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Sadržaj / Contents

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Dragi čitaoci,

Pred vama je novo izdanje našeg Časopisa ''Sportske nauke i zdravlje". Zadovoljni smo povećanim interesom za objavu radova u našem Časopisu, o čemu govori činjenica da imamo radove autora iz Srbije, Sjedinjenih Američkih Država, Sjeverne Makedonije, Indonezije, Italije, Ujedinjenih Arapskih Emirata, Malezije, Hrvatske i Bosne i Hercegovine. U ovom broju ćete pročitati radove koji se odnose na ASH test i brzina servisa kod vrhunskih odbojkaša, procjenu efikasnosti integrisanog sistema prese za luk i table za izvlačenje na preciznost složenog luka, obrasce karijere u nacionalnim omladinskim košarkaškim timovima, korelaciju između zavisnosti od interneta i fizičke aktivnosti među studentima Univerziteta u Džogdžakarti: posrednička uloga kvaliteta sna, korelaciju fizičke aktivnosti, rizika od poremećaja u ishrani i sastava tijela kod mladih studentkinja, razvoj veb-zasnovanog informacionog sistema za upravljanje sportskim događajima za NPCI Istočne Jave, razlike u funkcionalnim sposobnostima kod mlađih karatista u predtakmičarskom i takmičarskom periodu, razlike u nekoliko testova koordinacije i preciznosti kod jedanaestogodišnje djece sa Kosova, istraživanje barijera u učenju i participacije studenata na univerzitetskim časovima košarke, istraživanje odnosa između snage stiska šake, mase tjelesne masti i bezmasne mase kod rukometaša i rukometašica, unapređenje krupne motorike u ranom djetinjstvu: kroz akvatične igre i hodanje na štulama od kokosove ljuske u pogledu ravnoteže, poboljšanje fizičke spremnosti sportista u borilačkoj vještini Penčak Silat putem kružnog treninga sa sopstvenom težinom, latentnu strukturu antropometrijskih karakteristika kod adolescenata muškog pola uzrasta 12–14 godina: dvotalasna faktorska analitička studija, metrijske karakteristike kratke skale za samoprocjenu kvaliteta života studenata tokom pandemije COVID-19, fizičku aktivnost i kognitivni razvoj: posrednička uloga svjesnosti o tijelu u akademskom postignuću, igra u sportskom treningu: empirijski dokazi o njenoj motivacionoj, obrazovnoj i psihofizičkoj ulozi, donošenje odluka rukometnog trenera prije utakmice korišćenjem kvalitativnih i kvantitativnih metoda, polne razlike u parametrima sastava tijela kod šesnaestogodišnjaka primjenom BIA metode, tradicionalne igre u fizičkom vaspitanju i šire: sistematski pregled eksperimentalnih istraživanja, evaluacija razvoja performansi u muškoj odbojci u posebnom regionu Džogdžakarta.

Uredništvo Časopisa kao i svaki put do sada želi da se zahvali svim autorima i recenzentima na uloženom trudu i ovom prilikom pozivamo naše dosadašnje saradnike, a posebno nove, mlade koleginice i kolege, da svojim radovima daju doprinos nastojanju da sportske nauke budu sve značajniji faktor dobrog zdravstvenog stanja ljudi. Nadamo se da će i ovaj broj ispuniti očekivanja šire čitalačke populacije. Jer kao što je rekao Roger Bannister, „Nauka nam daje alate, ali sport nam daje priliku da testiramo granice ljudskog duha."

UREDNIŠTVO ČASOPISA

Dear readers,

Another issue of the Journal "Sports Science and Health" is in front of you. We are pleased with the growing interest in publishing within our journal, as evidenced by the fact that we have contributions from authors representing Serbia, the United States, North Macedonia, Indonesia, Italy, the United Arab Emirates, Malaysia, Croatia, and Bosnia and Herzegovina.". In this issue, you will read articles regarding the ASH test and serve velocity in elite volleyball players, the assessment of the effectiveness of the integrated bow press and draw board system on compound bow precision, career patterns in national youth basketball teams, the correlation between internet addiction and physical activity among Yogyakarta State University students: the mediating role of sleep quality, the correlation of physical activity, risk of eating disorder, and body composition in young female students, the development of a web-based sporting event management information system for the East Java NPCI, differences in functional abilities in junior karatekas in the pre-competition and competition period, differences in several coordination and precision tests in 11-year-old children from Kosovo, exploring learning barriers and student participation in university basketball classes, exploring the relationship between handgrip strength, body fat mass and fat-free mass in male and female handball athletes, improving gross motor skills in early childhood through aquatic games and coconut shell stilt walking in terms of balance, improving physical fitness in Pencak Silat athletes through circuit bodyweight training, the latent structure of anthropometric characteristics in male adolescents aged 12–14: a two-wave factor analytical study, metric characteristics of a short scale for student quality of life self-assessment during the COVID-19 pandemic, physical activity and cognitive development: the mediating role of body awareness in academic achievement, play in sports training: empirical evidence of its motivational, educational, and psychophysical role, pre-game decision making by a handball coach using qualitative and quantitative methods, sex-based differences in body composition parameters among 16-year-olds using BIA, traditional games in physical education and beyond: a systematic review of experimental research, and the evaluation of men's volleyball performance development in the Special Region of Yogyakarta.T

The editorial board as always, would like, to thank all authors and reviewers for their hard work. We take this opportunity to invite our previous collaborators, and especially new, young female and male colleagues, to contribute through their work to the effort of making sports sciences an increasingly significant factor in people's good health. We hope that this issue will meet the expectations of the wider reading population. For as Roger Bannister said, "Science provides the tools, but sport gives us the chance to test the limits of the human spirit."

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ASH Test and Serve Velocity in Elite Volleyball Players

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Abstract: *The Athletic Shoulder (ASH) test is a novel assessment designed to measure the isometric force-time characteristics of the shoulder joint at three angles of abduction: 180° (I), 135° (Y), and 90° (T). Despite its increasing popularity, there is limited evidence linking this test to sport-specific tasks in overhead sports. This study aimed to provide normative data on peak isometric force during the ASH test and to examine its association with jump serve ball velocity in elite male volleyball players. We conducted a cross-sectional study involving 13 athletes. Peak isometric force in the I, Y, and T positions was measured using force plates, while jump serve ball velocity was assessed with a radar gun. The average peak force recorded during the ASH test was as follows: 199.15 ± 26.42 N in the I position, 193.38 ± 31.75 N in the Y position, and 173.69 ± 35.42 N in the T position. We found a weak positive, not statistically significant correlation between jump serve ball velocity and the peak isometric force produced in the I position (r=0.17, p=0.574) and weak negative, not significant correlations between jump serve ball velocity and the peak isometric force produced in the Y and T positions (r=-0.28, p=0.357 and r=-0.29, p=0.344). The univariate linear regression analysis showed no significant association between jump serve ball velocity and peak isometric force generated in any of the aforementioned positions: I (F=0.34, p=0.574), Y (F=0.91, p=0.357), or T (F=0.98, p=0.344). Our findings indicate that the peak isometric force produced in the ASH test is not a determinant of jump serve ball velocity in volleyball.*

Keywords: *ASH, Normative Data, Serve Speed, Elite Volleyball Players*

Introduction

Volleyball is an interesting, complex, and dynamic Olympic sport characterized by frequent high- intensity movements, where teams aim to score points through powerful attacks or by outsmarting their opponents (Gabbett et al., 2006; Lidor & Ziv, 2010). Since the basic elements of volleyball (e.g., serving and attacking) require a series of motor actions to be performed correctly and efficiently, it is crucial for coaches and physical trainers to understand the factors that affect the performance of these motor actions to achieve the best results. In volleyball, serving is a crucial skill that can significantly impact the game's outcome (Challoumas & Artemiou, 2018; Giatsis, 2022). Executing effective serves may lead to either a direct point (i.e., ace) or disruptions in the opponent's offensive play that may cause more errors and ultimately provide a strategic advantage to the serving team (Fernandez- Echeverria et al., 2015).

Ball velocity is a critical factor influencing serving effectiveness. (Moras et al., 2008). The determinants of ball velocity can be categorized into three groups: the technique of the motion, anthropometric characteristics, and motor skills (Altundag et al., 2024). While training can enhance the technique of motion and motor skills, many morphological factors are primarily determined by genetics. Although high-performance players exhibit only minor changes in their throwing technique, their motor skills can still be significantly improved through regular training (Marques et al., 2008). Therefore, investigating the relationship between various motor skills and sport-specific tasks is crucial. The relationship between volleyball serve ball velocity and motor skills remains limited. Studies investigating the association between isokinetic strength tests of the upper limbs and volleyball serve ball velocity (Aka et al., 2019; Altundag et al., 2019), produced mixed results. Aka et al.(2019) found that serve and spike velocity in elite volleyball players had no significant correlation to the wrist and shoulder joint isokinetic strength. This finding is not consistent with the results of a study conducted by Altundağet et al. in 2019, where the authors found a significant positive relationship between isokinetic shoulder muscle strength in the diagonal pattern and serving velocity among volleyball athletes (r=0.553-0.895).

Despite previous investigations into the relationship between isometric strength and various sport-specific tasks in overhead sports such as tennis, baseball, and handball (Hayes et al., 2021; Arnold et al., 2022; Schwesig et al., 2016), a notable gap remains in the literature regarding its association with serve ball velocity in volleyball. One of the most commonly used upper-body isometric assessments in applied sport settings is the Athletic Shoulder (ASH) test, developed by Ashworth et al. in 2018. This test comprises a series of long-lever isometric upper-body actions performed on force platforms. During the assessment, the athlete lies prone while the tested shoulder is positioned at three consecutive abduction angles: 180° (I position), 135° (Y position), and 90° (T position). Because force is applied against a fixed device, the ASH test reduces measurement error related to the tester's technique. Ashworth et al. emphasized that long-lever isometric tests more closely replicate the shoulder muscle demands of many sporting movements than short-lever tests, thereby enhancing the ecological validity of the assessment. However, despite its increasing use, the relationship between ASH test performance and serve ball velocity in volleyball has not yet been explored.To address this research gap, the aim of the study was to provide normative data on peak isometric force during the ASH test and to examine its association with jump serve ball velocity in elite male volleyball players.

Methods and Materials

Participants and Procedures

This cross-sectional study was conducted in June 2025 in Strumica, North Macedonia, during national-team preparation for the CEV European Golden League. Participants were 13 elite senior male national-team volleyball players (22–31 y; ≥5 y competitive experience; ~25–30 h·wk^{-1} volleyball-specific and strength & conditioning) who voluntarily participated in the study. All were medically cleared, free of musculoskeletal injury, and regular jump-serve users. To minimize learning effects before testing, athletes completed two familiarization sessions. To reduce interference from uncontrolled variables, all participants were instructed to maintain their habitual lifestyle.Testing followed a standardized team warm-up and a fixed order. First shoulder isometric strength was assessed with the ASH test (I/180°, Y/135°, T/90°) on a uni-axial force plate (ForceDecks Mini, VALD, Brisbane, Australia; 1,000 Hz, calibrated/zeroed between participants). 3 maximal trials of 30s were performed for each position with 60–90 s rest between trials and 2 min between positions. The highest peak force per position was retained. Jump-serve ball velocity was measured with a calibrated radar positioned 8 m behind the service line and 3 m above ground (contact-height alignment). After 10 warm-up serves, each athlete performed 5 valid jump serves with 60 s' rest in between them. The highest velocity was analyzed.

Statistical analysis

All statistical analyses were performed using a commercially available statistical software package. Descriptive statistics (mean, standard deviation, minimum, and maximum) were calculated for all variables. The Shapiro–Wilk test was used to assess the normality of continuous data. Differences in peak isometric force between the three ASH positions (I, Y, T) were examined using a Friedman repeated-measures ANOVA, followed by pairwise Wilcoxon signed-rank tests when the overall test was significant. The relationships between jump serve ball velocity and peak isometric force in each ASH position were evaluated using Pearson product–moment correlation coefficients with corresponding 95% confidence intervals. In addition, univariate linear regression analyses were conducted with jump serve ball velocity as the dependent variable and peak force in each of the three positions entered separately as the independent variable. The level of statistical significance was set a priori at $p < 0.05$.

Results

Participants had a mean age of 27.23 ± 6.6 years, an average body weight of 94.46 ± 8.17 kg, and an average height of 195.15 cm ± 5.97 cm. The demographic characteristics of the participants are presented in Table 1.

Table 1. *Demographic characteristics of the participants.*

Variables	n	Mean	SD
Age (years)	13	27.23	6.6
Body Mass (kg)	13	94.46	8.17
Body Height (cm)	13	195.15	5.97

During the ASH test, the highest peak force was recorded in the I position (180° abduction), with a mean peak force of 199.15±26.42 N. The minimum and maximum values observed were 150 N and 243 N. In the Y position (135° abduction), participants achieved a mean peak force of 193.38±31.75 N, with minimum and maximum values of 125 N and 232 N. The lowest peak force was generated in the T position (90° abduction), where the mean peak force was 173.69±35.42 N, with minimum and maximum values of 119 N and 220 N. The mean jump serve ball velocity among participants was 101.38±4.24 km/h, with minimum and maximum values of 95 km/h and 109 km/h. Peak isometric force in the I, Y, and T positions, and jump serve ball velocity, are presented in Table 2.

Table 2. *Peak isometric force in I, Y, and T positions and jump serve ball velocity.*

Variable	Mean	SD	Minimum	Maximum
ASH I (180°)	199.15	26.42	150	243
ASH Y (135°)	193.38	31.75	125	232
ASH T (90°)	173.69	35.42	119	220
Jump Serve Ball Velocity	101.38	4.24	95	109

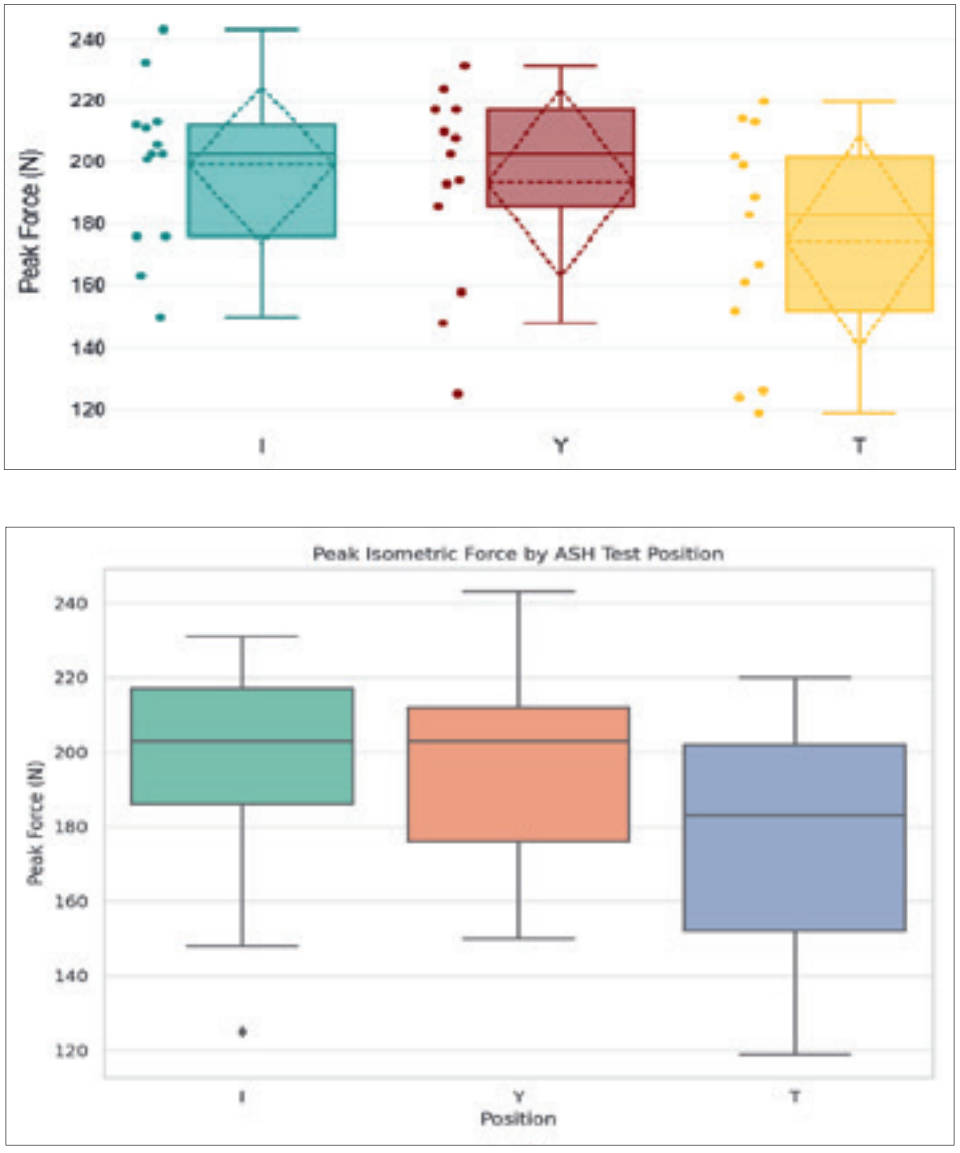


Figure 1. *Peak isometric force in I, Y, and T ASH positions.*

A Friedman repeated-measures ANOVA revealed a statistically significant difference in peak force across the three shoulder positions: χ^2 (2) = 11.69, p = 0.0029. Post-hoc Wilcoxon signed-rank tests showed:
I vs Y: Not significant (p = 0.376)
I vs T: Significant (p = 0.002)
Y vs T: Significant (p = 0.006)

Figure 1 presents a bar chart comparison of the peak isometric force produced in the I, Y, and T positions of the ASH test.

Pearson correlation analysis revealed a weak positive, not statistically significant correlation between jump serve ball velocity and the peak isometric force produced in the I position (r=0.17, p=0.574) and weak negative, not significant correlations between jump serve ball velocity and the peak isometric force produced in the Y and T positions (r=-0.28, p=0.357 and r=-0.29, p=0.344). The results of the Pearson correlation analysis are summarized in Table 3.

Table 3. *Results of Pearson correlation analysis.*

Parameters		n	r (95% CI)	p
	I	13	0.17 (-0.42, 0.66)	.574
JSBV	Y	13	-0.28 (-0.72, 0.32)	.357
	T	13	-0.29 (-0.73, 0.31)	.344

Note: JSBV – jump serve ball velocity

The univariate linear regression analysis presented in Figure 1 showed no significant association between jump serve ball velocity and peak isometric force generated in either the I (F=0.34, p=0.574), Y (F=0.91, p=0.357), or T position (F=0.98, p=0.344).

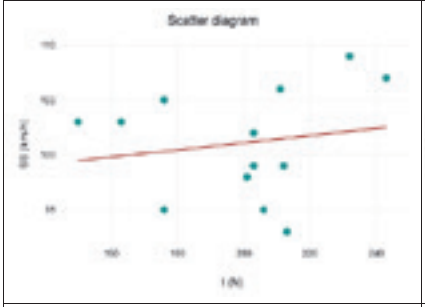
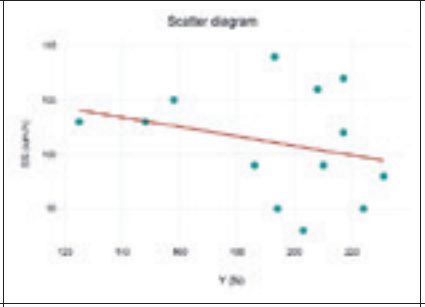
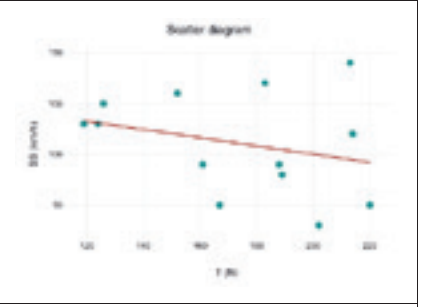
a)	*b)*	*c)*
		
r^2 = 0.03 95% CI = -0.42 to 0.66 y = 94.56 + 0.03*x F = 0.34, p = 0.574	r^2 = 0.08 95% CI = -0.72 to 0.32 y = 109.54 - 0.04*x F = 0.91 p = 0.357	r^2 = 0.08 95% CI = -0.74 to 0.31 y = 108.12 - 0.04*x F = 0.98, p = 0.344

Figure 2. *Results of univariate linear regression analysis. (a) Linear regression between jump serve ball velocity and peak isometric force produced in the I position. (b) Linear regression between jump serve ball velocity and peak isometric force produced in the Y position. (c) Linear regression between jump serve ball velocity and peak isometric force produced in the i position*

Discussion

Based on the obtained results, the following can be observed: The average peak forces recorded during the ASH test were as follows: 199.15 ± 26.42 N in the i position, 193.38 ± 31.75 N in the Y position, and 173.69 ± 35.42 N in the T position. Our participants demonstrated statistically significantly higher peak isometric force in the I and Y positions compared to the T position. To our knowledge, there is currently no existing evidence providing normative data on the peak force achieved in the ASH test specifically for volleyball players, nor on the comparison of force produced in the different shoulder abduction positions during the test. However, when compared to studies conducted in baseball and rugby, our results are consistent with their findings, which also show that participants exhibited higher isometric peak force values in the I and Y positions compared to the T position (Trunt et. al., 2022; Ashworth et al., 2018). The Pearson

correlation analysis revealed a weak positive correlation between the peak isometric force produced in the I position and jump serve ball velocity, as well as weak negative correlations between the peak isometric force generated in the Y and T positions and jump serve ball velocity. However, none of these correlations achieved statistical significance. Furthermore, the univariate linear regression analysis indicated no significant associations between the peak isometric force produced in the I, Y, or T positions and jump serve ball velocity. Overall, our findings suggest that peak isometric force generated in the ASH test is not a determinant of jump serve ball velocity in elite-level volleyball players. The relationship between peak isometric force in the shoulder joint and various tasks in overhead sports has been extensively studied. In contrast to our findings, a study by Baiget et al. (2016) found a strong positive correlation between serve velocity and isometric strength in shoulder internal rotation, as well as a moderate positive correlation between serve velocity and isometric shoulder flexion strength among competitive tennis players. The authors of that study reported that isometric strength in shoulder internal rotation and flexion accounted for 55% of the variance in tennis serve velocity. Aligning with our findings, Garcúa-Buendía et al. (2022) examined the link between shoulder internal rotation strength and standing throwing velocity in handball players and reported no significant covariation between the two variables. Additionally, in the context of volleyball, Terol-Sanchis et al. (2021) concluded that there was a strong correlation between isometric strength in shoulder internal rotation and the velocity of the power kick serve in beach volleyball ($r = 0.76$; $p < 0.05$), which contrasts with our results.The discrepancies between our study and that of Terol-Sanchis et al. (2021) may be attributed to differences in kinematic and kinetic factors between the jump serve in volleyball and the power kick serve in beach volleyball, as well as variations in the methods used to assess shoulder isometric strength. While both the jump serve and the power kick serve are dynamic movements requiring significant intra- and intermuscular coordination, beach volleyball athletes performing the power kick serve rely more on upper body strength to achieve higher ball velocities. This reliance is primarily due to the constraints of playing on sand, which limit their ability to generate kinetic energy from their lower body musculature. Furthermore, the methods used to quantify isometric shoulder strength show significant biomechanical differences. The ASH test, for example, involves longer levers and engages a higher percentage of upper body musculature compared to the shoulder internal rotation test.

