associated decline in both the amount and functionality of skeletal muscle mass, a condition known as sarcopenia (Larsson et al., 2019). Sarcopenia's onset can also occur early, leading to a reduction in skeletal muscle mass averaging 0.47% annually in men and 0.37% in women, rates which subsequently increase to 0.98% for men and 0.70% for women beyond the age of 75 (Berger et al., 2010; Marzetti et al., 2017). Additionally, owing to the significant correlation between skeletal muscle mass and bone mineral density, sarcopenia frequently coexists with osteopenia, defined as a decrease in bone mineral density that typically precedes the development of osteoporosis (Lee et al., 2016). As a result of sarcopenia, individuals may lose close to 30% of their peak skeletal muscle mass by their 80th year (Marzetti et al., 2017). This loss is especially significant given that skeletal muscle comprises approximately 40% of total body mass and plays vital roles in movement, postural support, and respiration, besides serving as a primary location for nutrient metabolism and storage (McLeod et al., 2016).

Lean body mass (LBM), encompassing organs like the kidneys, heart, liver, brain, and skeletal muscle, represents a highly metabolically active tissue compartment (Wang et al., 2010). While all these LBM constituents are susceptible to biological aging, skeletal muscle constitutes 70-90% of total LBM and is particularly affected by sarcopenia (Larson et al., 2019). Consequently, alterations in LBM may act as an indicator, reflecting the progression of sarcopenia throughout the lifespan. For example, research by Westerterp and colleagues (2021) indicated that LBM reaches its peak between 20-24 years in males and 19-20 years in females, subsequently remaining stable until about age 30. Likewise, Jackson and colleagues (2012) observed a stable LBM period from age 20 to 47, followed by reported annual decreases escalating from 0.42 kg in the fifth decade to 1.96 kg in the eighth decade. Findings from Guo and colleagues (1999) also suggest that LBM decreases become notable in both sexes between the ages of 40 and 50. Investigating LBM variations across healthy individuals aged 18 to 94, Kyle and colleagues (2001) identified the onset of decline around the age of 60. During aging, women typically experience smaller absolute and relative decreases in skeletal muscle mass compared to men, which largely accounts for the observed sex differences in LBM trajectories (Churchward-Venne et al., 2015). It is noteworthy that women possess approximately 40% less muscle mass in the upper body and 30% less in the lower body compared to men (Janssen et al., 2000). Research by Visser and colleagues (1997) documented that over a 50-year span (ages 20-70), total appendicular skeletal muscle mass loss amounted to 4 kg (~15%) in men and 2 kg (~11%) in women. Another longitudinal investigation by Gallagher and colleagues (1997) reported absolute appendicular skeletal muscle mass reductions of approximately 1 kg in men and 0.6 kg in women across a 7-year timeframe. Furthermore, research examining muscle atrophy rates in older populations indicated slower muscle mass reduction in women relative to men over a 2-year observation period (Zamboni et al., 2003).

Sarcopenic Obesity and Changes in Fat Mass

Declines in skeletal muscle quantity and functionality can lead to improper nutrient partitioning, manifesting as increased fat infiltration within skeletal muscle and the buildup of visceral and ectopic adipose tissue, conditions associated with insulin resistance, dyslipidemia, and specific types of cancer (Larsson et al., 2019). The coexistence of reduced skeletal muscle mass and elevated fat mass (FM) in later life defines sarcopenic obesity, a condition estimated to impact 4.1% of males and 2.65% of females aged 18 to 93 years (Frontera et al., 2015).

Regarding sarcopenic obesity, cross-sectional data suggest that FM expands annually by 1% in both sexes starting from the fourth decade of life (Churchward-Venne et al., 2015; Janssen et al., 2000; Kuk et al., 2009; Kyle et al., 2001). Conversely, one longitudinal investigation found that FM begins to increase from age 40, reaching a peak around age 60 in both males and females, with average yearly gains of 0.37 kg and 0.41 kg, respectively (Guo et al., 1999). A longitudinal study by Visser and colleagues (2003) identified peak FM occurring between the ages of 68 and 80 in both sexes. Comparable results emerged from a longitudinal study by Zamboni et al. (2003), where researchers also observed peak FM levels between 68 and 80 years for both men and women. These observations align with several cross-sectional investigations indicating that peak fat mass occurs between ages 60 and 76 in both male and female participants

(Churchward-Venne et al., 2015; Janssen et al., 2000; Kyle et al., 2001). Further research examining fat distribution patterns in older adults indicates that aging can foster altered fat deposition, resulting in excessive fat accumulation, particularly as visceral fat in the abdominal region (Hirose et al., 2016; Huffman et al., 2009). Indeed, a diagnosis of sarcopenic obesity may be considered when waist circumference surpasses 90 cm for men and 85 cm for women (Barazzoni et al., 2018). Notably, aging correlates with an average yearly increase in waist circumference of about 0.7 cm (Noppa et al., 1980). For instance, longitudinal data from Hughes and colleagues (2019) show that older women experienced an average waist circumference gain of 4 cm over nine years, whereas older men showed a non-significant increase of 1 cm during the same timeframe. Comparable results were reported in another study, with older women exhibiting larger increases in waist circumference over five years than men (+2.8 cm versus -0.2 cm, respectively) (Hairston et al., 2009). These longitudinal findings are corroborated by cross-sectional studies where older women demonstrated greater age-related waist circumference increases compared to their male counterparts (Sakai et al., 2005; Singh et al., 2019). Collectively, these studies suggest that aging women exhibit a greater tendency towards fat mass accretion, particularly the deposition of visceral fat in the abdominal area.

Indirect Markers of Ageing
Muscle strength

Independent of sarcopenia or sarcopenic obesity, the age-associated reduction in muscle strength can further diminish quality of life by negatively impacting personal mobility and overall neuromuscular function. This decline in muscle strength, occurring independently of overt disease, is specifically referred to as dynapenia (Clark et al., 2012). Indeed, the diminution of muscle strength can commence as early as the third decade, exhibiting an average annual decrease of 1.5% between ages 50 and 60, which accelerates to 3-5% per year between ages 60 and 80 (Keller et al., 2014). Generally, muscle strength is commonly evaluated via handgrip dynamometry, with values below 27 kg often considered indicative of sarcopenia and dynapenia (Cruz-Jenoft et al., 2019). The reduction in strength is primarily attributed to the atrophy and denervation of type II muscle fibres at the neuromuscular junction (NMJ), fibers characterized by high glycolytic capacity and greater force-generating potential compared to type I fibres (Callahan et al., 2014). Consequently, the preferential loss of type II fibres in older adults often results in challenges performing routine daily activities, such as ascending stairs, lifting moderately heavy objects, or rising from a seated position (Goodpaster et al., 2006). Furthermore, dynapenia is thought to interfere with the excitation-contraction coupling mechanism, potentially by hindering calcium release from the sarcoplasmic reticulum (Clark et al., 2012). As a consequence, functional limitations are evident, with 17% of women and 9% of men over 65 reportedly unable to lift a 5 kg weight or kneel. Significantly, dynapenia is estimated to affect approximately one-quarter of individuals over the age of 50 (Siparsky et al., 2014).

Aerobic Capacity

Alterations in body composition can lead to modifications in aerobic fitness. For example, maximal oxygen consumption (VO2max) represents the capacity of the body to transport and utilize oxygen within skeletal muscle. At the population level, VO2max serves as a key indicator of overall cardiopulmonary fitness, a parameter strongly associated with health span and risk of all-cause mortality (Hawkins et al., 2007). Consequent to sarcopenia and sarcopenic obesity, VO2max typically decreases, primarily owing to impaired mitochondrial dynamics (fusion and fission), leading to reduced numbers of functional mitochondria, and a diminished mitochondrial biogenesis response to physical activity (PA) (Liu et al., 2020). Consequently, VO2max generally begins to decrease after the age of 25, declining by approximately 1% annually, with this rate potentially increasing to 1.5% per year between the ages of 50 and 75 (Betik et al., 2008), mirroring age-related shifts in body composition and metabolic function. Furthermore, VO2max is recognized as a significant indicator of brain health. Indeed, recent research demonstrated that VO2max strongly predicts brain health metrics, such as brain volume and mass (Neves et al., 2023).

Appetite

Indeed, there is extensive evidence indicating the presence of age-related changes in brain plasticity which predisposes older individuals to neurological diseases such as dementia and Alzheimer's disease (Hou et al., 2019). Biological ageing, however, tends to also affect the appetite-signalling cascade in the brain, which is the master orchestrator of energy balance (Matafome et al., 2017). For instance, age-related dysregulation in energy intake is characterised by altered appetite due to dampened sense of taste and smell and impaired gastric motility, which contribute to the reduced desire to eat (Clarkston et al., 1997; Crogan et al., 2014; Schiffman, 1997). This phenomenon is now known as, anorexia of ageing and it is estimated to affect 15% to 30% of older adults, with higher rates in older age groups (Malafarina et al., 2013). More specifically, anorexia of ageing has been reported to manifest in 25% of home-dwellers, 60% in hospital inpatients and 80% of nursing home residents (Roy et al., 2016). In turn, this can translate in smaller meals eaten and poor preference for less-palatable nutrients such as dietary proteins, which are key in promoting muscle protein synthesis. This is particularly concerning as older individuals require more dietary protein per meal to elicit a muscle protein synthetic response (Moore 2014). Furthermore, ageing is also related with a reduction in the orexigenic drive that promotes hunger. Ghrelin, a major orexigenic hormone, is known to decrease with advancing of age (Serra-Prat et al., 2009). Similarly, leptin, an anorectic hormone, increases with age pre-prandially and post-prandially (Adamska-Patruno et al., 2019). Ultimately, these adverse effects of anorexia of ageing are mainly the result of age-related changes in homeostatic and non-homeostatic brain circuity that regulates energy balance and body weight.

Energy Expenditure

Energy intake, including appetite, track the energy demands imposed by LBM and PA. On this note, LBM and PA have been shown to modulate food intake in older adults. For example, in a recent systematic review and meta-analysis Hubner and colleagues (2021) reported that physically active older individuals (60+yrs) have a better regulation of energy intake to match their energy needs. On this note, a higher appetite is a behavioural response to an elevated total daily energy expenditure (TDEE). A major static component, resting metabolic rate (RMR), comprises of 60-70% of TDEE and can be defined as the energy yield required to maintain biological processes within the body, particularly in metabolically demanding tissue of LBM such as the kidneys, heart, liver, brain and skeletal muscle (Blundell et al., 2012; Villablanca et al., 2015). The latter yields only 13 kcal per kilogram, however, because skeletal muscle accounts for 70 to 90% of all LBM, this highly metabolically active organ becomes a major determinant of RMR in healthy adults (Heymsfield et al., 2018). On this note, Pontzer and colleagues (2021) recently examined differences in TDEE across the life course of 6400 individuals using doubly labelled water and indirect calorimetry, which are gold standard techniques to assess daily energy expenditure and basal metabolic rate in free living individuals. Their findings suggest that there are four metabolic life stages. First, new-borns have similar RMR to an adult, however, at one year of age, infants display a 50% higher RMR when compared to the RMR of an adult, which is due to the increased energy requirements for organ growth. From approximately one year of age, when relative RMR is at its highest, RMR tends to slowly decrease until reaching a plateau at ~20 years of age and remaining stable thereafter until ~60 years of age. Menopause for women as well as puberty in males and females were not factors contributing to substantial changes in RMR (Pontzer et al., 2021). However, the age-related decline in RMR adjusted for body size and body composition becomes significant in older individuals (60+ years). This age-related reduction in RMR is multifactorial, and mainly driven by blunted muscle protein synthesis, organ specific atrophy, as well as decreased enzymatic activity (Manini 2010). In addition, mass of the brain, kidney, liver, skeletal muscle, as well as bone mass, tend to decline by 10-20% from 20 to 60 years of age resulting in substantial reductions in RMR (Zampino et al., 2020). To summarize, promoting maintenance of LBM is a desirable outcome, which may promote metabolic health and locomotion, but also aid appetite regulation in older individuals.