The primary strength of this research lies in its status as the first study to investigate the relationship between the peak isometric force produced during the ASH test and jump serve ball velocity among elite volleyball athletes. However, several limitations should be considered. First, the findings should be interpreted with caution due to the small sample size, the specific characteristics of the population, and the method employed to assess shoulder strength, as well as the nature of the sporting task involved. Additionally, we relied solely on a non-time-constrained metric (peak force) to establish the association between ASH and jump serve ball speed. Finally, because this is a cross-sectional study, it does not establish causal relationships between the variables.

Despite the limitations of this study, we recommend that practitioners avoid using ASH test peak force values in isolation as indicators of jump serve performance in volleyball. Instead, the peak force produced in the ASH test may be more suitable for monitoring shoulder strength profiles, identifying asymmetries, or tracking rehabilitation progress (Trunt et. al., 2022; Ashworth et al., 2018). Existing research (Ashworth et al., 2018) indicates that early indicators of rate of force development (RFD) and combined strength tests (such as ASH and jump tests) are more effective predictors of performance in dynamic overhead sports actions. Therefore, coaches are encouraged to incorporate combined, more sport-specific, ballistic assessments when evaluating or training for serving power.

Conclusion

To our knowledge, this is the first study was to provide normative data on peak isometric force during the ASH test and to examine its association with jump serve velocity speed in elite male volleyball players. Our results indicated a weak positive correlation between the peak isometric force in the i position and jump serve ball speed and weak negative correlations for the peak isometric force in the Y and T positions relative to jump serve ball velocity. However, none of these correlations achieved statistical significance. The univariate linear regression analysis also demonstrated no significant association between peak isometric force in any of the I, Y, or T positions and jump serve ball velocity. Our findings indicate that the peak isometric force produced in the ASH test is not a determinant of jump serve ball speed in volleyball. However, due to the limitations of our study, further research in this area is necessary.

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Assessment of the Effectiveness of the Integrated Bow Press and Draw Board System on Compoud Bow Precision

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Abstract: *Introduction: archery, particularly in the compound division, requires precise tuning of bowstring systems to achieve consistent shot accuracy. improper adjustment of string tension and cam synchronization often reduces performance even in skilled archers. Objective: the purpose of this study was to evaluate the effectiveness of the bow press and draw board all-in-one system in improving the precision of compound bow string alignment and shooting accuracy. Methodology: the research adopted an experimental design with a one-group pretest–posttest approach involving six trained university-level archers. participants practiced for four weeks using the integrated tuning system, and data on string precision were collected before and after the intervention. paired sample t-test analysis was used to determine the significance of improvements. Results: results indicated a significant increase in mean string precision scores ($p < 0.05$) after training, with an average improvement of 20.1 %. qualitative observations confirmed better postural stability, smoother release, and more consistent arrow grouping. Discussion: findings align with previous biomechanical studies that emphasize the influence of equipment tuning and postural control on archery performance. the integration of mechanical and digital feedback in the all-in-one system reduces alignment errors and enhances training efficiency. Conclusions: the bow press and draw board all-in-one system proved to be an effective, safe, and accessible tool to improve compound bow precision, supporting both athletic performance and coaching practice.*

Keywords: *accuracy; biomechanics; bow tuning; compound archery; training system*

Introduction

Archery is a precision sport that demands high levels of accuracy, particularly in the compound division, which heavily depends on proper equipment setup and tuning techniques. In Indonesia, archery has experienced significant growth in popularity; however, limited attention has been given to the optimization of archery tools. Inappropriate equipment alignment often leads to decreased accuracy even among skilled archers (Author, 2023). Therefore, the use of an integrated Bow Press and Draw Board All-In-One System is considered essential to enhance the precision of compound bow string settings. The relationship between draw length and arrow length plays a crucial role in achieving desired accuracy. Many archers face challenges when their draw length does not match the bow specifications, leading to improper cutting of arrows and reduced shooting stability (Author, 2024). With the application of a bow press system, archers can fine-tune their bows more accurately, minimizing errors during setup. In Indonesia, access to high-quality tuning tools remains limited, forcing athletes to rely on manual devices that can damage bows and reduce precision (Author, 2024). Furthermore, the high cost of professional bow presses discourages many archers from acquiring them, thereby hindering their performance optimization.

Many local coaches lack adequate knowledge about bow tuning due to their dependence on external experts, who are not always consistently available. In addition, many athletes report a lack of understanding about bow tuning and maintenance, which often forces them to travel long distances for repairs, adding to the burden of time and cost (Author, 2024). Such a system can provide archers with the ability to tune their bows with precision without having to bear excessive maintenance costs.

Previous studies emphasize that mechanical factors, such as cam profiles and draw-force curves, significantly influence bow stability and accuracy (Denizhan & Chew, 2025). Similarly, biomechanical analyses indicate that postural stability parameters such as bow displacement, tremor, and center of pressure correlate strongly with shoot-

ing accuracy (Kim et al., 2025). Building upon these findings, this study introduces a novel integrated system that combines mechanical tuning and precision measurement within a single rigid framework, reducing potential setup errors and improving tuning consistency. The study aims to contribute to the field of sports engineering by providing an innovative, cost-effective solution that can improve archery performance, promote technological development in Indonesia, and support the advancement of sports science at both national and institutional levels.

Beyond equipment affordability and access, precision in compound archery also depends on how archers manage the perturbation induced at release. Recent experimental work characterizes anticipatory postural adjustments in trained archers and shows that elite performers trigger stabilization strategies earlier relative to string release, underscoring the centrality of postural control in accuracy-critical phases of the shot cycle (Kuch et al., 2024). The mechanical dynamics of modern compound bows have been increasingly examined through computational and experimental models to enhance accuracy and stability. He et al. (2025) demonstrated, via finite-element simulations of round-wheel cam configurations, that minor deviations in cam profile geometry can alter the draw-force curve and synchronization, thereby affecting release smoothness and target consistency. Such modeling supports the refinement of tuning devices that minimize asymmetrical stress during draw and release. Furthermore, practical tuning techniques such as *walk-back* and *paper tuning* have been empirically proven to improve grouping precision by reducing string deflection and optimizing arrow spine alignment (Perkasa, Wibafied, & Yachsie, 2022). These engineering and practical perspectives jointly underline the significance of developing an integrated Bow Press and Draw Board All-In-One System to assist athletes and coaches in standardizing tuning operations.

Contemporary archery research increasingly acknowledges that equipment calibration alone is insufficient; athlete biomechanics also play a crucial role in precision outcomes. For example, a systematic review by Santos, Barreto, Atalaia, and Aleixo (2025) reported that higher center-of-pressure (COP) sway during the aiming phase is negatively associated with shot accuracy, suggesting that tuning systems must support neuromuscular stability, not just mechanical alignment.

Method

This study employed an engineering and experimental research approach oriented toward research and development (R&D). The purpose of this design was to develop, test, and evaluate the Bow Press and Draw Board All-in-One System as an innovative tuning tool for compound bows, aimed at improving string precision, cam synchronization, and shooting accuracy. The research process began with a user needs analysis and a technical literature review, followed by conceptual design using Computer-Aided Design (CAD) software and Finite Element Method (FEM) simulations to verify the tool`s structural strength and stability. Subsequently, a prototype was fabricated and tested in a controlled laboratory setting to evaluate its mechanical performance and alignment accuracy. In addition, an empirical and biomechanical approach was employed, wherein the prototype was tested by active archers to observe its effects on shot precision and postural stability. This mixed approach combined mechanical engineering, digital instrumentation, and human performance evaluation to ensure that the developed system was not only technically effective but also scientifically validated for practical archery applications.

Participants

The participants in this study consisted of archery athletes from the Faculty of Sports Science and Health (FIKK), Universitas Negeri Makassar (UNM). A total of 15 athletes participated in the study, supported by three certified archery coaches who provided supervision during testing sessions. All participants provided informed consent before taking part in the research.

Procedure

This study was conducted at the Sports Science Laboratory, Faculty of Sports Science and Health, UNM. This location was chosen because it provides adequate facilities for archery training, including a special archery field, strength and fitness training areas, and biomechanical measurement equipment. The research process followed a One-Group Pretest–Posttest design, beginning with pretest data collection to measure the athletes' bowstring precision under baseline conditions. Participants then underwent a four-week training intervention using the Bow Press and Draw Board All-in-One System during their regular training sessions. After completing the intervention, a post-test

was conducted to assess changes in bowstring precision, shooting accuracy, and equipment calibration consistency. Observations and questionnaires were also used to collect feedback from athletes and coaches regarding the ease of use, safety, and practicality of the equipment.

Instrument

The Bow Press and Draw Board All-in-One System prototype incorporated a mechanical frame equipped with adjustable jigs, pressure sensors, and digital gauges for real-time data acquisition.

Measurement tools such as the load cell and linear displacement gauge were employed to capture draw force and draw length, respectively. In addition, a Likert-scale questionnaire was used to collect qualitative data on user satisfaction, tool safety, and perceived benefits. All measurement instruments were validated by two archery experts and one mechanical engineering lecturer to ensure reliability and construct validity before data collection. Physical Activity Quiz A brief physical activity and readiness questionnaire was administered before testing to confirm that participants were in proper physical condition for archery practice and laboratory measurements.

Data analysis

Data analysis followed quantitative and descriptive qualitative procedures. Descriptive statistics (mean, standard deviation, and percentage increase) were used to present pre-test and post-test results. To determine the significance of the intervention, a paired sample t-test was performed at a 0.05, the result was considered statistically significant, indicating that the Bow Press and Draw Board All-in-One System effectively improved string precision. Qualitative data from observations and coach questionnaires were analyzed descriptively to reinforce the quantitative findings, especially in relation to tool safety, ease of use, and training practicality.

Resulth

The experimental analysis evaluates the effectiveness of the Bow Press and Draw Board All-in-One System in improving the precision of compound bow strings among university-level archers. Six participants completed pre-test and post-test precision assessments after a four-week training intervention. The results indicate a consistent improvement across all participants, as shown in Table 1.

Table 1. *Comparison of Pre-test and Post-test Scores of String Precision*

Experimental Group (n=6)				
Variable	**PRE**	**POST**	**P value**	**Effect size**
	(Mean ± SD)	**(Mean ± SD)**		
String precision score	71.3 ± 2.22	85.7 ± 2.35	0.002	2.48

**Significant differences, p< .05*

The results show a statistically significant increase in string precision scores from the pre-test (M = 71.3, SD = 2.22) to the post-test (M = 85.7, SD = 2.35), representing an average improvement of 20.1%. The paired sample t-test yields a p-value of 0.002, confirming that the enhancement is statistically significant at the 0.05 level. The effect size (d = 2.48) indicates a large effect, suggesting that the tool has a substantial impact on improving bow tuning precision and shooting consistency. Qualitative feedback collected from coaches also supports these findings. All respondents rated the system as safe, functional, and beneficial for training, noting improvements in arrow groupings and reduced cam misalignment during repeated draws. Observations further reveal that athletes demonstrate increased stability in posture and smoother release phases after the intervention, indicating both technical and biomechanical improvements (Figure 1).

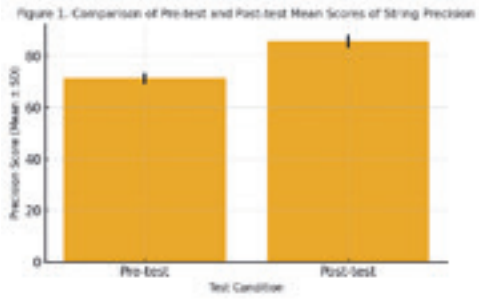

Figure 1. *Comparison of Pre-test and Post-test*

Discussion

The results confirm that the Bow Press and Draw Board All-in-One System effectively enhances compound bow tuning precision and shooting accuracy. These findings align with prior research emphasizing the importance of mechanical stability and postural control in archery performance. Kim et al. (2025) demonstrated that reduced bow displacement and tremor during aiming correlate with improved shot grouping, reinforcing the biomechanical relevance of the current study's outcomes. Similarly, Fan et al. (2025) highlighted that posture control and muscle stability play a decisive role in optimizing shot precision, supporting the notion that mechanical alignment tools can aid archers in maintaining consistent draw cycles. In the same line, Song and Kim (2024) emphasized that consistent follow-through and controlled release significantly determine shot accuracy principles reinforced by the functionality of the integrated draw board mechanism in this study.

From a technical standpoint, Zanevskyy and Zanevska (2023) noted that precise bow tuning, particularly through mechanical calibration of string tension and cam synchronization, is crucial for consistent arrow flight.The current system`s design addresses this requirement by combining a bow press and draw board into a single calibrated unit, minimizing user error and ensuring repeatable alignment during setup. This aligns with Jacquot et al. (2024), who demonstrated that integrating biomechanical and mechanical optimization leads to higher overall archery performance. The present findings align with the broader motor control literature indicating that accuracy improvements emerge when the athlete constrains center-of-pressure excursions and times muscular synergies to counter release-induced perturbations. Documented evidence of earlier anticipatory adjustments among elite archers supports the interpretation that our integrated tuning system—by improving consistency of draw-force and cam timing helps athletes stabilize posture during aiming and release, thereby facilitating tighter groupings (Kuch et al., 2024)

Dorshorst (2019) emphasized through a biomechanical anthropological analysis that repetitive mechanical loading from archery induces adaptive bone remodeling patterns consistent with increased non-dominant arm robustness and reduced humeral asymmetry. These findings support the notion that tuning interventions promoting balanced mechanical loads are critical for both performance and long-term musculoskeletal health. Overall, the study provides empirical evidence that integrating digital instrumentation (load cells, linear gauges, and angle sensors) into a mechanical tuning system results in quantifiable gains in archery precision.A study by Kesilmiş, Söğüt & Çömelekoğlu (2024) investigated the relationship between dynamic balance performance and shooting scores among 18 archers, finding moderate positive correlations between Y-Balance reach distances and archery accuracy ($r = 0.670$, $p < 0.05$), thereby suggesting that reduced postural sway contributes to precision in compound bow shooting.

Another study by Humaid, Wattimena, Hernawan, Ramadhan, Utama, & Wenly (2025) implemented a 12-week posterior-chain mobility program for archers and reported large effect sizes in improving hamstring and hip flexibility, which in turn correlated with better draw-phase mechanics and more accurate string alignment during arrow release. The importance of upper-limb muscle strength and endurance in archery was demonstrated by a 2023 study by Prasetyo, Siswantoyo, & Hartanto, in which bosu-ball circuit training enhanced balance and stability during arrow release, resulting in improved accuracy scores after the intervention. Moreover, with systematically and well-planned circuit training, both fitness and accuracy were found to improve compared to previous levels (Susanto et al., 2021).

An ergonomic analysis by Lee & Owens (2024) employed motion-capture technology and biomechanical software on 13 archers with different bow draw weights and found distinct gender-based postural compensations during

the aiming phase. These findings suggest that bow tuning systems should be adjustable to individual anthropometry rather than adopting a "one-size-fits-all" approach. A systematic review by Yachsie, Suharjana, Graha & Hartanto (2023) synthesised evidence from 16 studies and concluded that lower center-of-pressure displacement, smaller COP ellipse areas, and reduced bow-sway were consistently associated with superior shooting performance, reinforcing the necessity of integrating balance training with equipment tuning. A controlled trial by Wattimena, Humaid, Lubis, Pratama & Resmana (2025) assessed medicine-ball training loads among collegiate archers and found significant improvements in upper-limb muscular endurance and balance ($p < 0.05$) across both 3 kg and 4 kg groups, supporting the view that enhanced physical conditioning complements tuning devices for precision enhancement.

Recent developments in sensor-based technologies have introduced new methods for analyzing and predicting archery performance through real-time data acquisition. Ogasawara, Fukamachi, Aoyagi, Kumano, Togo, and Yamaguchi (2023) designed an automatic shooting detection system that uses acceleration sensors to predict archery scores by identifying draw-phase and release-phase kinematic patterns. Their findings demonstrated that acceleration data captured from the bow and archer's body could accurately classify successful and less-accurate shots with high precision. This evidence supports the integration of sensor-based analytics into mechanical tuning systems, allowing archers to monitor draw consistency and release dynamics quantitatively. Consequently, combining biomechanical tuning devices such as the Bow Press and Draw Board All-In-One System with embedded motion sensors could enable data-driven feedback for improving alignment precision and shooting accuracy (Ogasawara et al., 2023).

Conclusion

Based on the research conducted at the Faculty of Sports Science and Health (FIKK), Universitas Negeri Makassar, it was concluded that the Bow Press and Draw Board All-In-One System was effective in improving the string precision of compound bows. 1% in string precision after one month of training using the developed tool. This improvement demonstrated that the device successfully assisted athletes in stabilizing bow draw, maintaining consistent arrow release, and improving string control through accurate tuning. The safety aspect included the stability of the device during use, the usefulness related to its effectiveness in technical practice, and the superiority concerned with ease of setup and time efficiency during training sessions. Overall, this study reinforced previous findings asserting that bow stability, postural balance, and consistent draw technique are crucial elements in enhancing shot precision. The integration of the Bow Press and Draw Board into a single all-in-one system provided a more efficient, practical, and biomechanically grounded training approach. Therefore, it was concluded that the Bow Press and Draw Board All-In-One System is an effective and feasible innovative training tool for improving precision and shooting accuracy among university-level compound archery athletes.

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Career Patterns in National Youth Basketball Teams

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Abstract: *This study examines the trends and factors influencing the performance and career trajectories of players within the National men's senior basketball team from Croatia. The research analyzes data from 189 Croatian youth national team players born between 1992 and 2003, who competed in major international tournaments between 2008 and 2022. Key factors such as the player's year of birth, the number of appearances for youth national teams (U16 to U20), and the senior A-team are explored. The findings reveal important insights into the structure of Croatian basketball talent development, the role of continuity and consistency, and the impact of international competition experience. Data on the duration of the players' representative careers shows that the majority of careers lasted one year (40.2%), followed by two or three-year careers (54%), with four or five-year careers being the least common (less than 5%). Statistical tests reveal moderate to significant relationships between career duration, career type and appearances for the senior national team. Binary logistic regression results indicate a positive correlation between participation in youth categories (U18, U19, and U20) and senior team appearances, with the strongest association seen for U19 World Championship participants.This study also highlights the significance of long-term career trajectories in shaping successful transitions to senior teams.*
Keywords: *basketball, performance, selection, talent development*

Introduction

The identification and development of sports talent is a critical component of national sporting organizations' strategies. These organizations are dedicated to identifying and nurturing elite athletes to achieve international sporting success. Kalen et al. (2021) emphasize the commitment of sports organizations to invest in specialized programs for talent identification and development. However, this process is complex and dynamic, involving continuous selection, reselection, and deselection of athletes. To illustrate this complexity, the German Football Association (DFB) and the German Football League (DFL) have developed an advanced talent identification and development concept (Schroepf et al., 2018). This holistic approach includes systematic implementation of development programs for young athletes, the formation of academies for professional clubs, and the identification and promotion of elite talents through youth teams.

In the context of building successful teams, Dogan et al. (2015) identified key factors such as offensive efficiency, team coordination, and possession of the ball as critical elements of team success. These insights are invaluable for coaches and scouting teams in decision-making processes and optimizing player performance. Beyond technical and tactical factors, biological maturation also plays a key role. Arede et al. (2021) found that players who are biologically more advanced have a greater likelihood of being selected for representation. This further underscores the importance of accurately assessing various aspects of players in the selection process. In their analysis of NBA professionals, Moxley et al. (2015) identified several key early career indicators, such as player height, age, college basketball experience, and performance at the NBA Draft Combine, as significant predictors of future performance.

On the other hand, the phenomenon of relative age effects (RAE), which points to an overrepresentation of players born in the first quarter of the year, plays an important role in team sports selection (Arrieta et al., 2016; de Subijana et al., 2018). This phenomenon highlights developmental differences in physical, cognitive, and motivational aspects among athletes, leading to inequality in the selection process. This often results in a disadvantage for players born later in the year. These findings highlight the need for further research and innovations in talent identification and development strategies.

Methods

The aim of this research is to identify the career patterns of top young Croatian basketball players across different time periods by tracking their appearances in youth national teams. The study involved a significant number of young Croatian national basketball players during a 14-year period from 2008 to 2022. Players born between year 1992. and 2003. were selected for this study, as they had the opportunity to go through U16 to U20 teams and had already reached senior status by the time of the study. A total of 189 players were included in this research. Success at the senior level in this study was defined as an appearance for the Croatian senior national team. All appearances of young players who participated in at least one official match in their respective age categories between the 2007./2008. and 2021./2022. seasons were included in the data analysis. For each player, the following data was collected: name, year of birth, number of appearances in youth national teams (from U16 to U20), professional status, and appearances for the senior national team. Table 1 highlights the European (U16, U18, U20) and World Championships (U17, U19) in which the Croatian youth national team participated during each season, with relevant years marked in grey.

Table 1. *Cohorts included in this study*

	Youth categories										
Season	**1992.**	**1993.**	**1994.**	**1995.**	**1996.**	**1997.**	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**
2007./2008.	**U16**										
2008./2009.	U17	**U16**									
2009./2010.	**U18**	U17	**U16**								
2010./2011.	**U19**	**U18**	U17	**U16**							
2011./2012.	**U20**	U19	**U18**	**U17**	**U16**						
2012./2013.		**U20**	**U19**	**U18**	U17	**U16**					
2013./2014.			**U20**	U19	**U18**	U17	**U16**				
2014./2015.				**U20**	**U19**	**U18**	U17	**U16**			
2015./2016.					**U20**	U19	**U18**	U17	U16		
2016./2017.						**U20**	U19	**U18**	U17	**U16**	
2017./2018.							**U20**	U19	**U18**	**U17**	**U16**
2018./2019.								U20	U19	**U18**	U17
2019./2020.									**U20**	U19	**U18**
2020./2021.										**U20**	U19
2021/2022.											U20

** Championships in which the Croatian youth national team participated are marked in grey*

A vector of length five was generated to describe the player's status between U16 and U20. Appearances were coded as 1, and non-appearances as 0. The first digit in the binary representation indicates an appearance in U16, the second for U17, the third for U18, the fourth for U19, and the fifth for U20. Out of the 25 possible career patterns, 24 were found in the sample of players included in the study. The remaining eight career patterns were excluded as they were not found in the sample. Furthermore, the 24 career patterns were classified into six types of careers for further statistical analysis by grouping similar career patterns. These similarities were characterized by the number of appearances as well as the timing of selection. The study identified the following categories: "one appearance," which refers to national careers in youth national teams consisting of a nomination in just one year; "short career," consisting of two or three nominations; and "long career," which consists of four or five nominations. Appearances at European, World, or both championships were classified as a sixth career type and also served as a classification criterion.

The data used in this study was sourced from FIBA.com and scoutbasketball.com. Statistical analysis was performed using IBM SPSS software. Descriptive statistics were applied to obtain basic characteristics of the sample. The Kruskal-Wallis test was used to determine differences between positions and the number of appearances for the senior team. The chi-square test was used to determine the probability of a relationship between different classifications of players and their appearances for the senior national team, with Cramér's V used as a measure of effect

size for the chi-square test (indicating the strength of association between two categorical variables). Binary logistic regression was used to examine possible connections between players' appearances in specific categories and their appearances for the senior national team. Binary logistic regression was used to predict the outcome of a binary variable based on one or more predictor variables. In this case, the outcome was an appearance for the senior national team (yes/no), and the predictor variables were the appearances in various categories.