Daily Steps Towards Optimal Health-span

Typically, older individuals cover shorter walking distances compared to younger adults, even when their daily time spent walking is comparable (Zhao et al., 2015). This observation is especially relevant considering reported declines in lifetime peak physical activity (PA) ranging from 40% to 80% (Westerterp, 2018). Indeed, current evidence indicates that a higher walking pace (such as brisk walking) positively correlates with overall fitness levels among older adults (Wu et al., 2021). Consequently, it aligns with the World Health Organization's (WHO) recommendation for older adults to engage in 300 minutes of PA or 150 minutes of moderate-to-vigorous physical activity (MVPA) weekly (Rivera-Torres et al., 2019). At the population level, MVPA is often defined as intentional PA performed at an intensity between 3 and 6 metabolic equivalents (METs), with 1 MET representing the energy expenditure during quiet sitting. Alternative methods for quantifying MVPA include assessing intensity relative to maximal heart rate or using ratings of perceived exertion. A more recent proposal by MacIntosh and colleagues (2021) suggests categorizing MVPA based on ventilatory and/or lactate thresholds, identifying the first threshold with moderate intensity and the second with vigorous intensity PA. In simpler terms, the 'talk test'—where physical exertion makes carrying on a conversation slightly, but not overly, difficult—can serve as a subjective indicator of MVPA intensity (Reed et al., 2014). Thus, MVPA encompasses activities like brisk walking, ascending stairs, dancing, household cleaning, and gardening. Ultimately, MVPA involves an effort level capable of eliciting physiological adaptations akin to those from formal resistance and endurance training, albeit typically to a lesser degree (Loprinzi, 2015). These everyday, unstructured PA bouts of varying intensities can be measured using triaxial accelerometers (e.g., wrist-worn activity trackers), which also facilitate the quantification of PA through metrics like daily step counts (Henriksen et al., 2018).

While a common public health guideline promotes aiming for 10,000 steps daily (Choi et al., 2007), this specific target lacks robust support from current scientific findings (Hall et al., 2020; Jayedi et al., 2022; Paluch et al., 2022). For instance, a systematic review by Hall et al. (2020) found that higher daily step counts correlated with reduced risks of cardiovascular disease and all-cause mortality. However, this review was not designed to determine a specific dose-response relationship. This aspect was explored in a later systematic review by Jayedi et al. (2022), which identified a dose-response association between daily steps and all-cause mortality risk. Compared to individuals achieving 16,000 daily steps, those walking only 2,700 steps per day exhibited nearly double the risk of all-cause mortality, according to their findings. A more recent meta-analysis encompassing 15 international cohorts and 47,471 adults by Paluch et al. (2022) aimed to estimate the optimal daily step count for maximizing health benefits. Their analysis revealed that increased daily steps correlated with progressively lower mortality risk, with benefits appearing to level off around 6,000-8,000 steps/day for adults over 60 and 8,000-10,000 steps/day for those under 60. However, these large-scale analyses did not specifically examine how age-related variations in body composition might influence these relationships or contribute to suboptimal metabolic health and reduced mobility (McLeod et al., 2016). A cross-sectional study by Westerterp et al. (2021), including 2,000 participants aged 3-96, demonstrated that PA significantly influences body composition throughout life. Nevertheless, these authors emphasized that the specific type and intensity of PA appear particularly crucial for mitigating unfavourable body composition changes (Westerterp et al., 2021). Illustrating this, Scott et al. (2011), studying 697 older adults, observed a robust link between greater daily step counts and higher lower-limb LBM. Likewise, Aoyagi et al. (2010) reported beneficial effects of higher daily step counts on lower-limb strength in older adults, noting apparent thresholds around 8,000 steps/day for men and 6,900 for women. These results align with other research suggesting that achieving 7,000-8,000 steps and/or 15-20 minutes of MVPA daily was adequate for preventing sarcopenia in older men and women (Figure 2) (Park et al., 2010).

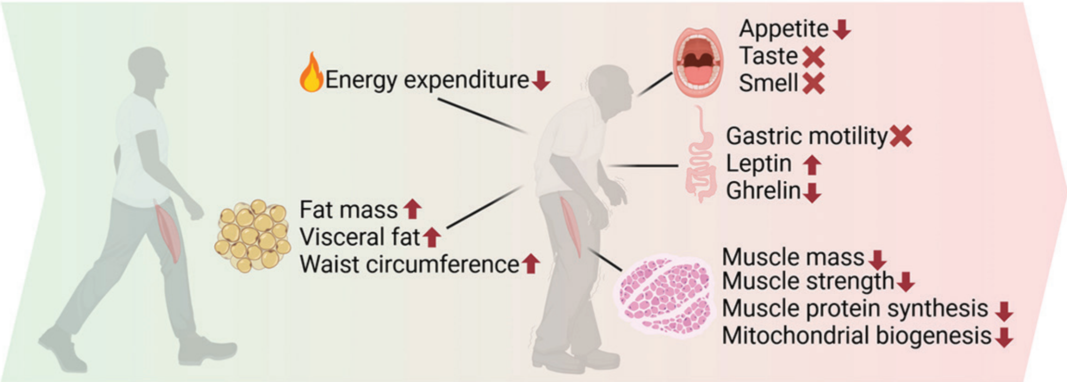

FIGURE 2. Daily step count and association with disease in younger and older adults

Several investigations suggest that substituting sedentary behaviour and low-intensity physical activity (PA), such as walking, with moderate-to-vigorous physical activity (MVPA) could represent a more effective strategy for preventing the development of sarcopenia and sarcopenic obesity (Hamer et al., 2014; Stamatakis et al., 2019; Yasunaga et al., 2018). Specifically, displacing sedentary time with 15 or 60 minutes of daily MVPA has been shown to potentially reduce sarcopenia risk by approximately 15% and 50%, respectively (Sánchez-Sánchez et al., 2019). Similarly, Ogawa and colleagues (2011) determined in a study of 48 older women that MVPA, unlike total daily steps, positively correlated with leg lean body mass (LBM). An observational study by Scott et al. (2021) involving 3,334 Swedish 70-year-olds reported a strong association between greater volumes of MVPA and a lower probability of sarcopenia, independent of MVPA bout duration or time spent sedentary. In a follow-up study with 3,653 community-dwelling individuals, the same research group demonstrated that high levels of MVPA and sedentary time can coexist without increasing the likelihood of sarcopenia (Johansson et al., 2021). Notably, this study also found that low sedentary time combined with low MVPA was insufficient to prevent sarcopenia onset. Conversely, Lai et al. (2022), studying 199 overweight community residents, found that replacing 30 minutes of sedentary time with MVPA decreased fat mass (FM) and waist circumference while maintaining skeletal muscle mass. However, research by Mijnarends et al. (2016) over a 5-year period indicated that while participating in at least 60 minutes of weekly MVPA delayed sarcopenia onset in older individuals, it did not entirely prevent it, highlighting the need for sufficient MVPA duration.

Aggio and colleagues (2016) examined the links between objectively assessed MVPA and indicators of sarcopenia and sarcopenic obesity among 1,286 older men. This research group observed a higher prevalence of sarcopenia among participants engaging in 22-33 minutes of daily MVPA compared to those undertaking 38-45 minutes per day. Furthermore, the study highlighted an inverse relationship between sarcopenia severity, assessed via upper arm circumference, and the duration of MVPA. Indeed, the investigators reported that incorporating an additional 30 minutes of daily MVPA nearly halved the risk of severe sarcopenia for individuals in the lower MVPA category (Aggio et al., 2016). A longitudinal study by Menai et al. (2017) including 3,749 adults aged 60-83 demonstrated that individuals classified as 'successful agers' engaged in 8 minutes more daily MVPA than 'unhealthy agers'. Their research underscored that, relative to those performing less than 10 minutes of daily MVPA, engaging in 10-20 minutes per day doubled the probability of successful aging. Yet, increasing MVPA further to 20-30 minutes daily resulted in only an additional 38% rise in the likelihood of successful aging, suggesting diminishing returns for additional daily MVPA time.

Conclusion and Future Perspectives

The process of biological aging inherently involves a decline in physiological functions, a trajectory often exacerbated by the absence of timely and targeted behavioural interventions capable of mitigating the onset and progression of sarcopenia and sarcopenic obesity. Sufficient levels of physical activity (PA) have demonstrated efficacy in counteracting the age-associated deterioration of body composition and metabolic health. While combined resistance and endurance training represents the principally recommended exercise approach for older adults, long-term adherence to such structured modalities remains challenging. Consequently, for older individuals less inclined to commit to structured exercise regimens, pursuing daily step targets of approximately 8,000 for men and 6,900 for women may be a suitable recommendation. If achieving these daily step counts proves difficult, incorporating additional minutes of moderate-to-vigorous physical activity (MVPA) could enhance health span, particularly when baseline MVPA levels are low (e.g., under 10 minutes daily). Nonetheless, the potential for diminishing returns with increasing daily MVPA duration exists, which might deter participation due to perceived excessive time and effort demands. Thus, advocating for approximately 30 minutes of daily MVPA could be a pragmatic and achievable guideline for preserving muscle mass and limiting fat mass (FM) accumulation in older adults for whom sustained exercise adherence is problematic. It is well-documented in empirical research that seasonal variations and weather conditions significantly influence PA levels, including MVPA. PA participation typically decreases during snowy periods and adverse weather conditions. Indeed, PA levels among community-dwelling individuals can plummet by as much as 75% during snowy intervals (Hasegawa et al., 2019; Matthews et al., 2019). This reduction in PA may, in turn, contribute to unintentional skeletal muscle loss and FM gain, potentially accumulating year-on-year and fostering the development of sarcopenia and sarcopenic obesity.

An area requiring further investigation involves exploring the effects of varying PA levels and age-related alterations on the appetite-regulating signalling pathways. Observations indicate that older adults generally exhibit lower energy consumption and reduced intake of protein-dense foods. This dietary pattern could potentially worsen the known age-related blunting of the muscle protein synthetic response to dietary protein ingestion. Hence, future studies should focus on examining how different durations and intensities of PA and/or MVPA influence energy intake, with particular attention to nutrient selection, especially dietary protein. Moreover, careful consideration of exercise modality, volume, intensity, and duration is warranted, as these variables might precisely modulate centrally regulated appetite control.

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Conflicts of Interest

The authors declare no conflicts of interest.

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1.1. Overview

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The submission with SM is free of charge but author(s) has to pay additional 215 euros per accepted manuscript to cover publication costs. If the manuscript contains graphics in color, note that printing in color is charged additionally.

SM adopts a double-blind approach for peer reviewing in which the reviewer's name is always concealed from the submitting authors as well as the author(s)'s name from the selected reviewers.

SM honors six-weeks for an initial decision of manuscript submission.

Authors should submit the manuscripts as one Microsoft Word (.doc) file.

Manuscripts must be provided either in standard UK or US English language. English standards should be consistent throughout the manuscripts accordingly.

Format the manuscript in A4 paper size; margins are 1 inch or 2.5 cm all around.

Type the whole manuscript double-spaced, justified alignment.

Use Times New Roman font, size eleven (11) point.

Number (Arabic numerals) the pages consecutively (centering at the bottom of each page), beginning with the title page as page 1 and ending with the Figure legend page.

Include line numbers (continuous) for the convenience of the reviewers.

Apart from chapter headings and sub-headings avoid any kind of formatting in the main text of the manuscripts.

1.2. Type & Length

SM publishes following types of papers:

Original scientific papers are the results of empirically- or theoretically-based scientific research, which employ scientific methods, and which report experimental or observational aspects of sports science and medicine, such as all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side. Descriptive analyses or data inferences should include rigorous methodological structure as well as sound theory. Your manuscript should include the following sections: Introduction, Methods, Results, and Discussion.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Original scientific papers should be:
- Up to 3000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 30;
- Maximum combined total of 6 Tables/Figures.

Review papers should provide concise in-depth reviews of both established and new areas, based on a critical examination of the literature, analyzing the various approaches to a specific topic in all aspects of sports science and medicine, such as all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Review papers should be:
- Up to 6000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 100.