Results

The total number of players who have represented the Croatian youth basketball national team in competitions, as well as their number of appearances for the senior national team, is presented in Table 2. The cumulative values for each national category indicate that the most frequently occurring number of appearances corresponds to the number of games a player can participate in during a single tournament (appearing in every match). Specifically, for the U16 category, this number is nine (35 different players), for U17 it is seven (10 players), for U18 it is nine (27 players), for U19 it is seven (7 players), and for U20 it is seven (22 players).

Table 2. *Descriptive statistics of the total number of appearances of the Croatian basketball national team*

	N U16	N U17	N U18	N U19	N U20	N SA
N	189	189	189	189	189	189
Mean	4.90	0.85	4.13	1.23	4.49	1.69
Median	5.00	0.00	1.00	0.00	4.00	0.00
SD	4.67	2.27	4.85	3.17	5.00	5.79
Skew	0.58	2.42	0.94	3.01	0.81	6.06
Kurt	-0.31	4.15	0.17	10.04	-0.27	47.85
Min	0	0	0	0	0	0
Max	18	8	18	18	19	57

N – *total number of participants in the study,* Mean – *arithmetic mean,* Median – *central value,* Min – *minimum value,* Max – *maximum value,* SD – *standard deviation,* Skew – *skewness,* Kurt – *kurtosis,* N U16 – *number of appearances at the U16 European Championship,* N U17 – *number of appearances at the U17 World Championship,* N U18 – *number of appearances at the U18 European Championship,* N U19 – *number of appearances at the U19 World Championship,* N U20 – *number of appearances at the U20 European Championship,* N SA – *number of senior appearances.*

Data on the duration of the players' representative careers, which shows that the majority of careers lasted one year (40.2%), followed by two or three-year careers (54%), with four or five-year careers being the least common (less than 5%) (Table 3).

Table 3. *Duration of the national team career*

Career duration	Frequency	Percentage	Cumulative frequency
1 year	76	40.2	40.2
2 years	55	29.1	69.3
3 years	47	24.9	94.2
4 years	9	4.8	98.9
5 years	2	1.1	100.0
Total	189	100.0	

Statistical tests (Cramér's V and chi-square tests) that reveal moderate to significant relationships between career duration, career type and appearances for the senior national team are presented in Tables 4-5.

Table 4. *Duration of national team career * BNS Crosstabulation*

			BNS		Total
			No appearance	Appearance	
Duration of national team career	1 year	Count	72	4	76
		Expected Count	62.3	13.7	76.0
	2 years	Count	49	6	55
		Expected Count	45.1	9.9	55.0
	3 years	Count	29	18	47
		Expected Count	38.5	8.5	47.0
	4 years	Count	5	4	9
		Expected Count	7.4	1.6	9.0
	5 years	Count	0	2	2
		Expected Count	1.6	0.4	2.0
Total		Count	155	34	189
		Expected Count	155.0	34.0	189.0

Table 5. *One appearance, short career, long career * BNS Crosstabulation*

		BNS		Total
		No appearance	Appearance	
One Appearance	Count	72	4	76
	Expected Count	62.3	13.7	76.0
Short career	Count	78	24	102
	Expected Count	83.7	18.3	102.0
Long career	Count	5	6	11
	Expected Count	9.0	2.0	11.0
Total	Count	155	34	189
	Expected Count	155.0	34.0	189.0

Binary logistic regression results indicate a positive correlation between participation in youth categories (U18, U19, and U20) and senior team appearances, with the strongest association seen for U19 World Championship participants (Table 6).

Table 6. *Results of binary logistic regression*

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1	BN16	0.44	0.48	0.836	1	0.36	1.550	0.606	3.963
	BN17	0.98	0.59	2.880	1	0.09	2.709	0.857	8.564
	BN18	1.100	0.48	5.334	1	0.02	3.005	1.181	7.646
	BN19	1.920	0.47	16.405	1	0.00	6.820	2.693	17.269
	BN20	1.069	0.47	5.210	1	0.02	2.913	1.163	7.294
	Konstant	-3.750	0.64	34.260	1	0.00	0.024		

**Variables included in step 1: BN16, BN17, BN18, BN19, BN20.*

Discussion

This study provides a thorough analysis of the factors influencing the career trajectory of players in Croatian youth basketball teams and their eventual transition to the senior national team. The results emphasize the importance of consistent participation in youth tournaments, with a particular focus on experiences gained at major international events like the U19 World Cup, which significantly increases the likelihood of players progressing to the senior level.

In the context of the total number of appearances for all categories of the Croatian national basketball team, the obtained results indicate that the average number of appearances per player varies across different age groups and tournaments. Given the lowest average values for the U17 and U19 World Championships (M = 0.85, M = 1.23), it can be inferred that participation in these tournaments represents a challenge in terms of placement and player availability. On the other hand, the highest number of appearances was recorded for the senior national team (Max =

57), suggesting a longer career at this level. This result contrasts with the maximum number of appearances in tournaments for Croatian youth teams (U16, U18, U19, and U20), which is significantly lower, suggesting that players typically appear at most twice in each of these tournaments. Particularly interesting is the difference in the maximum number of appearances in the U17 World Championship, which is smaller than in other tournaments. This is likely due to the fact that this tournament is held every two years, and there are certain qualification criteria for participation, which must be met at the U16 European Championship. A study by Arede et al. (2021) evaluated the impact of maturity timing on the functional abilities and situational efficiency indicators of U16 basketball players. Results from the situational efficiency of games during the U16 national championship and U16 European Championship were correlated with further selection into the U18 team (Arede et al., 2021).

The cumulative values for each national category reflect a trend where the most common appearance number is equal to the maximum number a player can achieve in a single tournament. This could point to a high level of competition and a tendency for players to maximize their participation in international tournaments. The results of this study confirmed only the first hypothesis, which states that there is no statistically significant difference in the number of appearances for the senior national team among players of different positions ($p > 0.05$). The results show that a player's position on the court – whether they are point guards, shooting guards, forwards, small forwards, power forwards, or centers – does not influence the number of appearances for the senior national team. These findings, derived from the Kruskal-Wallis test, indicate that there are no statistically significant differences in the participation of players in the senior team based on their positions.

Analysis of the careers of players promoted to the Croatian youth national teams shows different forms of career durations, which may include – one appearance, short careers, and long careers. A significant number of players, as much as 40.2% of the total sample, had representative careers lasting only one year. This could suggest a high turnover of players within the youth teams, which may have been influenced by factors such as player development, injuries, or changes in tactical decisions and strategies. Schroepf and Lames (2018) also identified high player turnover within youth teams, with careers lasting one or two years accounting for 60.5% of the total sample. Similarly, in this study, a significant number of players (40.2%) had representative careers lasting only one year, and the majority (54%) had careers lasting two to three years (Schroepf et al., 2018). In contrast, the majority of players, over half of the total sample (54%), had careers lasting two to three years. This data reflects a certain stability within the youth teams, indicating that players managed to maintain continuity in their international appearances and development at the youth level. However, on the other hand, careers lasting four to five years are extremely rare, making up less than 5% of each category. This suggests that maintaining a long-term presence in the youth teams is challenging, perhaps due to competition for spots, physical demands, or player transitions to senior teams.

Direct comparison with the analysis focusing on the number of nominations shows similar trends. Most players ($N = 102$) had short careers with two to three nominations, while a significant number ($N = 76$) recorded only one appearance for the national team. In contrast, a relatively small number of players ($N = 11$) had longer careers with four or five nominations. These data point to similar factors that may influence the duration of careers and the number of nominations, such as competition, player performance, tactical decisions, and injuries. These two sets of analysis, while focusing on different aspects of players' careers, provide complementary insights into the dynamics within the Croatian youth basketball national team. The analysis shows a significant moderate probability of a correlation between the type of player's career and their appearances for the senior Croatian national team ($\chi^2 = 20.43$, $p < 0.01$). Players who made only one appearance in the youth teams recorded fewer appearances for the senior team than expected (4/13.4), while players with short and long careers in the youth teams made more appearances for the senior team than anticipated (24/18.3 and 6/2.0, respectively). Schroepf and Lames (2018) also found that early and short representative stints generally do not lead to a professional career, whereas later and longer careers in youth teams are more likely to result in a successful senior career. There is also a significant moderate probability of a correlation between the type of participation in major international tournaments – European Championship, World Championship, or both – and appearances for the senior Croatian national team ($\chi^2 = 27.53$, $p < 0.01$). Players who participated only in the European Championships or only in the World Championships did not achieve the expected number of appearances for the senior national team (13/21.0 and 1/4.7, respectively). On the other hand, players who participated in both major competitions made significantly more appearances for the senior team than expected (20/8.3). These results could suggest the importance of experience in different types of international competitions for

a successful transition to the senior level. Experience gained by participating in both major competitions may provide players with the necessary skills, experience, and confidence to succeed at the senior level.

Binary logistic regression analysis shows a positive correlation between all youth national team categories and appearances for the senior A national team. Statistically significant differences ($p < 0.05$) were observed in appearances for the U18, U19, and U20 categories. Particularly significant was the link between appearances at the U19 World Championship and appearances for the senior A national team (Exp = 6.8, $p = 0.00$). This result suggests that players who participated in the U19 World Championship were much more likely to appear for the senior A national team. These findings emphasize the importance of experience gained at the U19 World Championship, which could be a key factor in promoting players to higher levels, in line with research by Doğan et al. (2016), who also highlighted the importance of experience and performance in specific statistical categories for team success.

Conclusion

This study provided a detailed insight into the factors that are involved in talent developmental of Croatian basketball players in youth categories and their transition to the senior national team. The results consistently highlight the importance of continuous participation in international competitions, particularly the U19 World Cup, which emerged as one of the most significant predictors of later appearances for the senior national team. Differences in the average and maximum number of appearances across youth categories reflect structural challenges faced by young players, such as the biennial tournament cycle and demanding qualification criteria.

The analysis of career duration within the youth national teams revealed a high proportion of short-term involvement, which aligns with previous research indicating substantial player turnover. While most players had careers spanning two to three years, long-term continuity in youth teams was relatively rare. Nevertheless, players with longer and more stable participation in international competitions demonstrated a higher probability of progressing to the senior level. A similar pattern was observed in the analysis of nomination counts, where shorter careers were less likely to result in senior-level appearances.

Statistical analyses confirmed a moderate association between the type of career in youth national teams, participation in major international tournaments, and senior national team appearances. Particularly important was participation in both the European and World Championships, which proved to be a strong indicator of successful transition to the senior team. Furthermore, logistic regression identified the U18, U19, and U20 categories as the most influential developmental stages, with experience gained at the U19 World Cup standing out as the strongest individual predictor.

Ultimately, the findings of this study emphasize the importance of systematic and long-term planning in the development of young basketball players. A combination of consistent participation, exposure to different types of international competition, and involvement in key tournaments proved essential for successful advancement to the senior level. These results may serve as valuable guidelines for coaching staff and sports organizations in optimizing talent development and creating more effective selection strategies.

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Correlation Between Internet Addiction and Physical Activity Among Yogyakarta State University Students: The Mediating Role of Sleep Quality

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Abstract: *Internet addiction has become an increasingly prevalent concern among university students, adversely affecting various aspects of their quality of life. Overusing the internet is associated with sedentary behaviour, poor sleep quality and less physical activity, which could adversely impact students' health in general. The present study was conducted to investigate the correlation of internet addiction with physical activity in Yogyakarta State University's students because of sleep quality mediation. Quantitative cross-sectional design was used with purposive sampling of 210 respondents. Standardized questionnaires were administered, including the Internet Addiction (IA), Pittsburgh Sleep Quality Index (PSQI), and International Physical Activity Questionnaire (IPAQ). Path analysis and the Sobel test were used to analyse data from a mediation view. According to the results, there is a significant negative correlation between internet addiction and physical activity ($t = -8.225$, $p < 0.05$) and between internet addiction and sleep quality ($t = -7.86$, $p < 0.05$). Physical activity was highly positively associated with sleep quality ($t = 8.34$, $p < 0.05$). Additionally, the Sobel test ($Z = -8.31$, $p < 0.05$) showed that the mediating role of sleep quality in the association between internet addiction and physical activity was significant. These findings highlight the need for interventions in healthy use and sleep behaviour designed to enhance physical activity among students and overall well-being.*

Keywords: *Internet addiction, physical activity, sleep quality, mediating role, university students*

Introduction

Internet addiction has been identified as an increasing issue, especially in adolescents and young adults. It also has detrimental effects on several health behaviours, such as diet, physical activity, and sleep quality, which present a complex health problem among students (Mathew et al., 2019). Several studies have shown a positive association between problematic internet use and the prevalence of mental health problems, e.g., anxiety and depression (Shafi et al., 2023; Domenech et al., 2023). Furthermore, internet-related technology addiction (e.g., internet and social networks) has been suggested to decrease physical activity and increase feelings of social isolation (Lee & Ahn, 2020), which can ultimately exacerbate psychiatric conditions. The association of internet addiction with academic achievement is important because excessive use of the Internet may usually interfere with the study characteristics and efficiency of students (Mathew et al., 2019).

On the other hand, regular exercise is widely reported to be salutary for mental health and general well-being. It helps in decreasing stress and increasing sleep quality in university students (Lindegård et al.,2019). A well-being model that builds physical activity into daily life can counteract some of the adverse effects of internet addiction. More specifically, research has shown that higher levels of physical activity are associated with lower work-related exhaustion and more favourable mental health (Lindegård et al., 2019). Exercise is not just good for the physical, but it is also a helpful way to deal with the psychological side effects of excessive internet use. The quality of sleep is another critical axis for perceiving the health dynamics of the students. Low-quality sleep has been demonstrated to be a side effect of and an epicentre for internet addiction (Sağar & Eren, 2022). Increased screen viewing due to internet use correlates with impaired sleep quality, leading to negative consequences for cognitive performance and academic achievement (Mao et al., 2022; Okano et al., 2019). More importantly, there is evidence that improving sleep should be a priority in breaking the pathway of internet addiction and associated mental health problems, as sound sleep can promote positive academic achievements and emotional well-being (Rafi et al., 2021).

The research evidence on these elements creates complexity in the lives of university students. Insomuch as sleep quality functions as a mediator between internet addiction and physical activity, it is a crucial nexus for health intervention approaches. Encouraging physical activity and promoting good sleep hygiene would aid universities in reducing the harms associated with internet addiction, as well as promote student health and academic performance (SAĞAR & Eren, 2022; Rafi et al., 2021). Recent research has also demonstrated an association of IA with several physical and psychological health consequences, such as reduced physical activity or poor sleep quality. For instance, Liu et al. (2024) indicated that high internet addiction was associated with more depressive symptoms and lower physical activity levels among college students, suggesting they may overuse the Internet and suffer from health-related problems. Similarly, Noroozi et al. (2011) emphasized that excessive use of internet routines converges into an unhealthy way of living, considering factors such as sleep quality and general physical health. Thus, it stands to reason that Yogyakarta State University students' physical activity levels may be affected by their degree of internet addiction.

Overall, despite these results with respect to the co-occurrence of internet addiction, physical health, and sleep quality, several limitations merit attention. That is, despite many studies reporting that internet addiction is associated with low sleep quality (Ozcan & Acımış, 2020), the mediating role of sleep quality between internet addiction and the physical activity relationship was not well explained for college students. For example, Peris et al. (2020) concluded that psychological variables play a predictive role in internet addiction and do not empirically investigate how sleep quality could influence these relationships. In addition, previous reviews have not fully explored how sleep quality could moderate the relationship between internet addiction and levels of physical activity in specific populations or soft variables, such as university students in Yogyakarta, Indonesia (e.g., Özparlak & Karakaya, 2020).

This paper aims to develop further the theories on internet addiction with physical symptoms, which include sleep quality as a mediating variable. Previous studies focused more on the linear relationships between IA and PA, overlooking the complex mechanisms involved in sleep. For example, research shows that overuse of the internet can hurt lifestyle and psychological well-being, which may then lead to reduced physical activity levels (Sun et al., 2025). The current study seeks to fill this gap by systematically examining the moderation effect of sleep quality on these two key influential processes, adding layers of understanding beyond existing models on the pathways inter-relating these constructs. Furthermore, by confining the discussion to a specific demographic (students at Yogyakarta State University), this study can contribute to the literature, which suggests that existing models have been considered universal factors. It can be validated in other situations, especially for the Southeast Asian community, with cultural factors affecting people's internet use habits as well as lifestyle. The relationship between cultural context and mental health, especially in university settings, is critical in the management of public health problems such as internet addiction (Doğru & Kabasakal, 2023). The moderate influence of sleep quality as a mediating factor on internet addiction not only expands knowledge about mediation mechanisms but also offers potential directions for intervention research. Exploring such mediating pathways could aid our understanding of why lifestyle interventions and mental health treatments are effective. Some studies indicate possible bidirectional relations between physical activity and indicators of mental health, although the exact dynamics need to be further investigated (Yang et al., 2022).

The results of this study can be used to develop policy and practical application in the field of Yogyakarta State University and related institutions. By investigating digital device use as a function of sleep mediation, insights are gained that could be useful for interventions aimed at drawing positive attention to students' technology habits. The role of good sleep quality highlights that interventions focusing on improving sleep hygiene might mitigate the negative impact of internet addiction on physical activity levels (Martino et al., 2020). This investigation can also be incorporated into campus health initiatives, such as prevention workshops for balanced internet use, encouraging physical activity, and monitoring sleep. Universities might be able to improve the overall well-being of students by promoting environments that consider the interconnectivity between the variables. This kind of integrated approach relates well to physical activity policy frameworks, which argue for a holistic health perspective within schools (Pogrmilović et al., 2019). Based on previous studies, it was hypothesized that internet addiction would negatively affect sleep quality and physical activity, while sleep quality would positively influence physical activity. Furthermore, it was suggested that sleep quality mediates the internet addiction-physical activity association among students at Yogyakarta State University.

Methods

This research is a quantitative study with a cross-sectional design, which aims to analyse the relation among internet addiction, sleep quality, and physical activity of undergraduate students from the Sports Science at Yogyakarta State University. Survey responses were collected online from March 2025 to April 2025.

Inclusion: Participants were enrolled purposively through program WhatsApp groups and submitted an online Google Form, which commenced with an electronic informed-consent form. The inclusion criteria were being enrolled in the 1st year of a sports science degree (S1) and being physically active; non-students and individuals not practicing physical activity were excluded. The three instruments and demographic questions were interspersed in the online questionnaire. The study link was sent to the department's communications channels, and publications were anonymous, with a secure email system used. After reading an informed consent statement, respondents voluntarily completed the form. Bachelor students of the study population ($N \approx 445$) were registered for a sports Science course. Using the Yamane formula created by Taro-Yamane (Tapping, 1968) with a 5% error margin, the calculated value $n \approx 211$; the final sample analysis included 210 respondents who met the inclusion criteria.

Young Diagnostic Questionnaire (YDQ) is a well-known instrument to detect internet addiction, especially for problem use of the internet. Young, 1996), proven to be reliable and valid among Chinese adolescents (Li et al., 2014). The YDQ is an 8-item yes/no measure with a score of 0–8 (each item scored for "yes"=1 and "no"=0). Larger scores indicated a greater risk of internet addiction. The subjects were classified into three subgroups according to the total score: (1) adaptive internet use AIU (total score ≤2), (2) maladaptive internet use MIU (3~4), and pathological internet use PIU(≥5).

The Chinese version of the PSQI was used to scale sleep disturbance (Buysse et al., 1989), which is validated for the Chinese population. The 19-item questionnaire consists of seven components: subjective sleep quality (1 item), sleep latency (2 items), sleep duration (1 item), habitual use of sleeping medication (3 items), sleep disturbance (9 items), and interference with daily activity due to daytime fatigue (2 items). Scoring was 0-3 for each dimension. A global PSQI score (range from 0 to 21) was also obtained by summing scores of the seven components, with higher scores representing worse sleep quality. Sleep disorder was identified by a total score of PSQI >7 according to prior work in the Chinese general population (Liu, 1996).

To determine the levels of physical activity (vigorous, moderate, and low) in the previous week among participants, Craig et al. (2003) developed an instrument called the IPAQ (International Physical Activity Questionnaire). It includes seven questions that can generate data for collecting information on global trends in physical activity related to health. Employed IPAQ, which is one of the most widely used tools to assess PA level due to its cost-effectiveness, global applicability, sound validity, accessibility, and standardized protocol. Physical activity is assessed using the IPAQ scoring system that considers time spent walking, in moderate exercise (eg, cycling or brisk walking), and vigorous exercise (eg, intense workout or running). Walking counts for 3.3 METs, moderate activity for 4.0 METs, and vigorous activity for 8.0 METs. Each activity is expressed in MET-min·wk-1. The MET value is then multiplied by the number of days and minutes an individual exercises every week to calculate a total score. Students are categorized as low (no active group), moderate (active group) if their weekly MET min is 600 or more, and vigorous (high-activity group) if their weekly MET min is 3000 or greater, according to the total score.

Data were analysed using SPSS (version 25) and path-analysis methods. Descriptive statistics were conducted, and normality was assessed (Kolmogorov–Smirnov). Bivariate relationships were evaluated with Pearson's r (parametric) or Spearman's rho (nonparametric), as applicable. For the estimation of direct effects, multiple linear regression and path analysis were employed; mediation was analysed by following the steps defined in Baron-Kenny's Screencast 2009 procedures and with the Sobel test to assess if an indirect effect ($X \rightarrow M \rightarrow Y$) is significantly different from zero. When appropriate, we reported effect sizes, p-values, and standardized path coefficients. Missing data were accounted for via listwise deletion in the reported analyses.

Result and Data Analysis

Table 1. *Descriptive Statistics*

	N	Minimum	Maximum	Mean	Std. Deviation
Internet Addiction	210	1	8	3.88	1.830
Physical Activity	210	30.600	578062.500	7652.712	39919.598
Sleep Quality	210	0	17	7.50	3.395

The descriptive statistics of Internet addiction, physical activity, and sleep quality for the 210 involved students are shown in Table 1. Internet addiction scores ranged from 1 to 8 (mean = 3.88, SD = 1.83), suggesting medium level of differences in internet use among the participants. Physical activity scored on an average 7,652.71 on physical activity and had a large standard deviation of 39,919.60 (range:30.60 to 578,062.50). This large spread indicates a high diversity in the physical activity, which may be due to outliers or extreme values. The sleep quality scores had a mean of 7.50 (standard deviation: 3.40) and were distributed from 0 to 17 indicating moderate deviations in participants' sleeping behaviours. The normality of the data was tested using Kolmogorov–Smirnov test. The results demonstrated that all 3 main variables (Internet addiction, physical activity, and sleep quality) appeared as distribution of non-normal. Namely, the Kolmogorov–Smirnov statistics of Internet addiction, PA and sleep quality were 0.135, 0.424 and 0.101 (all p-values < 0.05) respectively. Since the obtained p-values for all the variables were less than 0.05, failed to fulfil the normal distribution assumption, and thus data did not meet with normality. In terms of gender, the sample included 152 men (72.4%) and 58 women (27.6%). This indicates that most of the subjects were males and there was a minority of females in the sample.