Editorials are written or commissioned by the editors, but suggestions for possible topics and authors are welcome. It could be peer reviewed by two reviewers who may be external or by the Editorial Board.

☐Open Submissions ☑Indexed ☑Peer Reviewed

Editorials should be:
- Up to 1000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 10.

Short reports of experimental work, new methods, or a preliminary report can be accepted as two page papers. Your manuscript should include the following sections: Introduction, Methods, Results, and Discussion.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Short reports should be:
- Up to 1500 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 15.

Peer review - fair review provides authors who feel their paper has been unfairly rejected (at any journal) the opportunity to share reviewer comments, explain their concerns, and have their paper reviewed for possible publication in SM.

☑Open Submissions ☑Indexed ☐Peer Reviewed

Peer review - fair review should be:
- Up to 1500 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 15.

Invited papers and award papers include invited papers from authors with outstanding scientific credentials. Nomination of invited authors is at the discretion of the SM editorial board. SM also publishes award papers selected by the scientific committee of the International Scientific Conference on Transformation Processes in Sport.

☐Open Submissions ☑Indexed ☐Peer Reviewed

Invited papers and award papers should be:
- Up to 3000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 30;
- Maximum combined total of 6 Tables/Figures.

1.3. Submission

SM only accepts electronic submission to the e-mail of the Journal Office: **office.sportmont@gmail.com**.

Submitted material includes:

- A manuscript prepared according to the Guidelines for the Authors;
- A signed form that states the study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere, that states that all of the authors are in agreement with submission of the manuscript to SM, and that, for studies that use animal or human individuals, authors must include information regarding their institution's ethics committee, and which identifies the official approval number;
- A signed form that there is no conflict of interest.

Name the files according to the family name of the first author. Authors submitting revised versions of the manuscript can use the identification number of their manuscript as provided by the Journal Office. *See* example:

- ✓ FAMILY NAME-manuscript.doc – (main manuscript file)
- ✓ FAMILY NAME-statement.PDF – (authorship statement)
- ✓ FAMILY NAME-declaration.PDF – (declaration of potential conflict of interest)
- ✓ FAMILY NAME-fig1.tiff – (Figure 1)

1.4. Peer Review Process

A manuscript submitted for publication will be submitted to the review process as long as it fits the following criteria:

- The study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere;
- All persons listed as authors approved its submission to SM;
- Any person cited as a source of personal communication has approved the quote;
- The opinions expressed by the authors are their exclusive responsibility;
- The author signs a formal statement that the submitted manuscript complies with the directions and guidelines of SM.

The editors-in-chief and associate editors will make a preliminary analysis regarding the appropriateness, quality, originality and written style/grammar of the submitted manuscript. The editors reserve the right to request additional information, corrections, and guideline compliance before they submit the manuscript to the ad-hoc review process.

SM uses ad-hoc reviewers, who volunteer to analyze the merit of the study. Typically, one or two expert reviewers are consulted in a double-blind process. Authors are notified by e-mail when their submission has been accepted (or rejected). Minor changes in the text may be made at the discretion of the editors-in-chief and/or associate editors. Changes can include spelling and grammar in the chosen language, written style, journal citations, and reference guidelines. The author is notified of changes via email. The final version is available to the author for his or her approval before it is published.

1.5. Open Access License and Publisher Copyright Policies

SM applies the Creative Commons Attribution (CC BY) license to articles and other works it publishes. If author(s) submit its paper for publication by SM, they agree to have the CC BY license applied to their work. Under this Open Access license, the author(s) agree that anyone can reuse their article in whole or part for any purpose, for free, even for commercial purposes. Anyone may copy, distribute, or reuse the content as long as the author(s) and original source are properly cited. This facilitates freedom in re-use and also ensures that SM content can be mined without barriers for the needs of research. On the other hand, the author(s) may use content owned by someone else in their article if they have written permission to do so. If the manuscript contains content such as photos, images, figures, tables, audio files, videos, et cetera, that the author(s) do not own, SM will require them to provide it with proof that the owner of that content has given them written permission to use it, and has approved of the CC BY license being applied to their content. Otherwise, SM will ask the author(s) to remove that content and/or replace it with other content that you own or have such permission to use. SM provides a form the author(s) can use to ask for and obtain permission from the owner.

In addition, the author(s) may freely use the content they previously published in a paper through another publisher and they own the rights to that content; however, that's not necessarily the case and it depends on the license that covers the other paper. Some publishers allow free and unrestricted reuse of article content they own, such as under the CC BY license. Other publishers use licenses that allow reuse only if the same license is applied by the person or publisher reusing the content. If the article was published under a CC BY license or another license that allows free and unrestricted use, the author(s) may use the content in the submitted manuscript provided that the author(s) give proper attribution, as explained above. If the content was published under a more restrictive license, the author(s) must ascertain what rights they have under that license. SM advices the author(s) not to include any content in the submitted manuscript which they do not have rights to use, and always give proper attribution.

The editors of SM consider plagiarism to be a serious breach of academic ethics. Any author who practices plagiarism (in part or totality) will be suspended for six years from submitting new submissions to SM. If such a manuscript is approved and published, public exposure of the article with a printed mark ("plagiarized" or "retracted") on each page of the published file, as well as suspension for future publication for at least six years, or a period determined by the editorial board. Third party plagiarized authors or institutions will be notified, informing them about the faulty authors. Plagiarism will result in immediate rejection of the manuscript.

SM only publishes studies that have been approved by an institutional ethics committee (when a study involves humans or animals). Fail to provide such information prevent its publication. To ensure these requirements, it is essential that submission documentation is complete. If you have not completed this step yet, go to SM website and fill out the two required documents: Declaration of Potential Conflict of Interest and Authorship Statement. Whether or not your study uses humans or animals, these documents must be completed and signed by all authors and attached as supplementary files in the originally submitted manuscript.

1.6. After Acceptance

After the manuscript has been accepted, authors will receive a PDF version of the manuscripts for authorization, as it should look in printed version of SM. Authors should carefully check for omissions. Reporting errors after this point will not be possible and the Editorial Board will not be eligible for them.

Should there be any errors, authors should report them to the Office e-mail address **sportmont@ucg.ac.me**. If there are not any errors authors should also write a short e-mail stating that they agree with the received version.

1.7. Code of Conduct Ethics Committee of Publications

C O P E COMMITTEE ON PUBLICATION ETHICS

SM is hosting the Code of Conduct Ethics Committee of Publications of the **COPE** (the Committee on Publication Ethics), which provides a forum for publishers and Editors of scientific journals to discuss issues relating to the integrity of the work submitted to or published in their journals.

2. MANUSCRIPT STRUCTURE

2.1. Title Page

The first page of the manuscripts should be the title page, containing: title, type of publication, running head, authors, affiliations, corresponding author, and manuscript information. *See* example:

Body Composition of Elite Soccer Players from Montenegro

Original Scientific Paper

Elite Soccer Players from Montenegro

Dusko Bjelica[1]

[1]Univeristy of Montenegro, Faculty for Sport an Physical Education, Niksic, Montenegro

Corresponding author:

Dusko Bjelica

University of Montenegro

Faculty for Sport and Physical Education

Narodne omladine bb, 81400 Niksic, Montenegro

E-mail: sportmont@t-com.me

Word count: 2,946

Abstract word count: 236

Number of Tables: 3

Number of Figures: 0

2.1.1. Title

Title should be short and informative and the recommended length is no more than 20 words. The title should be in Title Case, written in uppercase and lowercase letters (initial uppercase for all words except articles, conjunctions, short prepositions no longer than four letters etc.) so that first letters of the words in the title are capitalized. Exceptions are words like: “and”, “or”, “between” etc. The word following a colon (:) or a hyphen (-) in the title is always capitalized.

2.1.2. Type of publication

Authors should suggest the type of their submission.

2.1.3. Running head

Short running title should not exceed 50 characters including spaces.

2.1.4. Authors

The form of an author’s name is first name, middle initial(s), and last name. In one line list all authors with full names separated by a comma (and space). Avoid any abbreviations of academic or professional titles. If authors belong to different institutions, following a family name of the author there should be a number in superscript designating affiliation.

2.1.5. Affiliations

Affiliation consists of the name of an institution, department, city, country/territory (in this order) to which the author(s) belong and to which the presented / submitted work should be attributed. List all affiliations (each in a separate line) in the order corresponding to the list of authors. Affiliations must be written in English, so carefully check the official English translation of the names of institutions and departments.

Only if there is more than one affiliation, should a number be given to each affiliation in order of appearance. This number should be written in superscript at the beginning of the line, separated from corresponding affiliation with a space. This number should also be put after corresponding name of the author, in superscript with no space in between.

If an author belongs to more than one institution, all corresponding superscript digits, separated with a comma with no space in between, should be present behind the family name of this author.

In case all authors belong to the same institution affiliation numbering is not needed.

Whenever possible expand your authors' affiliations with departments, or some other, specific and lower levels of organization.

2.1.6. Corresponding author

Corresponding author's name with full postal address in English and e-mail address should appear, after the affiliations. It is preferred that submitted address is institutional and not private. Corresponding author's name should include only initials of the first and middle names separated by a full stop (and a space) and the last name. Postal address should be written in the following line in sentence case. Parts of the address should be separated by a comma instead of a line break. E-mail (if possible) should be placed in the line following the postal address. Author should clearly state whether or not the e-mail should be published.

2.1.7. Manuscript information

All authors are required to provide word count (excluding title page, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References), the Abstract word count, the number of Tables, and the number of Figures.

2.2. Abstract

The second page of the manuscripts should be the abstract and key words. It should be placed on second page of the manuscripts after the standard title written in upper and lower case letters, bold.

Since abstract is independent part of your paper, all abbreviations used in the abstract should also be explained in it. If an abbreviation is used, the term should always be first written in full with the abbreviation in parentheses immediately after it. Abstract should not have any special headings (e.g., Aim, Results…).

Authors should provide up to six key words that capture the main topics of the article. Terms from the Medical Subject Headings (MeSH) list of Index Medicus are recommended to be used.

Key words should be placed on the second page of the manuscript right below the abstract, written in italic. Separate each key word by a comma (and a space). Do not put a full stop after the last key word. *See* example:

Abstract

Results of the analysis of

Key words: *spatial memory, blind, transfer of learning, feedback*

2.3. Main Chapters

Starting from the third page of the manuscripts, it should be the main chapters. Depending on the type of publication main manuscript chapters may vary. The general outline is: Introduction, Methods, Results, Discussion, Acknowledgements (optional), Conflict of Interest (optional). However, this scheme may not be suitable for reviews or publications from some areas and authors should then adjust their chapters accordingly but use the general outline as much as possible.

2.3.1. Headings

Main chapter headings: written in bold and in Title Case. *See* example:
- ✓ **Methods**

Sub-headings: written in italic and in normal sentence case. Do not put a full stop or any other sign at the end of the title. Do not create more than one level of sub-heading. *See* example:
- ✓ *Table position of the research football team*

2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

2.3.3 Statistics reporting

SM encourages authors to report precise p-values. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Use normal text (i.e., non-capitalized, non-italic) for statistical term "p".

2.3.4. 'Acknowledgements' and 'Conflict of Interest' (optional)

All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

2.4. References

References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

2.4.1. References style

SM adheres to the American Psychological Association 6th Edition reference style. Check "American Psychological Association. (2009). Concise rules of APA style. American Psychological Association." to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

2.4.2. Examples for Reference citations

One work by one author
- ✓ In one study (Reilly, 1997), soccer players
- ✓ In the study by Reilly (1997), soccer players
- ✓ In 1997, Reilly's study of soccer players

Works by two authors
- ✓ Duffield and Marino (2007) studied
- ✓ In one study (Duffield & Marino, 2007), soccer players
- ✓ In 2007, Duffield and Marino's study of soccer players

Works by three to five authors: cite all the author names the first time the reference occurs and then subsequently include only the first author followed by et al.