Table 2. *Internet Addiction*

	Frequency	Percent
Adaptive Internet Use	51	24.3
Maladaptive Internet Use	91	43.3
Pathological Internet Use	68	32.4
	210	100.0

Table 2, Percentage distribution of Internet addiction among the participants (n = 210) More than half (67.3%) were in non-problematic levels of internet use, leaving the rest in problematic levels. Findings showed that 51 (24.3%) were assigned to adaptive Internet use, characterized by balanced and controlled involvement in the online worlds. More participants, 91 persons (43.3%), were categorized in maladaptive Internet use which is defined as an excessive or problematic use that may disrupt daily life but does not fulfill the criteria of pathology dependence. At the same time, pathological Internet use was identified in 68 participants (32.4%): showing signs of severe compulsive Internet Web use, novelty seeking-impulsivity trait and addictive behavior leading to disability in everyday life and total disability).

Table 3. *Physical Activity*

	Frequency	Percent
High	120	56.7
Low	31	14.3
Moderate	59	28.1
Total	210	100.0

The prevalence of physical activity within three levels, high, moderate, and low is summarized in Table 3 among the total 210 participants. Most of the sample (n = 120; 56.7%) became classified as highly active, demonstrating and overall active lifestyle. Fifty-nine (28.1%) of the participants demonstrated moderate practice PA, indicating that they were living a balanced life without exercising very physically active lifestyle. In contrast, 31 participants (14.3%) had a low election of PA indicating insufficient physical activity, which is not healthy and narrows down the human well-being. These results indicate most respondents does still exercise, but that it is almost half (42.4%) who

engaged in moderate to low activity range; underscores the relevance of advocating the continuous and appropriate practice among them.

Table 4. *Sleep Quality*

No	Frequency	Percent
0	*1*	.5
1	4	1.9
2	6	2.9
3	13	6.2
4	16	7.6
5	25	11.9
6	20	9.5
7	29	13.8
8	20	9.5
9	21	10.0
10	13	6.2
11	15	7.1
12	11	5.2
13	4	1.9
14	6	2.9
15	2	1.0
16	3	1.4
17	1	.5
Total	210	100.0

The distribution of scores for Sleep Quality among the 210 participants is shown in Table 4 scores range from 0 to 17. The score distribution shows a peak at 7 (29 respondents—13.8%), followed by 5 (11.9%) and 9 (10.0%). Scores of 6 and 8 were also relatively common, with 9.5% for each score. Conversely, 0.5% of participants reported 0 or a maximum score of 17. Overall, the distribution indicates that there is a great deal of variation in sleep quality among participants and little inclination towards obtaining high or low scores. Although many responses indicated good sleep quality, the presenting low scores revealed poor sleep among some participants and their ability to manage daily activities and project well-being may have been impacted. The mediation model structure, as derived from the causal steps approach proposed by Baron and Kenny (1986), is shown in Figure 1. A path diagram was used to illustrate the theoretical model of mediation. In doing so, two independent sets of axioms are recognised and included in the model.

Figure 1. *The mediation model structure, as derived from the causal steps approach proposed by Baron and Kenny*

In the first framework, the direct path model depicts the overall effect of Internet addiction (independent variable) on physical activity (dependent variable). As shown in Figure 2, this relationship is represented by pathway **c**, which illustrates the total effect of Internet addiction on physical activity when the mediating variable is excluded from the model.

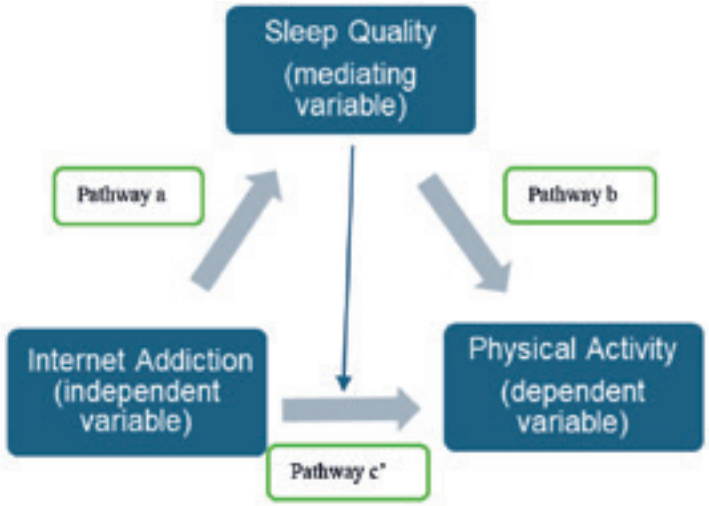

Figure 2. *Mediating Variable in Study*

The second diagram shows the relationships and paths variable included in this study "a" measuring path from Internet Addiction (independent variable) to Sleep Quality (mediating variable), "b' points out path from Sleep Quality (mediating variable) to Physical Activity (dependent variable) while 'c' pointing Direct effect from Internet Addiction (independent variable) to Physical Activity(Dependent Variable) when 'Sleep Quality' Mediating between those Variables under Study.

Further path models were performed utilizing Causal Steps and Product of Coefficients to capture direct and indirect effects among the study variables. In interpreting results, we used beta coefficients from regression tests. In the first path (path a), internet addiction was regressed on sleep quality and the score of –0.495(a) represented by coefficient (a, b and c). There was a significant effect of physical activity on sleep quality (M) in the second step (path b), change in coefficient, = 6.11. The overall of Internet addiction on physical activity while not controlling the meditating effect was denoted as path c with a coefficient c = –0.341. The direct effect (path c′) was calculated by performing a simultaneous regression of physical activity (Y) on Internet addiction (X) and sleep quality(M), which resulted in c′ = –0.187. The indirect effect (ab) was estimated by the product of a and b coefficients, ab = (-0.495 × 6.11) = -3.254. According to these results, the mediation model and relations between Internet addiction, sleep quality, and physical activity were established as follows and are shown in the subsequent mediation figure.

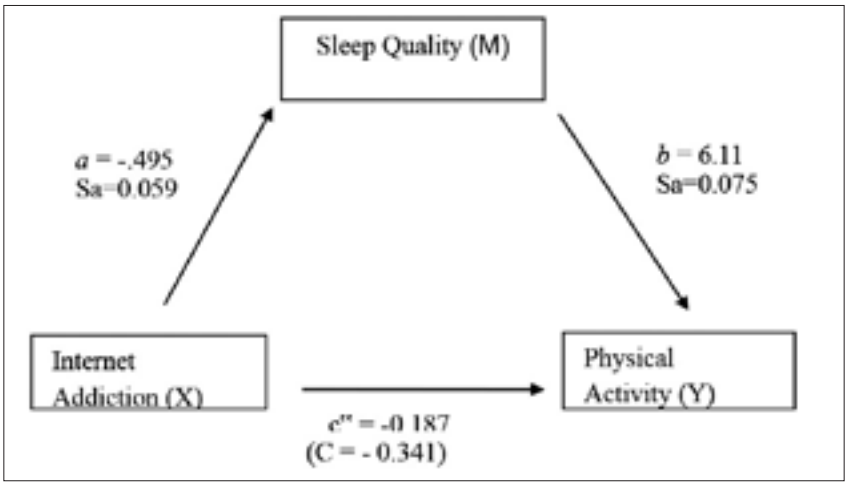

Figure 3. *Apply Sobel Test on Product of Coefficient to test whether the indirect effect of the association between Internet addiction and physical activity is significant or not*

Figure 3, Apply Sobel Test on Product of Coefficient to test whether the indirect effect of the association between Internet addiction and physical activity is significant or not. According to Sobel Test the computed Z (26.8)

was even greater in absolute value than 1.96, which is the critical value at a level of significance of.05. This shows that the association between independent and dependent variables is sensitive to mediator variable. The results of these findings demonstrate that the association between personality trait (internet addiction) and dependent variable (physical activity) is influenced significantly indirectly by the mediator variable (sleep quality). The finding of significance for coefficients a and b in the regression analysis suggests Causal Steps that there is mediation. The most critical condition for mediation, according to David A. Kenny (1986), is that paths a and b are significant. The mediation model is said to be complete mediation if the c‟ pathway is insignificant or has a value of 0. If the path c‟ causes the value of the dependent variable coefficient then and significantly, then partial mediation occurs.

A significant 'mediator' sleep quality mediates the connection between DV (physical activity) and IV (internet addiction). It is, however, significant when the coefficient value β on physical activity passing through the mediator variable reduces compared to the model where it does not pass through the mediator variable. This means that internet addiction variable influences the physical activity variable either with or without mediation of the sleep quality variable. That is, internet addiction has the statistically significant indirect effect on physical activity by sleep quality. Internet addiction is a negative effect upon sleep, as students who have poorer sleep are less physically active. At 95% confidence level, Z-value -8.34 is greater than critical value ±1.96 indicating there is very little chance of this result occurring by mere luck. Thus, sleep quality has a substantial mediating role in this association and can shed light on the how or why alterations in physical activity are linked with internet addiction. These findings suggest that improving students' sleep quality may help reduce the negative impact of excessive internet use on their physical activity behaviours.

Discussion

Internet Addiction and Physical Activity

The results show a significant negative relationship between IA and physical activity, which verifies H1. This finding indicates that the higher level of internet addiction the less physical activity among students in Universitas Negeri Yogyakarta. The p-value (0.000) falls lower than the α-level of 0.05, and the given t-count value in absolute terms (-8.225), is greater than ±1.96 for a confidence level of 95%. These findings imply that internet addicts become more sedentary, i.e., spend too much time on the Internet instead of staying physically active. This result is like that of Sun et al. (2025) who found a large and negative sign correlation between internet addiction and college students' physical exercise were highly significant ($P < 0.001$, $Z = –12.40$), indicating that the risk of internet addiction was less likely if they have higher levels of body activity. Engaging in physical activity has also been shown to improve psychological and emotional health, which could also result in decreased preference for addictive behaviour including excessive internet use. Similarly, a previous study on international student in Java reported a significantly positive relationship between physical activity and life satisfaction ($r = 0.806$, $p = 0.002$), where 63% of the variance in life satisfaction were accounted for by physical activity (Salman et al.,25). Collectively, these results reinforce that regular exercise improves both physical health and mental & emotional well-being.

Similar findings were reported by Alshehri and Mohamed (2019) who found a negative relationship between eGaming and PA involvement. Their results point to a shared pathway by which screen addictions diminish the opportunities for exercise. Furthermore, Lin et al. participants "physical activity moderated or buffered the negative effects of internet addiction on psychological and physical health. The evidence highlights the necessity to have an active lifestyle to mitigate untoward health consequences of excessive internet especially among students performing their academic duties.

Internet Addiction and Sleep Quality

These findings provide strong support for H2: internet addiction had a significant negative relationship with sleep quality. The t-value (-7.86) is higher than the critical t-value (±1.96) at a 95% confidence level and $p = 0.000$ which means that the result obtained is very significant ($p <0.05$). This result implies that people with greater internet addiction had worse quality of sleep. Spending too much time on the internet, especially late into the night, is upsetting people's internal clocks and depriving them of quality sleep. This finding agrees with Arayici et al. (2025) who reported an association ($r = 0.593$, $p < 0.001$) between the use of computer and sleep quality degradation. Results of Lin et al agreed with these. (2019) failed to find any individual subtypes of online addiction symptoms that have a

negative influence on healthy sleep quality in female students. Hammad et al. (2024) further showed that difference in sleep patterns accounted for much of the variance in internet addiction and remained significant even after controlling demographic/lifestyle variables such as smoking habits and living status.

Corroborating evidence from alternative settings can also strengthen these conclusions. During the COVID-19 pandemic, Saudi Arabian medical students and university students who spent more time on screens had decreased sleep times as well as higher daytime dysfunction (Nagori et al., 2019; Kumar et al., 2022). Similarly, Karki et al. (2021) found a significant negative correlation of internet addiction with sleep quality in Nepalese adolescents, which was congruent to those reported from Taiwanese and Turkish sample. Taken together, these results reflect the pattern that there appears to be a robust association between internet over-use and negative sleep outcomes across national contexts.

Sleep Quality and Physical Activity

The findings of this study show a significant positive association between sleep quality and physical activity which support H3. The t-statistic (8.34) is greater than the critical value, and the p-value (0.000) is less than 0.05 alpha level of significance. These results indicate that sleep quality could be used to predict whether an individual will participate in physical activity, and vice versa. In line with this observation, Alime et al. (2024) observed that greater physical activity is protective against sleep disruption, emphasising its contribution to the maintenance of good health. Byun et al. (2024) also remarked that regular exercise significantly increases sleep quality, yet not at a cost of side effects. In addition to this, the evidence demonstrates that acute physical activity has a positive effect on deep sleep, REM sleep and total duration of slept – all three are significant indicators of sleep quality (Wunsch et al., 2017). Thermogenic effects of physical activity that further contribute to metabolic control, and potentially the regulation of restorative sleep, could explain these associations (Master et al., 2019).

These conclusions are also supported by meta-analytic evidence indicating that exercise is an effective non-pharmacological treatment for sleep problems (Oudjedi et al., 2022). More specifically, a moderate exercise routine has been shown to promote total sleep time and decrease latency of sleep onset. This bidirectional relationship posits that good sleeping quality boosts motivation and energy for physical activity, but at the same time exercise is associated with better sleep (Gothe et al., 2020). This relationship has been demonstrated to hold true among different age categories such as college students and elderly people (Santos et al., 2023; Osundiya et al., 2021).

Mediating Effect

There is a significant mediating effect of sleep quality in the relationship between internet addiction and physical activity as well. The Z-statistic (-8.34) is higher than the critical value of ±1.96 at α=.05, suggesting that sleep quality mediates the relationship. More specifically, sleep suffers from internet addiction and poor sleep quality leads to less physical activity. These findings indicate that enhancing sleep quality may help reduce the harmful effects of IA among students' PA behaviours. Byun et al. (2024) have shown that those who sleep better are more likely to be active, indicating a reciprocal association between the two variables. This emphasizes the mediating effect of sleep in the relationship between IA and PA. Similarly, Gothe et al. (2019) found that sleep quality is an independent factor for physical activity and HRQL, implying that interventions focused on high-quality sleep can contribute to both behavioural outcomes and health status.

There is also more evidence for the mediating role of sleep quality. Kashfi et al. (2023) and Bhandari et al. (2017) stated that young adults with high internet addiction display more sleep difficulties, which reduce their willingness and ability to engage in regular physical activity. The work of Tran et al. (2016) found that internet addicted students were more sleep-deprived, resulting in lower physical activity levels. In parallel, Zhao and Kou (2024) confirmed that internet addiction, especially short video content one, decreased sleep quality and ultimately reduced physical activity in college students. Overall, these results indicate that sleep quality is an important mediating process to interpret the relation between internet addiction and physical activity. Improving the sleep quality of students may be helpful to reduce the maladaptive behavioural patterns and health problems that result from excessive internet use.

Conclusion and Suggestion

Findings from this study revealed a negative association between Internet addiction behaviour and physical activity among the Yogyakarta State University students, sleep quality as an important mediator. Higher amounts of

internet use anomalies were associated with worse sleep quality and less physical activity in students, thereby suggesting both behavioural and health physiological risk for problematic online involvement. In contrast, high sleep quality was significantly correlated with an increase of physical activity as well, reflecting a mutual benefit between enough sleep and active life. The mediation analysis supported sleep quality as a partial mediator in the link between internet addiction and physical activity which is crucial to preserve overall health status of students. Considering these findings, interventions targeting sleep behaviour might effectively counteract the negative effects of internet use on PA levels. Practically, the universities need to establish a combined health-promotion programme that targets digital balance, sleep, and physical activity. Workshops might also be introduced that focus on responsible internet use, sleep hygiene and organised exercise for improvements in both physical and psychological health. Longitudinal or experimental research is needed to better describe causal models and more broadly generalizable psychosocial pathways explaining the association between internet use, sleep, and physical activity among a variety of student populations.

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Conflict of Interest
The authors have no conflicts of interest to disclose.

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Correlation of Physical Activity, Risk of Eating Disorder, and Body Composition in Young Female Students

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Abstract: *Introduction: Body composition, physical activity, and the risk of eating disorders play a specific role in shaping the health of young female students during their first year of university, a period in which they develop autonomy, self-regulation, social interaction, and learning skills. The aim of this study was to determine the associations between physical activity levels, body composition, and the risk of eating disorders among female students aged 19–21 years at the University of Banja Luka. Methodology: A cross-sectional epidemiological observational study included a representative sample of 408 healthy female students with a mean age of 20.5 years. Data were collected using a brief sociodemographic questionnaire, the International Physical Activity Questionnaire (IPAQ), the Eating Attitudes Test-26 (EAT-26), and the OMRON BF 511 digital medical device for body composition assessment.Results: The majority of participants (76.2%) were classified as highly physically active. Participants displayed ideal body composition parameters: BMI 22.1 ± 3.2, body fat percentage 31.80 ± 6.47%, and skeletal muscle percentage 28.15 ± 2.81%, while 16.7% of participants were at risk for eating disorders. Correlation analyses between EAT-26 subscales—Dieting, Bulimia, and Oral Control and total IPAQ physical activity scores showed no statistically significant associations. ROC analysis confirmed that BMI, body fat percentage, and visceral fat percentage are not reliable for detecting individuals at risk for eating disorders. Conclusion: Understanding the relationships between body composition components, eating disorders, and physical activity levels is essential for planning effective strategies to promote and prevent psycho-physical health issues and ensure the well-being of young female students. This requires ongoing evaluation and research into biopsychosocial factors.*
Keywords: *body composition, physical activity, risk of eating disorders, young female students*

Introduction

The health profile of young women reflects a comprehensive assessment of health, encompassing physical, mental, and social well-being, while also addressing risks and needs specific to age and sex (WHO, 2025). Key components for understanding the holistic health profile of young women at the transitional stage between adolescence and early adulthood include body composition (BC) as a physiological/anthropometric characteristic, physical activity (PA) as a health-related behavior, and risk of eating disorders (RED) as a psychosocial factor. Each of these characteristics plays a distinct role in shaping women's health. Body composition and PA are measurable components: BC provides objective data on an individual's physical status and nutritional condition, whereas PA reflects an active lifestyle and serves as an important predictor of long-term health, energy levels, and mood. RED, on the other hand, represents a mental health domain that explains the formation of habits during specific life stages. In essence, these components can form a vicious cycle. For example, young women may experience dissatisfaction with their body composition, which can contribute to RED. Higher BMI, increased body fat percentage, and visceral fat are associated with greater RED, which is particularly relevant in women (Kwilosz et al., 2025). Furthermore, BC can create a pathological correlation between PA and RED: extreme physical activity may increase RED, particularly bulimic behaviors. For instance, students with higher PA levels also showed elevated RED; although increased PA is generally beneficial, it can become detrimental when linked to body dissatisfaction, thus exacerbating RED (Ruiz-Bravo, Ureña, Rodríguez-Rodríguez, Laiz & García-Merino, 2025). Vancampfort et al. (2020) emphasize that changes in PA are a key factor in the development and maintenance of RED, which cannot be ignored. Systematic reviews further support the behavioral and psychosocial interconnections. RED, driven by body dissatisfaction, can in turn influence PA, especially when exercise is motivated solely by the desire to achieve an ideal body image (Jiang, Y., & Meng,

X., 2025). Conversely, longitudinal studies by Rodgers et al. (2021) reinforce the connection and explore interactions between psychosocial factors (RED) and behavioral factors (PA changes) during critical transitional periods. This cyclical dynamic highlights the complexity of approaching and investigating these sequences, which is essential for planning preventive programs based on a student's health profile - a holistic, individualized approach (Ruiz-Bravo, P., Ureña, G. D., Rodríguez-Rodríguez, B., Laiz, N. M., & García-Merino, S., 2025; Saputra, Nugroho, Damayanty, & Asmawati, 2024). Given these considerations, a key question arises: can these associations also be observed in countries with lower socioeconomic status and limited awareness of sports and physical activity among young women?

Aim of the study: The aim of this study was to investigate the associations between physical activity, body composition, and the risk of eating disorders among female students aged 19–21 years at the University of Banja Luka.

Method

An observational, analytical epidemiological study with a cross-sectional (PEO) design was conducted between October 2019 and March 2021. The study sample consisted of 408 female students aged 19–21 years from the University of Banja Luka. Participants were recruited from multiple faculties, including the Faculty of Medicine and Health Sciences, the Faculty of Science and Arts, and Technical and Professional Faculties. Inclusion criteria were female students aged 18–21 years enrolled in the first and the second year of their undergraduate studies. Exclusion criteria included students outside the target age range, as well as those with acute or chronic medical conditions, hereditary disorders, physical deformities, or conditions requiring a medically prescribed diet.

Ethical approval for this study was obtained from the Ethics Committee of the Faculty of Medicine, University of Banja Luka, and all participants provided written informed consent prior to participation. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013) and did not pose any physical or psychological risks to participants, who were free to withdraw at any time without consequences. Research procedures were also carried out in compliance with local data protection regulations.

Participants first completed a brief sociodemographic questionnaire developed specifically for this study. Body composition was then assessed using the OMRON BF 511 digital medical device, which utilizes bioelectrical impedance analysis (BIA) to estimate body fat percentage and related body composition parameters. Physical activity levels were evaluated using the International Physical Activity Questionnaire (IPAQ) – Long version, a widely used and validated instrument for assessing physical activity in adult populations across different countries and cultural settings. Eating attitudes and disordered eating behaviors were assessed using the Eating Attitudes Test-26 (EAT-26), a standardized and validated screening tool commonly applied in research and clinical settings to identify risk of eating disorders in adolescents and young adults.

Stadiometer (SECA 700) is used to measure participant height following the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). After recording height, age, and sex, body weight was entered into the OMRON BF 511 device, which then provided data on body mass index (BMI), body fat percentage, visceral fat level (fat surrounding internal organs), skeletal muscle percentage, and basal metabolic rate (the minimum number of calories required to maintain bodily functions at rest over 24 hours).

IPAQ – long version is a standardized and valided tool designed to assess physical activity (PA) levels in adults aged 15–69 years. It evaluates PA across four domains: work-related activity, transportation, household activities, and leisure-time activity. The questionnaire comprises 26 items, focusing on the frequency (days per week) and duration (hours and minutes per day) of activities in each domain. Physical activity levels are quantified in MET-minutes per week (Metabolic Equivalent of Task) and categorized into three levels: low, moderate, and high **(**Craig, Cora L., et al**.**.2003). According to results obtained from the IPAQ, three subgroups were formed: inactive/low physically active students (threshold <600 MET-minutes/week), moderately physically active students (meeting the activity level required for health benefits, 600–1,400 MET-minutes/week), and highly active students (activity level >1,500 MET-minutes/week).

The Eating Attitudes Test-26 (EAT-26) is a standardized self-report questionnaire widely used to screen for symptoms and behaviors associated with eating disorders (e.g., anorexia nervosa, bulimia nervosa, and other disordered eating patterns) in adolescents aged 13 years and older. The questionnaire contains 26 items divided into three subscales: Dieting (13 items), Bulimia and Food Preoccupation (6 items), and Oral Control (7 items). Responses are scored on a 6-point Likert scale (ranging from "Always" to "Never") and recoded into a 0–3 scoring system for analysis, resulting in a total score range of 0–78. Higher scores indicate a greater risk of eating disorders (Garner &

Garfinkel, 1989; Garner, Olmsted, Bohr, & Garfinkel, 1982; McLean et al., 2023).

The variables examined in this study included physical activity (assessed by IPAQ), eating disorder risk (assessed by EAT-26), and nutritional status, including body weight, body mass index (BMI), skeletal muscle percentage, body fat percentage, and visceral fat status.