- ✓ First citation: Bangsbo, Iaia, and Krustrup (2008) stated that
- ✓ Subséquent citation: Bangsbo et al. (2008) stated that

Works by six or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Krustrup et al. (2003) studied
- ✓ In one study (Krustrup et al., 2003), soccer players

Two or more works in the same parenthetical citation: Citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically, then chronologically)

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that

2.4.3. Examples for Reference list

Journal article (print):

Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57-65. doi: 10.26773/mjssm.2017.09.008

Duffield, R., & Marino, F. E. (2007). Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. *European Journal of Applied Physiology, 100*(6), 727-735. doi: 10.1007/s00421-007-0468-x

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise, 35*(4), 697-705. doi: 10.1249/01.MSS.0000058441.94520.32

Journal article (online; electronic version of print source):

Williams, R. (2016). Krishna's Neglected Responsibilities: Religious devotion and social critique in eighteenth-century North India [Electronic version]. *Modern Asian Studies, 50*(5), 1403-1440. doi:10.1017/S0026749X14000444

Journal article (online; electronic only):

Chantavanich, S. (2003, October). Recent research on human trafficking. *Kyoto Review of Southeast Asia, 4*. Retrieved November 15, 2005, from http://kyotoreview.cseas.kyoto-u.ac.jp/issue/issue3/index.html

Conference paper:

Pasadilla, G. O., & Milo, M. (2005, June 27). *Effect of liberalization on banking competition*. Paper presented at the conference on Policies to Strengthen Productivity in the Philippines, Manila, Philippines. Retrieved August 23, 2006, from http://siteresources.worldbank.org/INTPHILIPPINES/Resources/Pasadilla.pdf

Encyclopedia entry (print, with author):

Pittau, J. (1983). Meiji constitution. In *Kodansha encyclopedia of Japan* (Vol. 2, pp. 1-3). Tokyo: Kodansha.

Encyclopedia entry (online, no author):

Ethnology. (2005, July). In *The Columbia encyclopedia* (6th ed.). New York: Columbia University Press. Retrieved November 21, 2005, from http://www.bartleby.com/65/et/ethnolog.html

Thesis and dissertation:

Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport.* Unpublished Doctoral Dissertation. Tallahassee, FL: The Florida State University.

Book:

Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human kinetics.

Chapter of a book:

Kellmann, M. (2012). Chapter 31-Overtraining and recovery: Chapter taken from Routledge Handbook of Applied Sport Psychology ISBN: 978-0-203-85104-3 *Routledge Online Studies on the Olympic and Paralympic Games* (Vol. 1, pp. 292-302).

Reference to an internet source:

Agency. (2007). Water for Health: Hydration Best Practice Toolkit for Hospitals and Healthcare. Retrieved 10/29, 2013, from www.rcn.org.uk/newsevents/hydration

2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word *Note* (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. [a, b, c]), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript [a].

- ✓ [a]One participant was diagnosed with heat illness and n = 19.[b]n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

- ✓ *P<0.05,†p<0.01.

2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

- ✓ Table 1 (first letter in all capitals and no full stop)
- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
- ✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. SM prefers TIFF, EPS and PNG formats.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.

Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of SM.

2.6.1. Figure legends

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

2.6.2. Figure citation

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
  - × figure 1
  - × Figure 1.
  - ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
  - ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
  - ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
  - ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

2.6.3. Sub-figures

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

Signs should be placed immediately preceding the relevant number.		
✓ 45±3.4	✓ p<0.01	✓ males >30 years of age
× 45 ± 3.4	× p < 0.01	× males > 30 years of age

2.8. Latin Names

Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

- ✓ First time appearing: *musculus biceps brachii*

Abbreviated: *m. biceps brachii*

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SportMont
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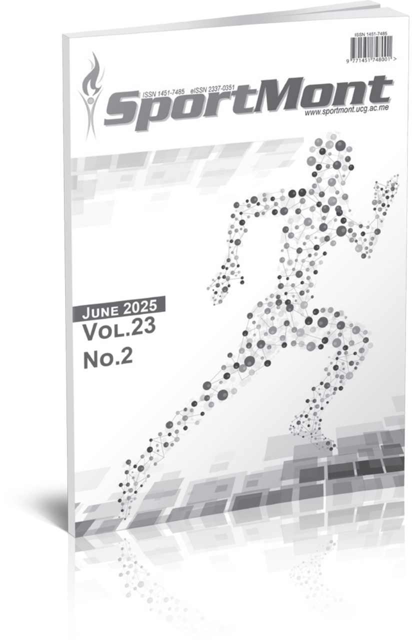

ISSN 1451-7485

Sport Mont Journal (SMJ) is a print (ISSN 1451-7485) and electronic scientific journal (eISSN 2337-0351) aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimize the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. Hence, it provides:

- Open-access and freely accessible online;
- Fast publication time;
- Peer review by expert, practicing researchers;
- Post-publication tools to indicate quality and impact;
- Community-based dialogue on articles;
- Worldwide media coverage.

SMJ is published three times a year, in February, June and October of each year. SMJ publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

SMJ covers all aspects of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

Prospective authors should submit manuscripts for consideration in Microsoft Word-compatible format. For more complete descriptions and submission instructions, please access the Guidelines for Authors pages at the SMJ website: http://www.sportmont.ucg.ac.me/?sekcija=page&p=51. Contributors are urged to read SMJ's guidelines for the authors carefully before submitting manuscripts. Manuscripts submissions should be sent in electronic format to sportmont@ucg.ac.me or contact following Editors:

Dusko BJELICA, Editor-in Chief – sportmont@t-com.me
Zoran MILOSEVIC, Editor-in Chief – zoranais@eunet.rs
Borko KATANIC, Editor-in Chief – borkokatanic@gmail.com
Nedim COVIC, Managing Editor – nedimcovic@gmail.com

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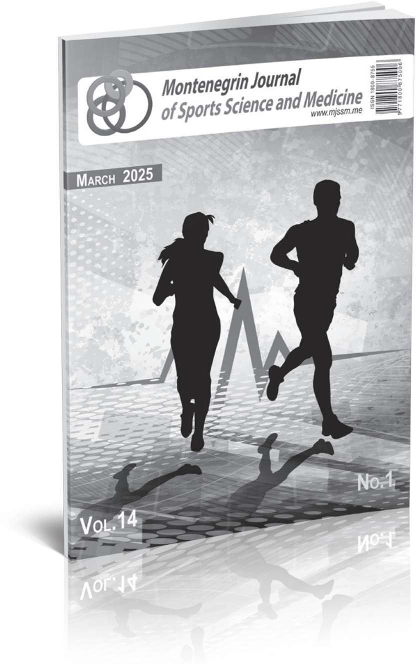
Montenegrin Journal of Sports Science and Medicine

MONTENEGRIN JOURNAL OF SPORTS SCIENCE AND MEDICINE



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CALL FOR CONTRIBUTIONS

Montenegrin Journal of Sports Science and Medicine (MJSSM) is a print (ISSN 1800-8755) and electronic scientific journal (eISSN 1800-8763) aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimize the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. Hence, it provides:

- Open-access and freely accessible online;
- Fast publication time;
- Peer review by expert, practicing researchers;
- Post-publication tools to indicate quality and impact;
- Community-based dialogue on articles;
- Worldwide media coverage.

MJSSM is published biannually, in September and March of each year. MJSSM publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

MJSSM covers all aspects of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

Prospective authors should submit manuscripts for consideration in Microsoft Word-compatible format. For more complete descriptions and submission instructions, please access the Guidelines for Authors pages at the MJSSM website: http://www.mjssm.me/?sekcija=page&p=51. Contributors are urged to read MJSSM's guidelines for the authors carefully before submitting manuscripts. Manuscripts submissions should be sent in electronic format to office@mjssm.me or contact following Editors:

Dusko BJELICA, Editor-in Chief – sportmont@t-com.me
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MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

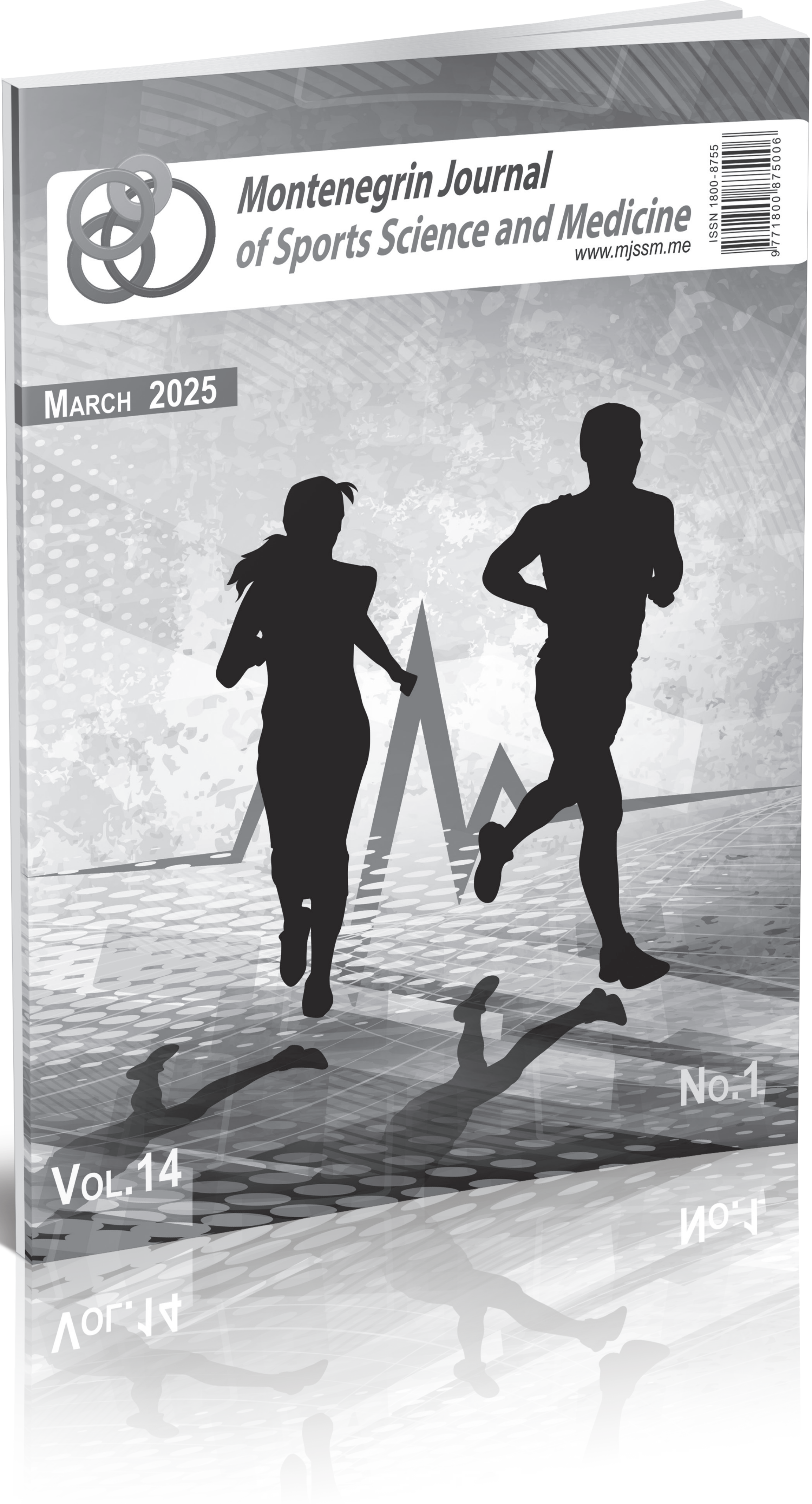
The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

It is our great pleasure to announce the upcoming 23th Montenegrin Sports Academy 23rd Conference “Podgorica Sports Science, Medicine & Health Forum 2025: Innovations, Achievements, Synergy and Challenges – A Bridge to the Future” to be held in Podgorica, Montenegro, from 18th to 19th September 2025. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).

The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.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Montenegrin Sports Academy
23rd Conference

MSA Conference 2025

Podgorica Sports Science, Medicine & Health Forum 2025:
Innovations, Achievements, Synergy and Challenges
A Bridge to the Future

https://csakademija.me/conference_podgorica/

18th - 19th September 2025,
Podgorica - Montenegro

Hotel – Crowne Plaza Podgorica