Data were analyzed using SPSS version 21.0 for Windows. Statistical significance was set at $p < 0.05$. Descriptive statistics, including mean, standard deviation, median, minimum, maximum, frequencies, and percentages, were used to summarize sociodemographic characteristics, body composition, physical activity levels, and EAT-26 scores. Data normality was assessed with the Kolmogorov–Smirnov test, and internal consistency was evaluated using Cronbach's alpha (acceptable range: 0.70–0.80). Between-group differences were analyzed using the Mann–Whitney U test. Associations between physical activity levels and eating disorder risk were examined using Pearson or Spearman correlation coefficients, depending on data distribution, followed by multiple regression analysis.

Results

The study included 408 female students, aged 19–21 years, in their first or second year, from the following programs: Faculty of Medicine – Integrated Studies (44.1%), Health Sciences (10.3%), Faculty of Science and Mathematics (15.2%), Faculty of Philosophy (14.2%), Faculty of Architecture and Civil Engineering (4.4%), Faculty of Law (7.4%), and Faculty of Political Science (4.4%).

Anthropometric assessment of the participants (n = 408) showed a mean height of 168 cm, mean age of 20.5 years, and mean body mass of 63.1 kg. Based on body composition measurements using the OMRON BF device, we found that based on BMI, 8.1% of participants were underweight (<18), 76.2% had a normal BMI (18.5–24.9), 13.0% were overweight (25–29.9), 2.0% had mild obesity (30–34.9), and 0.7% were classified with severe obesity (35–39.9); no cases of extreme obesity (≥40) were observed. Visceral fat levels were within the normal range for all participants. Analysis of skeletal muscle percentage among the participants indicated that 5.9% had a low percentage (0–24.29%), 76.0% were within the normal range (24.3–30.3%), 16.7% had a high percentage (30.4–35.3%), and 1.5% had a very high percentage (≥35.4%). Analysis of skeletal muscle percentage for adult females aged 18–39 years indicated that 5.9% had a low percentage (0–24.29%), 76.0% were within the normal range (24.3–30.3%), 16.7% had a high percentage (30.4–35.3%), and 1.5% had a very high percentage (≥35.4%).

IPAQ was used to assess participants' physical activity levels. Descriptive analysis of total physical activity by domain showed the following median values: work-related physical activity (Median = 0 min/week; range 0–1890), transport-related activity (Median = 1386 min/week; range 0–5598), household activity (Median = 1158 min/week; range 0–15,678), and leisure-time activity (Median = 1485 min/week; range 0–15,678). Median values were reported in accordance with the IPAQ scoring protocol.

Analysis of continuous summary variables showed that the median total physical activity from walking was 46.2 MET-hours/week, with the lower quartile at 23.1 MET-hours/week and the upper quartile at 72.6 MET-hours/week. The median moderate-intensity physical activity was 28 MET-hours/week, with the lower quartile at 12 MET-hours/week and the upper quartile at 56 MET-hours/week. For vigorous-intensity physical activity, both the median and lower quartile were 0 MET-hours/week, while the upper quartile was 19.5 MET-hours/week.

The results of the IPAQ and EAT-26 are presented in Table 1.

Table 1. *Descriptive Analysis of IPAQ and EAT-26*

	Mean	SD	Min	Max	Percentiles		
					25th	50th Median	75th
Total Walk MET-min/week	3237.15	2333.14	.00	12474	1386	2772	4356
Totalmoderate-intensity PA MET-min/week	2325.69	2180.99	.00	13440	720	1680	3360
Total Vigorous-intensity PA MET-min/week	1024.90	2120.33	.00	17280	.00	.00	1170
Total MET PA WMV	6587.74	4792.34	.00	25440	3101.6	5616	8586

EAT26 - Diet	7.76	5.57	0	29	4.00	6.00	10.00
EAT26- Bulimia	1.91	2.76	0	16	.00	1.00	3.00
EAT26 – Oral control	3.57	3.44	0	16	1.00	3.00	5.00
EAT26 Total	13.24	7.97	1	54	7.00	12.00	17.00

The Kolmogorov–Smirnov test results ($p \leq 0.001$) indicated that physical activity scores in all domains were not normally distributed. Based on total physical activity levels from the IPAQ, participants were classified into three subgroups: 2.0% with low, 21.8% with moderate, and 76.2% with high physical activity.

Eating attitudes were assessed using the Eating Attitudes Test-26 (EAT-26), whose descriptive analysis is presented in Table 1. The Cronbach's alpha reliability analysis confirmed good internal consistency for two subscales: Dieting ($\alpha = 0.80$) and Bulimia ($\alpha = 0.71$), whereas the Oral Control subscale showed lower reliability ($\alpha = 0.57$), which is below the acceptable threshold.

Normality of the distribution for all three subscale scores and the total EAT-26 score was assessed using the Kolmogorov–Smirnov test, which indicated non-normal distribution. Therefore, non-parametric analysis was performed using the Friedman test, yielding $\chi^2 = 410.74$, $df = 2$, $p < 0.001$, and indicating a statistically significant difference among the three subscales.

Based on the total EAT-26 score, participants were stratified into two groups: at risk and not at risk for eating disorders. As shown in Table 2, 16.7% of participants were classified as at risk by the age of 20.5 years, compared with 83.3% who were not at risk.

Table 2. *Classification of Participants Based on IPAQ and EAT-26 Subscale Scores*

		Frequency	Percentage
IPAQ	Low physical activity group	8	2.0
	Moderate physical activity group	89	21.8
	3. High physical activity group	311	76.2
EAT - 26	No risk of eating disorder	340	83.3
	At risk of eating disorder	68	16.7

To examine the association between physical activity and the risk of eating disorders, the IPAQ test analysis demonstrated an unequal distribution favoring highly active female students. Overall physical activity was presented using stratified samples across the three EAT-26 subcategories—dieting, bulimia, and oral control—expressed through two outcome groups: individuals at risk and individuals not at risk for eating disorders, as shown in Table 3.

Table 3. *EAT-26 Test Outcome: Sample distribution by individuals with and without Risk of Eating Disorders*

	Total MET PA		
EAT26	**N**	**Mean**	**Std. Deviation**
0 - without risk of eating disorders	340	6645.5029	4858.05217
1 - with risk of eating disorders	68	6404.7426	5087.44221
Total	408	6605.3762	4891.45339

From the descriptive analysis, it was observed that, compared to the average total physical activity (PA), individuals at risk of eating disorders had slightly lower total PA values than those without risk. Further analysis using the Mann–Whitney U test ($Z = -0.681$, $p = 0.496$) indicated that there was no statistically significant difference in total PA between individuals at risk and those not at risk of eating disorders.

As an additional and final analysis, we examined the correlation between the EAT-26 subcategories—diet, bulimia, and oral control—and the total physical activity (PA) score from the IPAQ test.

Within the EAT-26, we found high statistical significance with moderate to strong correlations for each subcategory relative to the total EAT-26 score. However, no correlation or clinical significance was observed between high physical activity, represented by Total MET PA, and the EAT-26 subcategories (Table 4).

Table 4. *Correlation between IPAQ and EAT-26 tests*

			Total MET PA	EAT26 Diet	EAT26 Bulimia	EAT26 Oral control	EAT26 Total
Spearman's rho	Total MET PA	r.	1.000	.015	-.079	.005	-.028
		p	.	.755	.112	.924	.568
	EAT26 Diet	r	.015	1.000	.266**	.007	.717**
		p	.755	.	.000	.889	.000
	EAT26 Bulimija	r	-.079	.266**	1.000	.047	.519**
		p	.112	.000	.	.342	.000
	EAT26 Oral control	r	.005	.007	.047	1.000	.536**
		p	.924	.889	.342	.	.000

*Correlation coefficient (r) ** Correlation significance at the 0.01 level*

To fully examine the relationship between physical activity level and the risk of eating disorders, body composition was included as an additional independent variable. Using ROC analysis, we further examined the relationship between the dependent EAT-26 categories (individuals at risk and not at risk of eating disorders) and the independent categories of BMI, body fat, and visceral fat. Based on all examined body parameters (showing relatively low sensitivity and relatively low specificity), BMI, as well as the percentage of body and visceral fat alone, cannot serve as reliable indicators for detecting individuals at risk of eating disorders, as summarized in Table 4.

Table 5. *Distribution of Eating Disorder Risk Across BMI, Body Fat, and Visceral Fat Categories*

	EAT risk	EAT without risk
BMI 21.65	69.1%	45.6%
Body fat 33.15	57.4%	33.8%
Visceral fat 3.5	52.9%	35.3%

Finally, a multiple regression analysis was conducted including all mentioned parameters, body composition sub-scores, and EAT-26 sub-scores in relation to total MET physical activity.

Using a backward regression approach, BMI and MUSCULAR mass were identified as statistically significant predictors of total MET physical activity. Specifically, BMI showed a significant effect ($t = 2.466$; $p = 0.014$), while the effect of muscle mass was even stronger and highly statistically significant ($t = 3.334$; $p = 0.001$).

Discussion

The objective of this study was to examine whether a significant association exists between physical activity levels, body composition, and the risk of developing eating disorders. Previous evidence suggests that overeating and disordered eating behaviors are commonly associated with reduced physical activity. Young women often strive to achieve an ideal body composition and perceived physical attractiveness through two primary approaches: increasing physical activity or engaging in restrictive dietary behaviors, including dieting, fasting, or bulimic practices. Such compensatory behaviors, either excessive physical activity, prolonged sedentary habits, or restrictive dieting may contribute to the onset of non-communicable diseases and postural or musculoskeletal disorders later in life. Preventive strategies led by healthcare professionals can help modify misconceptions about the "ideal body" by promoting awareness among young women regarding the risks associated with eating disorders, the essential role of physical activity in overall health, and the limitations of relying solely on BMI as a standard indicator of physical status (Ispas, Forray, Lacurezeanu, Petreuș, Gavrilaș, & Chereches. 2025). Enhancing early recognition of harmful behaviors and encouraging timely medical support are critical components in reducing the prevalence and consequences of eating disorders.

Descriptive analysis of anthropometric characteristics and body composition parameters classified our participants as young women with a mean age of 20.5 ± 0.7 years, mean height of 168.65 ± 6.01 cm, and mean body mass of 63.09 ± 9.9 kg, corresponding to a normal BMI range (22.1 ± 3.2). A total of 46% of participants were positioned within the central percentile range of 60 to 68.18 kg. The mean BMI was 22.10, with 76.2% of the sample falling

within the normal BMI range (18.5–25). In terms of body composition, 57.84% of participants had a normal body fat percentage, while 96.32% presented with normal muscle mass distribution. When comparing BMI values to a study conducted among female students of similar age at the University of Sarajevo, which included 1,178 participants, the mean BMI reported was 21 (Kovačević et al., 2021). Comparable findings were observed in the study by Mašina (2019), where the average fat mass among 596 female participants of the same age was 30.36 ± 6.66%, with a distribution ranging from 12.8% to 54.1%. Muscle mass values in that study averaged 28.80 ± 3.35%, with a percentage range from 13% to 42%. In our study, a more detailed analysis indicates a slight variance in mean height across BMI categories. Students within the lowest BMI category demonstrated the greatest height and highest percentage of muscle mass. As BMI increased, muscle mass percentage consistently decreased, whereas body mass, subcutaneous fat, and visceral fat values showed a predictable progressive increase.

Physical activity contributes to the development of functional, morphological, motor, conative, and cognitive characteristics of the human body, exerting a systematic influence across biological, health, educational, economic, recreational, and creative domains of human functioning (Bajrić S., Srdić, Bajrić O., 2021; Ilić, Pang, Vlaški, Grujičić, & Novaković , 2022; Han, Li, Wang, Ke, Meng, Li & Tong, 2022).. Regular exercise improves quality of life, reduces emotional distress, and enhances the ability to cope with life stressors (Brundtland, 2002; Strain et al., 2024). These findings are widely documented in the scientific literature, with Guthold et al. (2018) being among the most frequently cited authors in this field.

Analysis of continuous variables related to walking, moderate, and vigorous physical activity confirmed that walking is the dominant form of daily physical activity among participants. The median value for walking activity was 2772 MET-min/week (IQR: 1386–4356 MET-min/week). Moderate physical activity demonstrated a median of 1680 MET-min/week (IQR: 720–3360 MET-min/week). Vigorous physical activity showed a median of 0 MET-min/week, with an upper quartile of 1170 MET-min/week. The total physical activity level reached a median of 5616 MET-min/week, which represents a high weekly physical activity level, consistent with the anthropometric profile of the sample. To highlight walking as the primary form of physical activity among female students of the University of Banja Luka, it is necessary to compare moderate and vigorous physical activity levels with those reported for university students in other European countries. As shown in Table 1 our participants exhibited the highest median value for moderate physical activity (1680 MET-min/week) when compared to female students from the Czech Republic, Poland, and Germany (all 720 MET-min/week), as well as students from the Netherlands (1200 MET-min/week). Conversely, vigorous physical activity was entirely absent in our sample, while the highest values were reported among students in the Czech Republic (4320 MET-min/week), followed by Germany (2880 MET-min/week), the Netherlands (2640 MET-min/week), and Poland (1440 MET-min/week) (Maciaszek et al., 2020). Countries with lower economic status have reported declines in physical activity among young individuals across multiple life domains (Strain et al., 2024), which is also evident in our context. However, there remains a lack of data regarding the health status and attitudes toward sports participation among the student population. Despite this, the present study showed a high level of physical activity: only 2% of the participants were categorized as physically inactive, 21.8% as moderately active, and 76.2% reported being highly active according to IPAQ scoring.This high level of activity may be partly attributed to socioeconomic factors, where limited access to transportation promotes walking as the primary mode of mobility among students. Our findings differ from a study conducted at the University of Kragujevac, which included both male and female students, reporting 23.3% physically inactive, 62.5% moderately active, and only 14.2% highly active students (Stojmenović & Milošević, 2017). Generally, participation in organized sports remains low, and maintaining physical appearance is more frequently achieved through caloric restriction and stress-related lifestyle adjustments associated with academic expectations. Alarmingly, only 5% of our participants reported engaging in any type of sport over the past five years. Thus, the high total physical activity score in our sample is primarily attributed to self-reported walking, with a median of 2772 MET-min/week (IQR: 1386–4356 MET-min/week). Potential contributing factors include limited financial resources, reduced availability of sports facilities, low awareness of the health benefits of physical activity, and limited engagement in sports among youth. Additionally, environmental and climatic conditions, characterized by a moderately continental climate with cold winters and warm summers may further promote walking, whereas cycling is not widely adopted as a common means of daily transportation.

Transitioning to university life can be a stressful period for young adults, and coping strategies may include changes in eating behaviors (Murtaj, Pireva, Mikić, 2023; Provost, 1989). Within this population, rapid increases in risky behav-

iors, altered health perceptions, and a subjective decline in well-being have been observed, resulting in disordered eating patterns (Pilipović-Spasojević et al., 2020). Eating disorders are characterized by unhealthy eating habits and/or behaviors related to eating and weight control (American Psychiatric Association, 2000), and are influenced by a combination of sociocultural, psychological, biological, and genetic factors that form the core of their etiology (Jaruga-Sękowska, Staśkiewicz-Bartecka & Woźniak-Holecka,2025). Psychosocial factors often involve pressure from close social networks, peers, and mass media, which contribute to dissatisfaction with body appearance (Brytek-Matera, 2021). Body dissatisfaction frequently drives individuals to initiate dieting, while excessive and restrictive eating patterns may lead to the development of eating disorders (Kosmas, Garza, Kells, Hahn, Davis, 2025; Eck, Quick & Byrd-Bredbenner, 2022).

In our study, the Eating Attitudes Test-26 (EAT-26) was used to assess the risk of eating disorders. Based on the total sample, 16.7% of participants were classified as being at risk for developing an eating disorder. The overall EAT-26 score demonstrated a mean of 12, with an interquartile range of 7 to 17 points. These values indicate a higher level of risk compared to the findings reported by Malaram et al. (2023). However, our results are consistent with those from a study conducted in Tuzla, where 16.3% of female university students were identified as being at risk for eating disorders (Ćosić-Mulahasanović et al., 2021).

Initially, we observed an uneven distribution favoring high levels of physical activity. Therefore, total physical activity was compared with the summary EAT-26 outcomes—participants classified as at risk versus those not at risk for eating disorders. Descriptive analysis indicated no statistically significant difference in physical activity levels between individuals at risk and those not at risk. Correlation analyses were conducted between EAT-26 subscales—Dieting, Bulimia, and Oral Control—and both the total EAT-26 score and total physical activity measured by the IPAQ. As expected, within the EAT-26 score, more frequent dieting behavior was associated with a higher risk of eating disorders, showing a statistically significant and strong correlation ($r = 0.71$, $p < 0.001$). The Bulimia and Oral Control subscales also showed good correlations with the total EAT-26 score ($r = 0.52$ and $r = 0.54$, respectively, $p < 0.001$). Due to the very similar levels of physical activity across all three EAT-26 subscales, we conclude that no significant association exists between physical activity and the risk of eating disorders, consistent with the findings of previous studies (Mroz, 2022; Fatih, 2025; Gonzaga, 2024; Alsaleha, 2025; Gunes, 2025). Additionally, we found that BMI was not correlated with eating disorder risk. However, as expected, a positive correlation was observed between higher percentages of muscle mass and visceral fat with higher levels of physical activity.

Conclusion

BMI and the percentage of muscle mass were identified as significant predictors of high levels of physical activity. In contrast, neither body composition nor high physical activity levels predicted the risk of eating disorders. In this sample, BMI was not a reliable indicator of eating disorder risk and therefore should not be considered an independent indicator of health status. Developing a comprehensive health profile that distinguishes individuals at risk for eating disorders (as a mental health component) from those defined by physical health components—where body composition reflects physiological/anthropometric characteristics and physical activity represents a health-related behavior—requires further research employing an expanded set of assessment tools. Developing a complete health profile that separates mental health risks, such as eating disorders, from physical health factors—where body composition reflects the body's structure and physical activity reflects healthy habits—requires further research using more comprehensive assessment tools.

Understanding the relationship between body composition, eating disorders, and physical activity levels is essential for designing effective strategies to promote and prevent psycho-physical health issues among young female students. Such efforts demand continuous evaluation and investigation of biopsychosocial factors influencing health outcomes.

Conflict of Interest

The authors declare no conflict of interest in the design, data collection, analysis, interpretation, or writing of this manuscript.

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Development of a Web-Based Sporting Event Management Information System for the East Java NPCI

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Abstract: *The participation of disabled athletes in sporting events faces barriers such as the lack of inclusive and efficient information system management. The East Java NPCI requires digital media to support the registration, validation, scheduling, and real-time reporting of competition results. This study aims to develop and evaluate a web-based championship information system for East Java NPCI using ADDIE development model. Research and Development with five ADDIE stages: Analysis, Design, Development, Implementation, and Evaluation were performed. The sample consisted of two experts and ninety-three East Java NPCI coaches. Data were collected through interviews, observations, documentation, and questionnaires. Analyses used descriptive statistics, validity and reliability tests (factor analysis), and gender-based t-tests. The feasibility test results indicated an average score of 89% for the experts (very feasible category). User evaluations obtained an average perception score of 4.12 out of 5 (excellent category). Four aspects of the system —usability, customisation, access speed, and content— were found to be valid and reliable. No substantial difference existed between male and female coaches in rating the quality of the system which indicates that the system can be utilised fairly and equally by all users, without gender bias. The web-based information system for East Java NPCI is considered effective and feasible for managing disability sports championship in East Java, with potential for replication in other regions.*
Keywords: *ADDIE, event information system, NPCI, disabled athletes, system evaluation*

Introduction

Despite sports participation being a fundamental human right, numerous disabled people experience restricted access to sporting activities (Kiuppis, 2018). They are less likely to participate than individuals without disabilities (Kamil-Rosenberg, Greaney, & Garber, 2021). While there are many reasons one might be motivated to engage in sport, disabled athletes face barriers such as cost, time constraints, and lack of opportunities in performance sport participation (McLoughlin, Fecske, Castaneda, Gwin, & Graber, 2017).

Despite promoting inclusion through sporting events has received significant attention in the literature, very little research exists regarding the development of disabled athletes (Dehghansai, Lemez, Wattie, & Baker, 2017). The paucity of research clearly indicates the need for attention to disability sport. Moreover, opportunities for participation of disabled athletes need to be increased; therefore, the provision of disability sports competitions is essential in terms of quantity and quality.

The National Paralympic Committee Indonesia (NPCI) exists in each regency and province. Nowadays, at least 12 sports have been organized at the XVI Papua National Paralympic Games (Peparnas) (Finaka, 2021) with the number of participants involved is 1,985 disabled athletes (Primus, 2021). Although Peparnas is the highest events for disability sports in Indonesia, the sporting event management organised by NPCI at the regional level is insufficiently effective regarding the utilisation of management information systems.Furthermore, participation at the provincial level is low, with 416 disabled athletes (NPCI Jatim, 2023). More crucially, the number of the regional level is followed by 156 disabled athletes (NPCI Kab Pasuruan, 2023). Therefore, publication through online media needs to be implemented strictly to increase the number of participants. Furthermore, sporting events management should be improved so that the participation of disabled athletes can be channelled. This study aims to develop and evaluate a web-based championship information system for East Java NPCI using ADDIE development model.

Methods

Design

Research and Development (R&D) approach with the ADDIE development model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation, was used. The ADDIE model provides a systematic and flexible framework in the development of information technology-based media (Nadiyah & Faaizah, 2015). The ADDIE model is commonly used in software development and web-based learning systems (Arnab, Petridis, Spatioti, Kazanidis, & Pange, 2022).

Participants

The subjects in this study consisted of two groups. The first group consisted of a media expert and content expert, who conducted the feasibility test of the product. Secondly, 93 coaches (Male= 77; Female= 15; mean age= 38.95; oldest participant= 62 years; and youngest participant= 16 years) from the East Java NPCI who became respondents in the evaluation stage. The sampling technique used was total sampling, which is the selection of the subjects based on the total number of individuals included in the research area (Maksum, 2018).

Data Collection

Data collection was conducted through three main methods; (1) interviews, observations, and documentation used at the needs analysis stage to identify problems in the management of previous events; (2) Product feasibility test questionnaires were used by experts to assess the quality of the web based on eight indicators; appearance, navigation, functionality, speed, content suitability, security, accessibility, and general feasibility; and (3) User perception questionnaires were used to assess the coaches' experiences of four main aspects of the system; ease of use, customisation, download delay, and content. Two instruments were used in the form of questionnaires (points 2 and 3) using a 5-point Likert Scale, ranging from strongly disagree (1) to strongly agree (5).

Data Analysis

Descriptive statistics were used to calculate the mean, standard deviation, skewness, and kurtosis to measure user perception of the system. Data distribution was considered normal if the skewness and kurtosis values were in the range of –1 to +1 (Demir, 2022). Validity and reliability tests were conducted on perception instruments using factor loading analysis (declared valid if > 0.6) and Cronbach's Alpha (declared reliable if > 0.7). Construct validity was conducted through Average Variance Extracted (AVE) and Construct Reliability (CR), where the instrument was considered valid if AVE> 0.5 and reliable if CR> 0.7 (Hair, Black, Babin, & Anderson, 2014). Independent t tests were used to determine differences in user perceptions based on gender, with a significance level of $p < 0.05$ as the limit of statistical significance. All analyses were conducted using statistical software such as the latest version of SPSS to ensure the accuracy of the results.

Results

Analisys

Data were collected through interviews, observations, and documentation studies on the management of previous events in the analysis stage. There were 22 errors in the input of participant data; therefore, as many as 66 participants had to be deleted. The most common errors were gender selection, race number, and classification. Moreover, the reporting of the competition results had constraints, resulting in prolonged delays that hindered the monitoring of the results. The main requirements determined through the needs analysis encompass an online registration system, race scheduling, participant validation, and real-time results reporting.

Design

The system design contains a user interface (UI/UX) design that is inclusive and easy to use by the East Java NPCI operators. A database design includes data on athletes, sports, fixtures, and results. The workflow diagram and navigation structure were determined to ensure ease of use. Figure 1 shows the design of the home page.

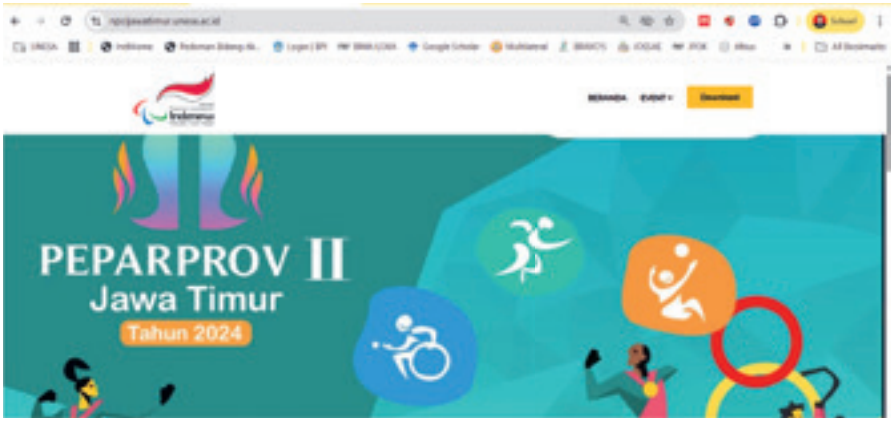

Figure 1. *Home page design (https://npcijawatimur.unesa.ac.id/)*

Development

The system was developed using the PHP framework and MySQL database. The main modules encompassed online registration of participants, validation of participants and real-time reporting of results, match scheduling, race results management, publication of event information. The prototype was tested internally with the support of the NPCI and input from potential users. Table 1 describes the results of the development which were tested by content experts and practitioners.

Table 1. *Results of product feasibility testing by experts*

No	Aspects	Statements	Score
1	Display	The web interface is attractive and easy to understand	90%
2	Navigation	Navigation between menus is easy to use	100%
3	Functionality	The athlete registration feature works well	80%
4	Speed	Web is responsive and fast to access	80%
5	Content suitability	Web content is in accordance with the needs of NPCI East Java	100%
6	Security	Secure login and validation system	80%
7	Accessibility	Web can be accessed on various devices (laptop and mobile phone)	90%
8	General feasibility	The web is feasible to use for competition management	90%

The feasibility test was conducted by experts on the website https://npcijawatimur.unesa.ac.id/ using eight assessment indicators including appearance aspects, navigation, functionality, speed, content suitability, security, accessibility, and general feasibility. The scores utilised on a Likert Scale of 1 – 5 which are then averaged and compared with the maximum value to obtain a percentage of feasibility.

The highest score (100%) was provided to the aspects of navigation and content suitability, indicating that the menu structure is easy to understand, and the website content meets the needs of the East Java NPCI. The lowest score (80%) was given to the aspects of functionality, speed, and security, which indicates that although functional, there is room for improvement in certain modules. Overall, the average score of the eight indicators is 89%, indicating that the product is in the "very feasible" category to be implemented as a web-based championship management system.

Implementation

The system was trialled at the regional competition of East Java NPCI and performed well. All participants successfully registered online, and match result data could be accessed in real time. Training was provided to NPCI operators to ensure their ability to operate the system independently.

Evaluation

Evaluation was conducted by measuring the coaches' perceptions of the East Java NPCI competition. They completed a perception questionnaire with the results in the descriptive statistics' form presented in Table 2.

Table 2. *Descriptive Statistics*

Descriptive Statistics	N	Min	Max	Mean (Categories)	SD	Skewness	Kurtosis
Ease of use	78	1.00	5.00	4.16 (Very good)	0.580	-0.933	0.412
Customization	78	1.60	5.00	4.09 (Very good)	0.622	-0.880	0.582
Download delay	78	1.50	5.00	4.08 (Very good)	0.643	-0.879	0.684
Content	78	2.00	5.00	4.16 (Very good)	0.566	-0.648	0.250
Total	78	1.47	5.00	4.12 (Very good)	0.549	-0.305	0.879

Based on the results of the analysis, 78 coaches completed the questionnaire with a value of aspects ease of use of 4.16 in the excellent category, a perception value of customization of 4.09 in the excellent category, a perception value of download delay of 4.08 in the excellent category, a perception value of content of 4.16 in the excellent category, and a total perception value of 4.12 in the excellent category. Each distribution is considered normal with skewness and kurtosis values in the range of skewness= -0.933 to -0.305, kurtosis= 250 to 0.879 (normal when in the range of 1 to -1). The measurement results are very feasible to be implemented to assess the quality of the East Java NPCI web. Evidenced by the validity and reliability of measurements depicted in Table 3.

Table 3. *Analysis of web feasibility evaluation measurement results based on coaches' perceptions*

Statement	Mean	SD	Loading Factor					Cronbach's Alpha
			A	B	C	D	Total	
A. Ease of use							0.905	0.883
Item-1	4.16	0.745	0.764					
Item-2	4.26	0.661	0.774					
Item-3	4.13	0.667	0.788					
Item-4	4.11	0.687	0.804					
Item-5	4.13	0.699	0.829					
Item-6	4.11	0.687	0.811					
B. Customization							0.904	0.864
Item-7	4.09	0.674		0.771				
Item-8	4.08	0.730		0.821				
Item-9	3.93	0.875		0.836				
Item-10	4.20	0.633		0.832				
Item-11	4.18	0.725		0.780				
C. Download delay							0.908	0.861
Item-12	4.17	0.656			0.793			
Item-13	4.13	0.744			0.918			
Item-14	4.03	0.702			0.889			
Item-15	4.04	0.837			0.774			
D. Content							0.932	0.772
Item-16	4.12	0.796				0.627		
Item-17	4.09	0.706				0.815		
Item-18	4.15	0.678				0.832		
Item-19	4.24	0.652				0.826		
Total (Item 1-19)								0.952

The results of the validity and reliability tests of the questionnaire used in measuring product quality based on the coaches' perceptions can be elucidated that in the aspect of ease of use the loading factor value range is 0.764-0.829>0.6; therefore, it is valid, the Cronbach's Alpha value is 0.883>0.7; therefore, the items in this aspect are reliable. The loading factor value in the customisation aspect is 0.771-0.836>0.6; so, it is valid, the Cronbach's Alpha value is 0.864>0.7, so the items in this aspect are declared reliable. In the aspect of download delay, the loading

factor value range is 0.774-0.918>0.6; therefore, it is valid, Cronbach's Alpha value is 0.861>0.7, so the items in this aspect are declared reliable. In the content aspect, the loading factor value range is 0.627-0.832>0.6, so it is valid, Cronbach's Alpha value is 0.931>0.7; therefore, the items are declared reliable.

The construct calculation of the 4 measurement aspects indicates that the eigenvalues formed by one significant measurement component are 3,331 with a cumulative percentage of 83.2%; therefore, the four aspects of product quality measurement can jointly explain 83.2% of the variance of the product quality measurement results. Four aspects of measurement in the form of ease of use, customisation, download delay, and content can be declared capable of forming a construct of total perceived value with construct validity and reliability results as shown in Table 4.

Table 4. *Construct validity and reliability of measurement results*

Aspects	λ	λ^2	$1-\lambda^2$	Construct Reliability (CR)	Average Variance Extract (AVE)
Ease of use	0.905	0.819	0.181	0.952	0.832
Customization	0.904	0.817	0.183		
Download delay	0.908	0.824	0.176		
Content	0.932	0.869	0.131		
Total	3.649	3.329	0.671		

According to Table 4, the loading factor of the ease-of-use aspect is 0.905, customisation is 0.904, download delay is 0.908, and content is 0.932; thus, aspects measured are declared valid. The ability of the four aspects is analysed based on the average variance extract (AVE) declared valid (AVE = 0.832>0.5) and based on Construct Reliability (CR) is reliable (CR = 0.952>0.7). The validity and reliability described above indicate that the data collected have qualified as research data. To determine the effect of gender on the perception of the assessment provided by the coaches, the differences in perception scores based on gender were analysed as shown in Table 5.

Table 5. *Differences in perception scores in terms of gender*

Aspect	Gender	N	Mean	SD	F	Sig.	t	Sig.
Ease of use	M	77	4.14	0.569	0.086	0.771	-0.560	0.577
	F	15	4.22	0.443				
Customization	M	77	4.11	0.625	1.897	0.172	0.398	0.691
	F	15	4.04	0.364				
Download delay	M	77	4.13	0.632	0.013	0.91	1.106	0.272
	F	15	3.93	0.547				
Content	M	77	4.16	0.572	1.279	0.261	0.381	0.704
	F	15	4.10	0.410				
Total	M	77	4.13	0.548	0.267	0.606	0.297	0.767
	F	15	4.09	0.385				

According to the analysis results presented in Table 4, there is no significant difference between the perceptions of male and female users on the five aspects assessed, such as ease of use, customisation, download delay, content, and total. In the ease-of-use aspect, the average score of men is 4.14 with a standard deviation of 0.569, while women have an average of 4.22 with a standard deviation of 0.443. The t-test results show a significance value of 0.577, which means there is no significant difference between the two groups.

The customisation aspect shows similar results, with an average score of 4.11 for men and 4.04 for women. The significance value of the t-test is 0.691, which indicates there is no significant difference. Similarly, in the download delay aspect, although men have a higher average score (4.13) than women (3.93), the t-test significance value of 0.272 indicates that the difference is not significant. The content aspect shows an average of 4.16 for males and 4.10 for females, with a significance of 0.704, again showing no significant difference.

Overall, the total value of men's perceptions is 4.13 and women's is 4.09, with the t-test results showing a significance value of 0.767. Hence, there is no statistically significant difference between men's and women's percep-

tions of all aspects measured. All significance values are well above the 0.05 threshold, indicating that gender does not substantially influence differences in perception.

Discussion

The findings indicated that the development of a web-based competition management information system for the East Java NPCI, utilising the ADDIE model, has been successfully executed and yielded results that are highly feasible to use. The high value of product feasibility (average 89%) from experts and positive responses from users (average perception score 4.12 out of 5.00) show that the system fulfills the needs of managing competitions efficiently and inclusively.

The ease-of-use aspect obtained an average score of 4.16, indicating that the system is easy to use by coaches, in accordance with system design principles that prioritise accessibility and ease of navigation. The findings are consistent with a previous study by (Arnab et al., 2022) which found that ADDIE-based systems are effective in designing user-friendly interfaces. On the customisation aspect, the score of 4.09 indicates that coaches experienced a flexible system to meet the specific needs of users. This is crucial since user perception of ease of use has a direct effect on acceptance of new systems (Venkatesh & Davis, 2000). The ease of use is very important for the product since the target users in the East Java NPCI are from various sports and disability classifications.

The download delay aspect scored 4.08, which indicates that the system access speed performance is in the excellent category; although, there is a room for improvement. The occurrence of small potential delays experienced by coaches, will affect user perceptions, increasing frustration and reducing satisfaction (Arapakis, Park, & Pielot, 2021). System delays can impede users' decision-making time and induce boredom, notwithstanding the system as a whole functions well (Harmon, 2022). In this context, system responsiveness is a key success factor in real-time match data management (Van Damme et al., 2024).

The content aspect obtained a score of 4.16, indicating that the content of the web is in accordance with the needs of the NPCI and the coaches in conveying competition information. This reinforces the opinion of (Nadiyah & Faaizah, 2015) that ADDIE-based systems are effective in accommodating content or information appropriately. Moreover, content quality is one of the main dimensions in the digital service quality model that affects user satisfaction and experience (Ighomereho, Ojo, Omoyele, & Olabode, 2022).

Assessing web usability through coaches, who are direct users of the generated product, is deemed appropriate to evaluate the development of a product, particularly in the context of information systems (Jordan, 2020). Therefore, it is very appropriate if the evaluation of web development is carried out using usability testing using coaches. Where usability tests are performed by testing from users, peers, pluralistic usability searches, visual searches, informal searches, contextual searches, and other usability testing modifications that offer a variety of methods to suit different purposes and contexts (Riihiaho, 2017).

The t-test results showed that there were no significant differences in perceptions between male and female coaches on the four aspects measured. This suggests that the system can be used fairly and equally by all users, without gender bias. This finding is consistent with the principle of inclusion in information technology design that digital services should accommodate equal access for all parties, including people with disabilities and various categories of users (Kiuppis, 2018).

The limitations of this study are the respondents were limited to one provincial area and the evaluation that was performed in the early stages of implementation. Further testing on a national scale and across competitions is needed so that the results are more generalisable. Furthermore, limited internet access in some areas may affect users' perceptions of the system's speed, even though the system is designed to be quite lightweight and responsive.

In general, the development of the web-based information system has a major contribution in supporting the management of disability sports competitions in Indonesia. This system can be used as an initial model to be implemented in other regional NPCIs, so that competition management can be executed more efficiently, transparently, and participatively. Future research is recommended to integrate this system with mobile devices and national databases to be more connected with central level reporting (Kemenpora or NPCI).

Conclusion

This study successfully developed a web-based competition management information system for the East Java NPCI using the ADDIE development model. This system is designed to answer the need for efficient, inclusive, and digital technology-based competition management, especially in the context of sports for disabled people. Validation results from experts indicated that the product was in the very feasible category with an average score of 89%. Moreover, a user evaluation involving 93 coaches showed an average perception score of 4.12 on a scale of 5.00, reflecting a very positive acceptance of the system.

The user perception instrument was valid and reliable. The four main aspects assessed, namely ease of use, customisation, access speed, and content quality, all obtained high scores, indicating that the system has met user expectations. There was no significant difference between male and female users' perceptions of the system.

Thus, this information system proved to be effective and feasible to be applied in competition management in the NPCI environment. The use of the ADDIE model is proven to be able to produce web-based products that are functional, responsive, and adaptive to user needs. In the future, this system has the potential to be replicated and further developed on a national scale, as well as integrated with a central database to increase transparency and efficiency in the management of disability sports competitions in Indonesia.

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Differences in Several Coordination and Precision Tests in 11-year-old Children from Kosovo

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Abstract: *Coordination abilities are among the most significant components of a child's motor development, with the greatest rate of growth between 7-11 years of age. This study aims to compare the difference between boys and girls on several different coordination and precision tasks among 177 children aged 11 in Kosovo (83 boys and 94 girls) using a cross-sectional design through the administration of standardized coordinated movement (i.e. rectangular run, side steps, dribbling slalom) and precision tasks (i.e. targeting accuracy, kicking & throwing). Independent-samples t-test indicates that there are significant differences between boys and girls concerning basic agility and applied ball-control tasks. Boys were found to complete the rectangular run (t = -3.05, p = 0.003) and side steps (t = -3.01, p = 0.003) more quickly than girls, demonstrating higher levels of applied coordination for both the hand (t = -5.38, p = 0.001) and foot dribbling slalom (t = -8.25, p = 0.001). In addition, boys exhibited greater performance on all short-stick targeting tasks (t = 3.17, p = 0.002), horizontal throwing with a run-up (t = 2.52, p = 0.013) and kicking at the goal with a run-up (t = 6.24, p = 0.001) than girls. However, there were no significant differences between the sexes on general coordination tasks that do not require the use of a ball. Results suggest that differences between boys and girls at age 11 are task-specific and that differences in movement experience seem to account for these differences rather than general neuromotor maturity.*
Keywords: *Coordination, Precision, Childhood Motor Development, Sex Differences, Physical Activity*

Introduction

Coordination is important for both developing motor efficiency in a child's daily life and sport. Coordination also has significant implications for physical development. Coordination is the interaction between the neuromuscular system and motor control as influenced by the following: (1) balance; (2) rhythm; (3) spatial orientation; (4) accuracy of movement; and (5) adaptability to changes in the environment. Studies show that coordination improves rapidly between the ages seven through eleven, when the neuromuscular system is developing rapidly and children's motor competence is expanding. Marchenko et al. (2024) found significant age-related improvements in the following dimensions of coordination: (1) spatial differentiation; (2) transitioning between physical movement (e.g., running to jumping); (3) balance; and (4) hand-eye coordination in boys aged seven through eleven with the most significant amount of improvement occurring between ages seven through ten and stabilizing around age eleven. Therefore, age eleven is an important time for children as certain aspects of coordination reach functional maturity, while others remain highly variable and will continue to develop. Research suggests coordination development is influenced by both age and sex. Opstoel et al. (2015) examined boys and girls aged nine through eleven who played various sports and found that the development of coordination does not occur the same between boys and girls in all areas of coordination. While boys and girls do improve at the same rate according to age, boys tend to perform better on tasks that require speed and control of multiple segments of their bodies. Conversely, girls tend to significantly outperform boys on tasks involving flexibility, rhythm, and precision which require a high degree of accuracy. The patterns of differences in coordination performance are likely due to factors such as (1) differing amounts of movement experience; (2) varying ways in which children play; and (3) the availability of a structured training environment. These factors, rather than biological maturation, play a major role in the motor development of all children at this stage of their lives. In general, studies from around the world have shown that coordination ability at age eleven differs minimally and only in conjunction with the specific task performed. Studies have shown that children with the same amount of physical activity (either at home or in a structured setting) generally have similar coordination abilities regardless of body composition and/or previous movement experience. Limited research is available in many

countries, including Kosovo, regarding the coordination development of children aged eleven. There has not yet been any published studies that have focused on the measurement of coordination performance and precision in eleven-year-old children from Kosovo. Therefore, the objective of the current research study is to explore coordination performance and precision ability differences between eleven-year-old boys and girls from Kosovo. This study will add to the body of knowledge concerning a population that is not well represented in international coordination literature.

Literature Review

The most dramatic increase in coordination occurs during the period of middle childhood. According to Marchenko, et al. (2024) Children will experience significant age-related improvements in many different aspects of coordination from 7-10 years of age, and the majority of aspects of coordination will reach a level of relative stability by age 11. At age 11, many children will have a comparable level of performance on common coordination tasks and continued development of skills like dynamic balance. Therefore, age 11 is an important point of distinction for identifying subtle variations in coordination performance. It is critical to expose children to structured movement opportunities to maximise positive outcomes related to coordination development. Opstoel et al. (2015) looked at children ages 9-11 years across 25 different sports and found that the difference in coordination between any two sports was minor, with gymnastics and racquet sports providing small advantages; specialization by age 11 is a consequence of training volume rather than genetic predisposition and participation in organized sport increases one's capacity to develop coordination. Similar to this conclusion, Biino et al. (2023) reported that children who participate in organized sports demonstrate higher levels of gross motor coordination (GMC) than children not involved in sports. A similar pattern of results was observed by Canli et al. (2023) who reported that children aged 6-9 years of age experience rapid improvements in motor coordination, and physical activity participation is an independent predictor of greater motor coordination across gender and age. The combined results from the above studies demonstrate that structured motor experience is important for optimal coordination development. In addition, there are many studies that demonstrate a relationship between body composition and motor competence.Studies conducted in Colombia, Morocco and Japan showed that higher fat mass (amount of fat tissue), BMI (body mass index), and waist circumference were associated with less physical fitness and lower motor efficiency in fast and agile movements requiring balance and endurance Allen et al., 2022; Alcalid et al., 2022; Ibrahim et al., 2021; Yanagi et al., 2024). In contrast to this finding, a greater amount of muscle mass is positively correlated with greater neuromuscular performance e.g., strength, power, and speed. Ivashchenko et al. (2023) confirmed such relationships in a sample of 7- to 10-year-old children, finding a positive correlation between muscle tissue and coordination, whereas fat percentage was negatively correlated with balance and agility. Similarly, Nikšić et al. (2025) reported on morphological characteristics and motor skills of a representative sample of elementary school children in grades two through five. Their findings indicated that boys had a significantly higher BMI and significantly greater skinfold thickness when measured on the subscapular region of their body. Additionally, motor tests demonstrated strong correlations between body composition (i.e., muscle versus fat) and motor skills performed at an early school age. These results provide further evidence of the direct association between body composition and physical education programs offered in schools as well as indicate that coordination differences are measurable prior to the age of 11 years, suggesting that differences in body composition may continue to have an effect during the primary education years. Mixed findings regarding sex-based differences in coordination are evident in studies performed by Yassin et al.According to research conducted by Adriyani et al., boys perform better in ball handling and precision-related tasks that require hand-eye coordination than girls. Likewise, Ivashchenko et al. also found that boys perform better than girls on strength-based tasks, while girls show superior flexibility compared to boys. Nikšić et al. demonstrated that boys typically outperform girls in tests measuring flexibility, trunk strength, and functional strength. On the other hand, girls typically outperform boys in static hand strength and explosive leg power tests. It should be noted that sex differences in performance at this age are highly dependent upon the given task, and therefore different types of tests should be utilized to measure coordination performance for 10- to 12-year-olds. Boys generally excel in power-type or ball-precision tasks, while girls demonstrate greater advantage with flexibility and static strength. The school physical education program is still one of the major contexts for children's motor development during childhood. Prior studies have proven that structured physical education greatly influences children's motor competence development. Klaričić, Petrički, and Marenčko studied the physical activity levels of children in third and fourth grade in Croatia and revealed that within these two

grades of primary education there are no differences in total physical activity levels; however, different indicators of partial physical activity demonstrate a difference between boys and girls depending upon specific contexts of physical activity, such as during recess or free time. This research suggests that while the volume of physical education (PE) received during the course of a week will not greatly impact total activity levels of children, differences do exist in how boys and girls engage in specific motor behaviours and the level of involvement in physical activity. Along with this evidence, researchers also developed predictive models using discriminant analysis to find which tests would accurately predict age-related coordination changes. Ivashchenko, Lee, and Price determined that the most accurate predictors for age-related coordination changes of boys from 11 to 13 years of age are long jump, rhythmic hand tapping, and precision throwing. In girls, the most accurate predictors for girls from 11 to 12 years are pull-ups, movement speed-perception, and static equilibrium, while rhythmic movements are also predictive for age-related coordination changes among girls from 12 years of age to 13 years of age (Ivashchenko et al., 2018). These studies show that, through these studies, targeted test batteries have the ability to detect differences in motor development using specific coordination and precision assessments in very narrow age ranges.

Methods and materials

The main aim of this research is to determine differences in types of coordination in 11-year-old children and to examine differences between participants with respect to age and sex.

Hypotheses

H: There are statistically significant differences between 11-year-old boys and girls in coordination and precision performance.

Sample of population

The sample of participants was obtained through random selection from the population of boys and girls aged 11 years. The total sample included 177 participants, age 11 years: 83 boys and 94 girls.

All individuals that participated provided informed consent to participate in this study, met the age requirement for participation and currently were enrolled in school at the time of the study. There were no medical diseases/disorders by the participants of this study.

Instruments and Procedures

This research represents a cross-sectional study designed to identify differences in coordination and precision between boys and girls. The experimental method was used, applying a testing technique for data collection. Each measurement was taken and recorded in accordance with the Assessment Manuals. As supporting methods, a partially applied survey method, historical method, and statistical analysis were used.

Table 1. *Set of variables for Coordination and Precision*

No.	Variables for Assessing Coordination	No.	Variables for Assessing Precision
1	CRRT – Rectangular Run (Envelope Test)	1	PTSS – Targeting with Short Stick
2	CRSS – Side Steps Test	2	PTHPT – Paddle Throw at Horizontal Target
3	CRF8 – Figure-Eight Run with Bending	3	PTVPT – Paddle Throw at Vertical Target
4	COBOP – Backward Obstacle Course	4	PKVT – Kicking at Vertical Target
5	CCST – Stick Coordination Test	5	PKG – Kicking the Ball into Goal
6	CAGA – Ground Agility Test	6	PTVBR – Vertical Ball Throw with Run-Up
7	CCHDS – Hand Dribbling Slalom	7	PTHBR – Horizontal Ball Throw with Run-Up
8	CCFDS – Foot Dribbling Slalom	8	PKGR – Kicking the Ball into Goal with Run-Up

Statistical Procedures

Independent-samples T-test was used to examine for sex differences in coordination and precision of 11-year-old adolescents. Descriptive statistics were computed to determine mean values and standard deviations for all variables derived from tests as well as their normal distribution. The assessment of normal distribution determined the

appropriate tests of correlation between variables. Correlation was investigated by means of Pearson's coefficient of correlation. Statistical significance was determined as $p<0.01$.

Results

Table 2. *Descriptive Statistics for Boys*

	N	Range	Min.	Max.	Mean	Std. Deviation	Variance	Skew.	Kurt.
CRRT	83	15.15	22.91	38.06	31.71	2.74	7.52	-0.13	0.94
CRRS	83	10.13	9.77	19.90	13.34	1.64	2.69	1.49	3.68
CRF8	83	8.51	17.14	25.65	21.72	2.15	4.64	-0.21	-0.81
COBOP	83	40.81	9.43	50.24	19.33	8.36	69.94	2.61	7.27
CCST	83	33.16	6.34	39.50	11.68	5.22	27.20	3.44	14.11
CAGA	83	23.94	7.85	31.79	20.04	4.29	18.40	0.53	1.04
CCHDS	83	13.53	9.13	22.66	12.94	2.37	5.62	1.21	2.67
CCFDS	83	15.67	10.02	25.69	15.72	3.51	12.32	0.96	0.59
PTSS	83	7.00	98.00	105.00	103.42	1.48	2.20	-1.29	2.05
PTHPT	83	54.00	19.00	73.00	48.35	12.94	167.42	-0.04	-0.69
PTVPT	83	32.00	4.00	36.00	19.20	6.43	41.36	0.29	0.30
PKVT	83	38.00	6.00	44.00	21.44	6.85	46.96	0.59	0.93
PKGK	83	33.00	3.00	36.00	7.78	4.21	17.69	3.89	24.08
PTVBR	83	9.00	0.00	9.00	3.39	2.16	4.68	0.56	0.05
PTHBR	83	71.00	0.00	71.00	6.98	12.30	151.34	4.16	17.64
PTGR	83	12.00	1.00	13.00	6.48	2.23	4.99	0.29	1.34

Compared to complex coordination such as the backward obstacle course, where mean time under test conditions varied substantially among individuals, with a mean time of 19.33s (SD=8.36), reflecting widespread differences in dynamic balance and coordination ability. In summary, boys had consistently accurate performances and relatively little variability in their ability to perform basic coordination activities during the test period (rectangular run) with a mean time of 31.71 s (SD=2.74) thus, the rectangular run demonstrated stable patterns of development for boys in structured coordination tasks through age eleven. By comparison, complex coordination activities had greater variability in individual performance than did basic coordination activities. Static aiming accuracy was consistently high for boys, with the aid of a short stick, as measured by a mean score of 103.42 (SD = 1.48) for targets. This data indicates that boys achieved a mature developmental level with static aiming accuracy by age 11. In contrast, considerable variability existed in the boys' ability to hit a target when aiming while running or making a throwing sequence. A paddle throw directed towards a horizontal target produced a mean score of 48.35 (SD = 12.94). Thus, while boys have matured with regard to static aiming accuracy, their ability to achieve accuracy while executing dynamic activity is still developing.

Table 3. *Descriptive Statistics for Girls*

	N	Range	Min.	Max.	Mean	Std. Deviation	Variance	Skew.	Kurt.
CRRT	94	16.87	26.23	43.10	32.89	2.44	5.97	0.66	3.12
CRRS	94	9.35	10.62	19.97	14.04	1.46	2.12	0.97	3.68
CRF8	94	20.80	18.36	39.16	22.48	2.79	7.76	3.63	18.97
COBOP	94	39.67	10.23	49.90	19.53	6.26	39.14	3.38	14.49
CCST	94	28.44	1.76	30.20	10.50	4.04	16.31	2.89	12.22
CAGA	94	21.52	9.91	31.43	22.00	3.77	14.19	-0.28	1.14
CCHDS	94	18.31	8.70	27.01	15.02	2.74	7.53	1.52	5.79
CCFDS	94	16.74	12.90	29.64	20.01	3.40	11.56	0.63	0.73
PTSS	94	11.00	94.00	105.00	102.71	2.15	4.64	-1.47	2.64

PTHPT	94	55.00	12.00	67.00	37.09	11.03	121.73	0.47	-0.06
PTVPT	94	36.00	0.00	36.00	12.94	5.70	32.52	0.75	2.16
PKVT	94	32.00	2.00	34.00	16.17	5.72	32.76	0.51	0.86
PKGK	94	9.00	1.00	10.00	5.94	1.79	3.21	0.00	0.24
PTVBR	94	8.00	0.00	8.00	2.22	1.52	2.30	1.17	2.78
PTHBR	94	41.00	0.00	41.00	4.46	5.14	26.45	5.02	32.19
PTGR	94	8.00	1.00	9.00	5.48	1.83	3.37	-0.05	0.25

Girls' performance in basic coordination activities was consistent. The average time spent on the rectangular run was 32.89 s (SD = 2.44), which shows that the way girls were able to perform basic running movements at age 11 did not vary much between them. Girls also exhibited a lot of variation in their abilities to perform more complex coordination activities. The average time taken to complete the figure-eight run was 22.48 s (SD = 2.79), and the times ranged widely (18.36–39.16 s), indicating that some girls were better able than others to change positions and control their bodies when moving in the figure-eight pattern. Girls consistently demonstrated that their ability to do basic coordination activities had reached a stable level, whereas their ability to perform more complex coordination activities still varies a lot between them. In terms of static precision, the girls showed a high degree of consistency in their performance. The average score achieved when aiming at a target using a short stick was 102.71 (SD = 2.15), which shows that girls' basic ability to aim accurately developed very well by age 11, with little to no difference between the scores of the girls. Dynamic precision tasks showed a greater spread of scores across the girls. The average score achieved while throwing a paddle at a horizontal target was 37.09 (SD = 11.03), which indicates that the girls exhibited a large amount of variability between them in terms of their timing, arm coordination, and accuracy when throwing the paddle while in motion. Overall, girls' static precision skills are relatively well developed, while their dynamic precision's, which requires the coordination of several muscle actions in a precise sequence of time and order, still shows considerable individual variation.

Correlation analysis Boys

Table 4. *Correlation matrix for Boys*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CRRT	1															
CRRS	.459**	1														
CRF8	.015	.074	1													
COBOP	-.013	.093	.068	1												
CCST	.196	.353**	-.014	-.033	1											
CAGA	.341**	.049	.190	.110	-.233*	1										
CCHDS	.441**	.331**	.157	-.077	.009	.341**	1									
CCFDS	.496**	.303**	-.074	-.127	-.135	.323**	.502**	1								
PTSS	-.146	-.045	-.136	-.142	-.123	-.025	-.284**	.289**	1							
PTHPT	-.215	-.248*	.065	-.027	-.018	-.382**	-.428**	.074	.206	1						
PTVPT	-.518**	-.191	.011	-.038	-.237*	-.250*	-.254*	-.026	.285**	.421**	1					
PKVT	-.067	-.161	.022	-.274*	.156	-.137	-.269*	.061	.198	.245*	-.019	1				
PKGK	-.238*	-.245*	.009	-.095	-.049	-.141	-.093	.206	.278*	.144	.278*	.063	1			
PTVBR	-.327**	-.073	.183	-.019	-.045	-.262*	-.159	.222*	-.034	.186	.062	.007	.172	1		
PTHBR	.074	.282**	.072	-.022	.016	.044	-.015	-.074	.025	-.080	.010	-.085	-.043	-.080	1	
PTGR	-.286**	-.127	.034	.000	-.097	-.224*	-.021	.071	.110	.146	.306**	.089	.058	.129	.111	1

The correlation analysis indicates that basic coordination tasks are positively related to one another, whereas precision tasks show generally weak or negative correlations with coordination measures. Many coordination tasks were highly correlated (e.g., Rectangular Run had a strong correlation with Side Steps, $r = .46$, $p < .01$), indicating that general movement speed and lateral agility have a common coordination basis. Hand dribbling slalom had a high

correlation with foot dribbling slalom (r = .50, p < .01), indicating that ball control with hand and foot have a shared basis of coordination. These relationships suggest that children who are skilled at applied coordination in one way will typically be good at other types of applied coordination, especially agility and directional change. Coordination and precision, on the other hand, were generally negatively correlated, as greater performance (lower time) in agility tasks was usually associated with lower precision scores. The likely source of this negative relationship is the different scoring systems; for example, Side Steps and Paddle Throw had a negative correlation (r = -.25, p < .05), while Rectangular Run and Vertical Paddle Throw displayed a strong negative correlation (r = -.52, p < .01). Since coordination tasks measure time (with lower time being better) and precision tasks measure scores (with higher scores being better), the negative correlation reflects an inverse correlation rather than a lack of skill.

A number of precision tasks were positively correlated: Short Stick Targeting was positively correlated with Vertical Paddle Throwing (r = .29, p < .01), which indicates that as an individual's static aim improves, so too does his or her success in guided precision tasks. Thus, both target aiming and paddle throwing indicate consistency in precision across hand-based tasks.

Correlation analysis Girls

Table 5. *Correlation matrix for Girls*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CRRT	1															
CRRS	.369**	1														
CRF8	.028	.021	1													
COBOP	.013	.204*	.598**	1												
CCST	.238*	.155	.020	.013	1											
CAGA	.181	.400**	.027	.105	-.188	1										
CCHDS	.367**	.158	-.020	.015	.194	.255*	1									
CCFDS	.146	.069	-.020	.060	-.062	.185	.314**	1								
PTSS	-.126	-.030	.095	.033	-.123	-.304**	-.414**	.200	1							
PTHPT	-.194	-.006	.058	.041	-.004	-.270**	-.300**	.083	.263*	1						
PTVPT	-.105	-.132	.110	-.034	.055	-.117	-.241*	-.045	.062	.449**	1					
PKVT	-.116	-.013	.014	-.008	-.042	.018	-.262*	-.009	.094	.213*	.102	1				
PKGK	-.092	-.126	-.034	.035	-.074	-.214*	-.092	-.209*	.028	.226*	.198	.148	1			
PTVBR	.204*	-.055	-.015	-.142	-.138	-.063	-.030	-.059	-.097	.041	.231*	.090	.022	1		
PTHBR	-.126	-.086	-.021	-.032	.174	-.086	.120	.139	-.194	-.096	.073	.041	.109	.061	1	
PTGR	-.231*	-.039	.207*	.043	-.051	-.188	-.095	-.003	-.078	.178	.215*	.049	-.052	.110	-.034	1

A number of coordination tasks indicated that they measure similar types of motor abilities due to their correlation with one another. The rectangular run and sideways steps were both positively correlated (r=.37, p<.01), indicating that for girls, lateral agility and basic spatial coordination are the same type of movement structure. Sideways steps and ground agility were also positively correlated (r=.40, p<.01), suggesting that girls who move quickly through directional changes are more likely to complete agility-related tasks successfully. A very strong relationship was seen between figure-eight running and the backward obstacle course (r=.60, p<.01), suggesting that girls with good higher-level spatial restructuring also have good dynamic balance. These relationships seem to indicate that girls who perform well in one form of complex coordination (such as figure-eight running) will also perform well in similar tasks, particularly those that involve balance, direction change, and spatial control. Conversely, coordination tasks were mostly negatively correlated to the different areas of precision due to their respective inverse scoring method (time versus points). As such, ground agility had a negative correlation with short-stick targeting (r=–.30, p<.01), indicating that the quicker an individual can complete ground agility (lower score), the higher the precision score she will earn. Similarly, the hand-dribbling slalom had a negatively related relationship to several precision tasks such as horizontal paddle throws (r=–.30, p<.01), indicating that, although some children possess better potential throwing accuracy than others because they are more coordinated, the relationship is reflected as a negative

correlation due to the different scoring directions used. Negative correlations between coordination and precision do not indicate the opposite skill but rather illustrate the different forms of checking speed (time) toward a lower score and checking accuracy (points) toward a higher score. Several precision tasks were positively correlated with one another. Vertical and horizontal paddle throws had a moderate positive correlation with one another ($r=.45$, $p<.01$); thus, throwing precision to different targets reflects an underlying shared accuracy skill. Kicking accuracy into a goal had a positively correlated relationship with horizontal paddle throws ($r=.23$, $p<.05$), indicating girls with higher hand-based accuracy are generally more capable in foot-based accuracy; however, this relationship was minor. This finding would suggest that precision motor skill development transfers from one form of movement (hands) to another (feet) when changing modes of activity.

Independent Samples t-Test Comparing Girls and Boys (Age 11)

Table 6. *T-test*

Variable	Girls (M)	Boys (M)	t	p
CRRT – Rectangular Run	32.89	31.71	–3.05	.003
CRRS – Side Steps	14.04	13.34	–3.01	.003
CRF8 – Figure Eight	22.48	21.72	0.04	.965
COBOP – Backward Obstacle	19.53	19.33	–0.37	.714
CCST – Stick Coordination	10.50	11.68	1.58	.117
CAGA – Ground Agility	22.00	20.04	–3.23	.001
CCHDS – Hand Dribbling Slalom	15.02	12.94	–5.38	.001
CCFDS – Foot Dribbling Slalom	20.01	15.72	–8.25	.001
PTSS – Short Stick Targeting	102.71	103.42	3.17	.002
PTHPT – Paddle Throw Horizontal	37.09	48.35	–1.40	.163
PTVPT – Paddle Throw Vertical	12.94	19.20	–1.09	.278
PKVT – Kick at Vertical Target	16.17	21.44	–1.39	.166
PKG – Kick at Goal (static)	5.94	7.78	–0.61	.542
PTVBR – Vertical Throw (run-up)	2.22	3.39	1.89	.060
PTHBR – Horizontal Throw (run-up)	4.46	6.98	2.52	.013
PKGR – Kick at Goal (run-up)	5.48	6.48	6.24	.001

Statistical analyses of the t-Tests performed on these data indicate that there are statistically significant differences between boys and girls in many of the measures of coordination and precision skills at age 11. The differences between boys and girls are most evident within the time-based coordination test measurements. For example, in both the rectangular run ($M = 31.71$ s for boys vs. $M = 32.89$ s for girls; $t = -3.05$, $p = .003$) and lateral side-steps ($M = 13.34$ s for boys vs. $M = 14.04$ s for girls; $t = -3.01$, $p = .003$), boys completed these tests faster than girls, indicating that boys had superior basic agility and speed and the ability to change direction. The results indicate that boys demonstrate more efficient patterns of movement in space than girls, which is likely attributable to the additional time spent participating in activities that require changes of direction and rapid acceleration. The largest differences in performance between boys and girls occurred within the area of coordination related to sports, particularly in dribbling. Boys outperformed girls when compared on the hand dribbling slalom ($M = 12.94$ s for boys vs. $M = 15.02$ s for girls; $t = -5.38$, $p = .001$) and foot dribbling slalom ($M = 15.72$ s for boys vs. $M = 20.01$ s for girls; $t = -8.25$, $p = .001$), indicating that boys exhibit greater applied states of coordination with respect to manipulating a ball than do girls. It is likely that this pattern of performance reflects differences in sports participation, whereby boys of this age are more likely to be playing ball-oriented sports such as football and basketball, which require complex combinations of coordination, timing, and perception-action coupling. For precision skills, boys performed slightly better than girls on short-stick targeting ($M = 103.42$ for boys vs. $M = 102.71$ for girls; $t = 3.17$, $p = .002$), which demonstrates that boys were slightly more accurate in aiming at targets that were stationary. The boys also produced better performance than the girls in dynamic accuracy tasks, such as horizontal throwing with a runway ($p = .013$) and kicking a soccer ball toward a goal with a runway ($M = 6.48$ for boys vs. $M = 5.48$ for girls; $t = 6.24$, $p = .001$),

indicating that boys are better able to perform precision tasks that require a combination of speed and precision of movement than are boys and girls combined due to the effects of motor confidence and practice developed through formal or informal play activities. Conversely, boys and girls displayed similar results on general coordination tasks without manipulating a ball (e.g., figure eight runs and backward obstacle runs), suggesting that boys and girls appear to have comparable levels of basic neuromuscular coordination at this age, with differences emerging only in activities influenced by sport participation.

Discussion

The purpose of the study was to examine if differences exist between male and female 11-year-olds with regard to coordination and precision performance for motor skills, as this is a developmental period where several components of coordination have become solidified while others continue to progress toward functional stabilization. As hypothesized and in agreement with previous research, the findings indicate that there are no uniform differences between the sexes for all motor skills, only a limited number of tasks reflect environmental experience, movement culture and sport participation. No differences were identified in general coordination tasks not requiring the use of a ball, such as the figure eight running and the backward obstacle course. The absence of difference suggests that all boys and girls at age 11 have established a similar level of fundamental neuromuscular coordination as indicated by prior research (Marchenko et al., 2024) establishing all components of coordination reached status quo by age 11. Conversely, positive sex differences were noted on those tasks involving the ability to perform rapidly changing direction as well as those involving applied ball controlling. Male participants demonstrated a greater percentage of increased speed of movement in the agility tasks measured, as well as higher scores for hand and foot dribbling performance on the slalom course than females, likely reflecting the degree of ball-related sporting activity that the male participants engage in on a frequent basis (football and basketball) at this stage of their development in Kosovo. These results are in agreement with those reported in Yassin et al. (2024) and Adriyani et al. (2020).When assessing precision in the current study, results indicated a parallel pattern. While the precision accuracy measures indicated a high level of consistency, the boys achieved a greater amount of improved accuracy on different forms of dynamic accuracy tasks that required both the component of movement rate as well as sequencing (the run-up); thus, the frequency of practised success in precision accuracy combined with the degree of success experienced leads researchers to associate them to a higher degree of coordination. It is important to note that both coordination and precision exhibit generally inverse correlation due to different method of measurement (timed vs. scored) and therefore the correlation exhibited by individual measures of coordination is a stronger predictor of performance on correlational precision tasks; children with higher scores in one category typically experience a significant advantage with respect to tasks that require use of similar categories. Results of the current research study suggest that differences at age 11 years are a result of both biological maturation and, to a greater extent, accumulated experiences within the area of motor movement. The research findings support those of Opstoel et al. (2015) and Biino et al. (2023), who report that exposure to training has a much greater impact on performance differences in middle childhood than does the timing of specialization. Therefore the need for increased emphasis on receiving structured and regular(safe) physical education as well as accessible sporting experiences for both sexes is needed to further develop coordination.

Conclusion

The current findings enable us to see that coordination and precision performances at 11 years have been shown through our analysis to be specific to tasks performed rather than a consistent difference between genders. For example, boys showed superior performance on agility-based exercises as well as ball control measures which likely reflect experiences that boys have had during sporting activities or developing directional change movements than girls, while no sex differences were found on coordination tasks that did not involve balls indicating that both genders were at an equivalent level of neuromuscular maturity for this type of exercise. Differences in precision mainly emerged on dynamic accuracy tests in which boys exhibited a greater level of combined movement speed and target accuracy than did girls. Therefore, there is great evidence of two major influences upon the development of coordination performance (motion experience and sport culture) when we consider coordination outcomes at school age; therefore, schools need to be aware of these factors if they are to promote diversity in motor opportunities for young girls and boys through physical education programs.

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Evaluation of Men's Volleyball Performance Development in the Special Region of Yogyakarta

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Abstract: *Volleyball, both indoor and beach, is one of the world's most popular sports and has grown significantly in Indonesia, particularly in Yogyakarta. Athlete development is essential not only for enhancing performance but also for shaping character and strengthening regional competitiveness. In Indonesia, schools, clubs, local governments, and the Indonesian Volleyball Association (PBVSI) share responsibility for talent identification and coaching in line with national policy (Law No. 11/2022). Despite structured programs, organizational strengthening, and regional development centers, challenges remain, especially regarding infrastructure, funding, and policy gaps. This study aimed to comprehensively evaluate the development of volleyball in Yogyakarta and identify strategies for improvement to restore competitiveness at the national level. The CIPP (Context, Input, Process, Product) evaluation model by Stufflebeam was employed for its comprehensive nature, assessing not only outcomes but also the initial context, available resources, and program implementation. The study involved 49 volleyball club coaches across five districts and cities.*

Findings show that while the program has produced promising young athletes, weaknesses persist in objectives, facilities, funding, and execution. Coaching goals remain unclear, infrastructure and financial support are limited, and incentives for athletes are suboptimal, although monitoring is relatively stronger. Achievements at the regional level have been evident, yet national success remains difficult to achieve. To address these barriers, improvements in strategic planning, investment, infrastructure, transparent funding, and monitoring are crucial. Furthermore, the SPLISS framework emphasizes that sustainable elite performance requires not only athlete talent but also integrated policy support across financial, organizational, and developmental domains.

Keywords: *Volleyball, evaluation, athlete development. PBVSI*

Introduction

Volleyball is one of the most popular sports worldwide, both in its indoor and beach volleyball forms. The development of volleyball athletes plays a crucial role in enhancing sports achievement and must be carried out in a planned and continuous manner. Such development is not only essential for improving the physical, mental, and spiritual aspects of athletes but also for shaping character and strengthening regional competitiveness. In Indonesia, particularly in the Province of Yogyakarta Special Region (DIY), efforts have been made to foster young athletes through schools and volleyball clubs as part of long-term talent development programs. In this context, local governments are responsible for implementing structured coaching and athlete development in accordance with their authority and mandate to advance regional and national sports achievements(Bompa and Haff, 2009; I Gede Widyatmika Pratama, 2018; Bompa and Buzzichelli, 2019; UU No 11 Tahun 2022, 2022). Volleyball has experienced rapid development both globally and within Indonesia. This progress serves as a fundamental asset for the Indonesian Volleyball Federation (*Persatuan Bola Voli Seluruh Indonesia* or PBVSI) and volleyball coaches in general to continue advancing the sport and improving the quality of national volleyball performance. Strengthening organizational structures, enhancing athlete training programs, and promoting volleyball at the grassroots level are essential strategies for sustaining this growth and elevating Indonesia's competitiveness in the international arena(Pakaya, Rahayu and Ks, 2012; PBVSI, 2025)

Coaching and development of competitive sports are carried out and directed to achieve achievements at the regional, national, and international levels. Coaching is carried out by the parent organization of sports branches at both the regional and central levels. Development is also carried out by empowering sports associations, devel-

oping national and regional sports development centers, and organizing competitions in a tiered and sustainable manner(Pakaya, Rahayu and Ks, 2012; UU No 11 Tahun 2022, 2022). The development process based on age calculations shows that peak performance in volleyball can be achieved around the age of 20 to 25, and the start of playing sports at the age of 11-12(Bompa and Haff, 2009; Bompa and Buzzichelli, 2019). To achieve success in the sport of volleyball, talent development must begin at an early age and be carried out consistently, continuously, fundamentally, systematically, efficiently, and in an integrated manner. It is therefore essential to cultivate habits that encourage children to enjoy playing and engaging in sports from a young age, as this will stimulate the development of their bodily functions. Through a persuasive and supportive approach, young children can gradually develop an interest in becoming athletes.

A comparative understanding of the development of insights and enriching the research agenda in this field, introducing the system and structure of sports coaching with analysis based on government policies and sports coaching from various contexts to outline the opportunities available for advanced coaching; and highlighting several issues and challenges that hinder the development of sports, steps aimed at recommendations for future policy and practice improvements(Chen and Chen, 2022).

The achievements of the Indonesian Volleyball Association (PBVSI) in the Special Region of Yogyakarta over the past ten years show a downward trend in quality. This can be seen from the achievements at the junior level, where the Special Region of Yogyakarta was ranked second in 2012 but fell to fifth place in 2013 (Faizin, 2015). Nevertheless, various efforts to develop young athletes continue to be carried out through the organization of regional indoor volleyball club championships as a means of monitoring the development of athletes. This development program is an important step, but a more comprehensive evaluation is needed to assess the extent of progress achieved and determine improvement strategies to restore the Special Region of Yogyakarta's volleyball achievements to a more competitive level nationally.

Method

This study was carried out in the Province of Yogyakarta, specifically at the PBVSI District and City Offices across the region, from October 15 to 22, 2024. The research population consisted of individuals with characteristics aligned with the study's objectives, namely administrators and coaches affiliated with the PBVSI District/City Offices throughout Yogyakarta. A program evaluation approach was employed to examine the effectiveness of sports coaching based on predetermined criteria. Evaluation in this context is understood as a systematic process of obtaining relevant information to support decision-making, conducted objectively and grounded in data (Sukardi, 2015; Suharsimi, 2020). Such an approach ensures that the findings not only reflect the current state of volleyball coaching within Yogyakarta but also provide a foundation for strategic improvements in fostering athlete development.

In this context, a program is defined as a series of structured, continuous activities that take place over a certain period of time (Arikunto, 2009; Daniel L. Stufflebeam, 2014; Endres, Fiekowsky and Holley, 2015). The evaluation model used is CIPP (Context, Input, Process, Product), developed by Stufflebeam. This model was chosen because of its comprehensive and applicable nature in evaluating sports coaching programs. CIPP evaluation focuses not only on the final results (products), but also on the initial conditions (context), availability of resources (input), and the program implementation process.

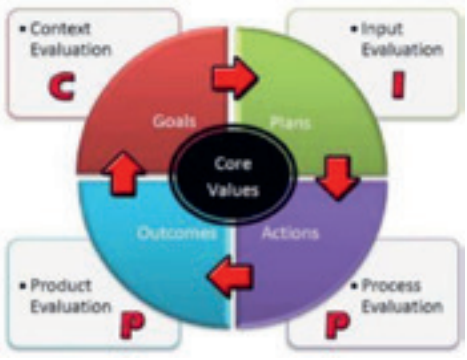


Figure 1. *CIPP Evaluation Model*

The strength of the CIPP evaluation model lies in its ability to formulate important and relevant evaluative questions while simultaneously providing systematic guidance for assessing each stage of a program (Stufflebeam, 2003; Hakan and Seval, 2011; Daniel L. Stufflebeam, 2014). This model operates through four interrelated components. Context evaluation focuses on assessing the background, identifying needs, and clarifying program objectives, as well as determining the relevance of the program to environmental conditions and target groups. Input evaluation examines the planning process, the adequacy and availability of resources, and the feasibility of the strategies used to achieve the program's objectives. Process evaluation emphasizes the assessment of program implementation in practice, including the identification of obstacles, the degree of conformity with the plan, and documentation of the process. Finally, product evaluation measures the outcomes of the program by analyzing the effectiveness of achievements, their broader impact, and the efficiency with which resources have been utilized. Through these components, the CIPP model provides a comprehensive and practical framework for evaluating programs in sports coaching and beyond.

The sampling technique employed in this study was purposive sampling, namely the selection of samples based on specific considerations relevant to the study objectives (Sugiyono, 2021). The research population consisted of individuals possessing characteristics aligned with the study's purpose, namely administrators and coaches under the supervision of PBVSI District/City Boards across the Yogyakarta Special Region (DIY). All subjects were considered to have an understanding of the athlete development programs implemented by the respective PBVSI District/City Boards. The sample, therefore, included administrators and coaches directly involved in these coaching activities.

Data collection represented a crucial stage of the research, as it provided the foundation for obtaining the necessary information. Creswell (2003), emphasized that the data collection process involves delimiting the focus of the study, gathering information through observations, questionnaires, interviews, documentation, and designing data recording protocols (Creswell and Creswell, 2018). Similarly, Sugiyono, (2021), asserted that data collection techniques are the most strategic step in research, as the essence of any study lies in obtaining valid and reliable data. In this study, both quantitative and qualitative data were collected using four main techniques: observation, interviews, documentation, and questionnaires.

Data Collection

The data collection in this study was conducted through four primary techniques: observation, interviews, documentation, and questionnaires.

- First, observation was carried out directly and systematically to understand the phenomena occurring in the field. The researcher could either be directly involved in the activities (participatory) or observe from outside (non-participatory). The main objective was to record the implementation of coaching programs conducted within PBVSI District/City Boards across the Yogyakarta Special Region
- Second, interviews were conducted to gather in-depth information from key informants regarding the coaching programs. This method was applied in both structured and unstructured forms, and the results were recorded for subsequent analysis
- Third, documentation served as a complementary technique, involving the collection and review of relevant archives such as official decrees on management structures, organizational statutes (AD/ART), performance records, and other formal documents from PBVSI, KONI, or related institutions.

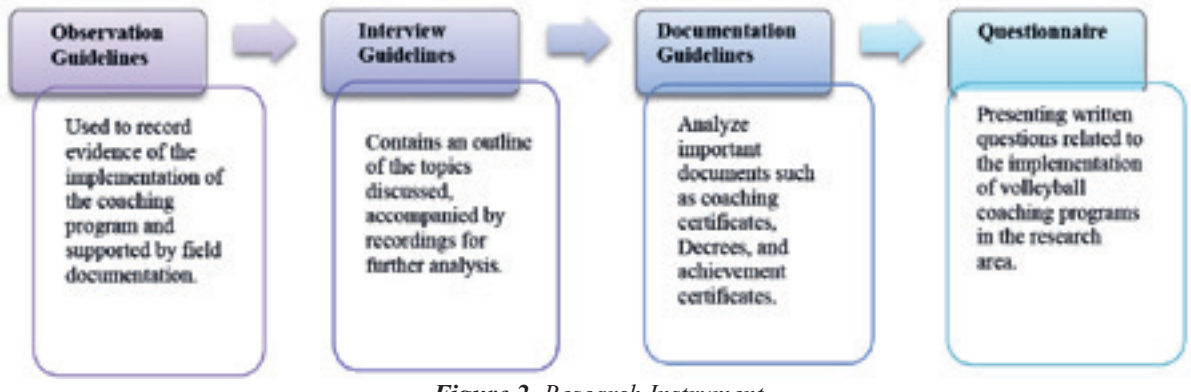


Figure 2. *Research Instrument*

- Finally, questionnaires were distributed to administrators and coaches under PBVSI DIY. These questionnaires consisted of written statements, and respondents were asked to provide answers according to their perceptions of the implementation of the coaching programs.
- Through these four techniques, data collection was expected to provide a comprehensive picture of the implementation and effectiveness of volleyball coaching programs in DIY.

Data Analysis

The data analysis process was carried out through the following stages: First, data collection, where information was obtained by ensuring its validity to guarantee the validity and reliability of the results. Second, data analysis and interpretation, which involved evaluating the athletic training programs at the PBVSI district/city offices throughout the Special Region of Yogyakarta, with a focus on the relevance of the programs as guidelines for men's volleyball training in the region. Third, drawing conclusions based on field findings, which are dynamic and can be adjusted if new, stronger data emerges, thereby summarizing the overall picture of the program and its suitability for the needs of men's volleyball coaching.

The criteria for program success are measured based on the achievement of established standards, with reference to Law Number 11 of 2022 concerning Sports, which regulates national sports performance development. The evaluation results are presented descriptively, based on the respondents' answers to the questions asked, and compared with the applicable coaching standards. Through this approach, the study is expected to provide a comprehensive picture of the successes and challenges in the volleyball coaching program in the Special Region of Yogyakarta, in line with the evaluation of sports programs that use a mixed method to support injury prevention and performance improvement.

Result

This research was conducted on the volleyball training program (men) at the PBVSI Regency Executive Board (Pengkab) throughout Yogyakarta Special Region (DIY) in five regions: 1) Sleman; 2) Yogyakarta City; 3) Bantul; 4) Kulonprogo; and 5) Gunungkidul. The following is a list of coaches involved in this study:

Table 1. *Description of the Number of Coaches in the Volleyball Training Program Evaluation Research at the PBVSI Regency Executive Board (Pengkab) throughout Yogyakarta Special Region*

No	Regency Executive Board	Coach
1	PBVSI Sleman	12
2	PBVSI Yogyakarta	10
3	PBVSI Bantul	10
4	PBVSI Kulon Progo	7
5	PBVSI Gunung kidul	11

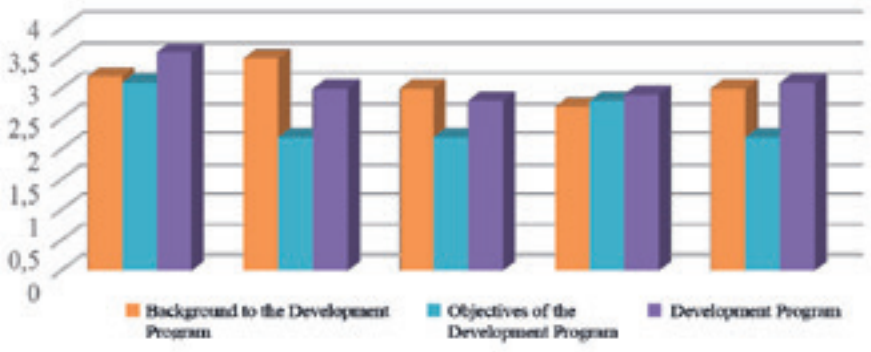
The results of the Aiken validity test showed that all items in the questionnaire were valid with a V Aiken's value above 0.871. The Cronbach Alpha reliability test showed that the instrument was reliable with a Cronbach's Alpha value of 0.812. The results of the reliability test using Cronbach's Alpha 0.812 had a high level of reliability, reinforced by the results of previous research that was in line with Ricky Susiono, that the Cronbach's Alpha value of 0.812 was concluded to have a good level of reliability (Tavakol and Dennick, 2011; Solikhin *et al.*, 2023; Susiono *et al.*, 2024)

Table 2. *Summary of Data Analysis of the Evaluation Questionnaire for the Volleyball Development Program (Men) at the PBVSI Regency Executive Board throughout DIY*

Indicator	Coach Data Source					Mean	Category
	Sleman	Yogyakarta	Bantul	Gunung Kidul	Kulon Progo		
CONTEXT							
a. Program Background Coaching	3,2	3,5	3	3	2,7	3,1	Good
b. Program Objectives Coaching	3,1	2,2	2,2	2,2	2,8	2,5	Not enough
c. Coaching Program	3,6	3	2,8	3,1	2,9	3,1	Good
INPUT							
Coaches	3,1	3	2,7	2,7	3	2,9	Not enough
b. Athlete	3,5	2,7	3	3	3,1	3,1	Good
c. Infrastucture	2,7	3	2,5	2,5	2,7	2,6	Very less
d. Funding	2,4	2,9	2,8	2,4	2,7	2,6	Very less
e. Parent Support	3,9	3	3,4	2,8	2,9	3,2	Good
PROCESS							
a. Implementation of the Mentoring Program	3	3,4	2,9	2,6	3	2,9	Not enough
b.Monitoring	3,5	2,8	3,5	3	2,9	3,1	Good
PRODUCT							
a.Achievement	3,2	3,7	3,3	2,7	2,3	3,1	Good

The Context of Component

The context evaluation covers the background, objectives, and development program. The results indicate that the development program at the PBVSI Regency/City levels throughout Yogyakarta has been running sustainably, although there are still shortcomings in its implementation.

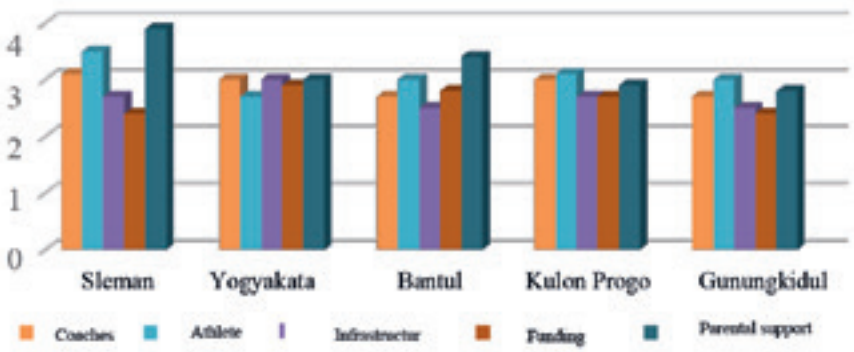


Graph 1. *Results of the Evaluation of the Context of the PBVSI District Executive Board*

Based on the questionnaire assessment results, it was explained that the evaluation of the coaching context in the Yogyakarta Special Region (DIY) PBVSI Regency Management Board has been ongoing in each district, although some shortcomings remain in its implementation. The context evaluation results, according to the average in Yogyakarta, showed a background score of 3.1 (good), a coaching program objective of 2.5 (poor), and a coaching program of 3.1 (good). Strong support from all parties is crucial to achieving optimal and sustainable results.

The Component of Input

The input evaluation included coaches, athletes, facilities and infrastructure, funding, and parental support. Results indicated that most input aspects were satisfactory, but facilities and infrastructure and funding remained inadequate.

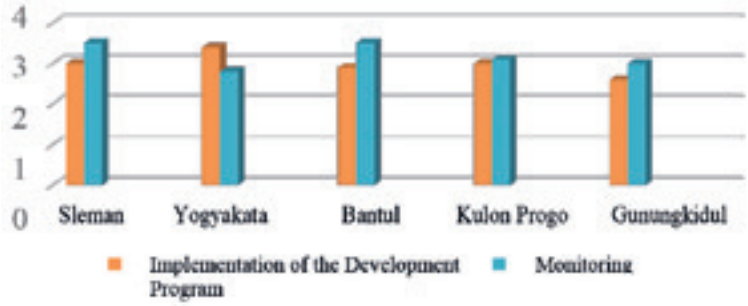


Graph 2. *Results of the Evaluation Results of PBVSI District Management Input Throughout DIY*

According to the input evaluation results chart above, the average achievement of DIY coaches is 2.9 (less), athletes 3.1 (good), infrastructure 2.6 (very less), funding 2.6 (very less), parental support 3.2 (good). The results of the coaching input evaluation at the DIY PBVSI Regency Executive Board have been running continuously in each district, although there are still some shortcomings such as the average in each region of infrastructure and funding which are still very lacking. So it requires direct intervention from the Regency Executive Board according to needs, because the provision of facilities and infrastructure and transparent funding are important elements in achieving achievements.

The Component of Process

Process evaluation includes the implementation of the coaching program and monitoring. Results indicate that the coaching program has been running well, but monitoring needs to be improved.

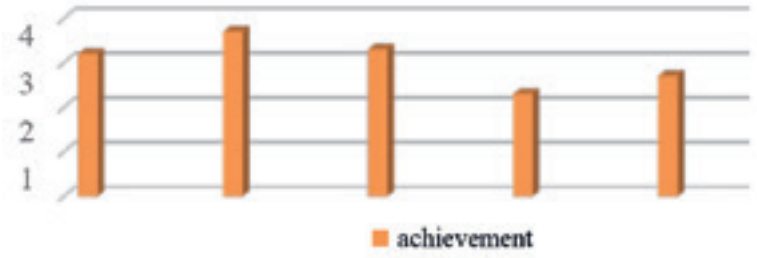


Graph 3. *Results of the Evaluation Process of the PBVSI Regency Executive Board throughout DIY*

According to the process evaluation results chart above, the average achievement of DIY in implementing the coaching program was 2.9 (poor), and monitoring was 3.1 (good). The evaluation results of the coaching process at the DIY PBVSI Regency Executive Board have produced superior seeds that can be managed and developed further. Furthermore, although the number of available athlete incentives is material, it still does not meet training needs. This can be a special concern for the administrators personally who always monitor and monitor ongoing training.

The Product Component

Product evaluation covers achievements at the district, provincial, and national levels. Results indicate that achievements at the district and provincial levels are quite good, but achievements at the national level still need improvement.



Graph 4. *Results of the Product Evaluation of the PBVSI District Executive Board throughout DIY*

According to the product evaluation results chart above, the average achievement of DIY was 3.1 (good). Based on the questionnaire assessment results, it was explained that the evaluation of coaching products at the PBVSI Se-DIY Regency has produced superior seeds that can be managed and developed further. Furthermore, although material incentives for the number of athletes are available, they still do not meet training needs. Therefore, this can be a special concern for administrators personally who always monitor and monitor ongoing training.

Discussion

At the 2024 PON XXI Aceh–North Sumatra, the Regional Management of PBVSI Yogyakarta Special Region has set a target of securing four gold medals in beach volleyball, three additional medals in other volleyball events, and one medal in indoor volleyball, while also expressing the expectation that other participating teams will contribute further to the overall medal achievements(Hutama, 2024). The entire DIY contingent has returned from the Aceh-North Sumatra PON. Previously, DIY had only targeted 16 gold medals to bring home. However, on the fourth day of the Aceh-North Sumatra PON 2024, that target was achieved. This result is certainly very different from the 2021 PON, where DIY only won 8 gold medals, 12 silver medals, and 18 bronze medals. In the 2018 PON held in West Java, DIY also won 16 gold medals, 15 silver medals, and 25 bronze medals. This is far from the results obtained this year. In terms of volleyball, the initial target was to win 1 bronze medal from Sand Volleyball (JogjaProv, 2024). While the overall medal tally for the province surpassed its general target of 16 gold medals matching and even improving upon previous PON performances the specific outcome in volleyball highlights the need for a more systematic evaluation. To address this gap, the CIPP (Context, Input, Process, and Product) evaluation model provides a comprehensive framework for reviewing the planning and implementation of training and competition strategies. Through context evaluation, the relevance of targets and their alignment with regional strengths can be assessed. Input evaluation examines the adequacy of resources, athlete preparation, and coaching methods(Hakan and Seval, 2011; Pakaya, Rahayu and Ks, 2012). Process evaluation focuses on training program implementation, competition strategies, and management support. Finally, product evaluation considers actual results compared to expected goals. By applying the CIPP model, PBVSI Daerah Istimewa Yogyakarta can gain valuable insights into factors contributing to poor performance in volleyball, while also identifying strengths that lead to overall success. This structured evaluation is essential to ensure better program design and sustained performance improvement in future competitions.

The results of the context evaluation show that the volleyball development program at the PBVSI Regency/City level in Yogyakarta has been running sustainably, although certain shortcomings remain in its implementation. The average scores indicate that the background of the program (3.1) and the development program itself (3.1) fall into the "good" category, while the objectives of the coaching program are still considered "poor" (2.5). This implies that the direction and targets of the coaching program are not yet fully clear or measurable, thereby requiring stronger support from various stakeholders to ensure optimal and sustainable results (Stufflebeam, 2003)

The input evaluation, which covered coaches, athletes, facilities and infrastructure, funding, and parental support, revealed that most input aspects were satisfactory, but facilities, infrastructure, and funding remained inadequate. The average scores showed that coaches were rated 2.9 (less), athletes 3.1 (good), infrastructure 2.6 (very poor), funding 2.6 (very poor), and parental support 3.2 (good). These findings indicate that while volleyball development has continued across all districts, the lack of adequate infrastructure and limited funding remain major challenges. Both aspects are crucial elements for achieving athletic performance, thus requiring direct intervention and resource allocation from the management board(Baker *et al.*, 2003; Gao *et al.*, 2023)

The process evaluation included the implementation of the coaching program and monitoring. The results showed

that the implementation of the program averaged 2.9 (poor), while monitoring was rated 3.1 (good). This suggests that although the coaching program has successfully produced potential young athletes, the execution of training and the provision of athlete incentives have not yet fully met the needs of the athletes. Improved program management and more systematic monitoring are necessary to sustain the progress of athlete development (Melvin M. Mark, Gary T. Henry, 2000)

The product evaluation indicated that volleyball achievements in Yogyakarta are generally good at the district and provincial levels, with an average score of 3.1, but national-level achievements still require improvement. The evaluation results showed that the program has succeeded in producing talented athletes who can be further developed. However, the limited provision of incentives and inadequate facilities remain barriers to achieving higher levels of success.

Overall, the CIPP evaluation highlights that volleyball development in Yogyakarta has been implemented sustainably and has produced promising young athletes. Nevertheless, critical weaknesses remain in terms of program objectives, facilities and infrastructure, funding, and program implementation. Therefore, improvements in program planning, increased investment in facilities, transparent funding mechanisms, and strengthened monitoring are urgently needed to ensure that volleyball development in Yogyakarta becomes more targeted, effective, and capable of contributing to national-level achievements.

Oakley and Green, as cited in De Bosscher *et al.*, (2006), emphasize that there are ten key factors that appear to be relatively consistent across different countries in supporting elite athletic achievement. First, there must be a clear understanding of the roles of the various institutions involved, accompanied by effective communication networks to sustain the system. Second, administrative simplicity is required, supported by the alignment of sport and political boundaries. Third, an effective system for identifying and monitoring the progress of both talented and elite athletes is essential. Fourth, the provision of sports services is necessary to create a culture of excellence in which athletes, coaches, managers, and sport scientists can interact both formally and informally.

Fifth, a well-structured competition program with continuous international exposure is critical. Sixth, the development of modern, sport-specific facilities with priority access for elite athletes is required. Seventh, resources should be targeted toward a limited number of sports disciplines that demonstrate realistic potential for success at the global level. Eighth, comprehensive planning is needed to address the specific requirements of each sport. Ninth, there must be recognition that the pursuit of excellence is costly, requiring adequate funding for both infrastructure and human resources. Finally, the tenth factor highlights the importance of lifestyle support and preparation for life after an athletic career. These ten factors indicate that sporting excellence is not solely the product of individual talent but rather the outcome of a comprehensive, well-planned, and systematically supported development process. Thus, effective sports policy development requires synergy between institutional, financial, and cultural factors to create an environment that is conducive to sustainable, long-term achievement.

Additional thoughts related to the conceptual framework for analyzing sports policy factors that lead to sports success according to De Bosscher *et al.*, (2006), which can be used as a reference for the concept of developing volleyball sports in DIY to achieve greater success, are presented in the following figure.

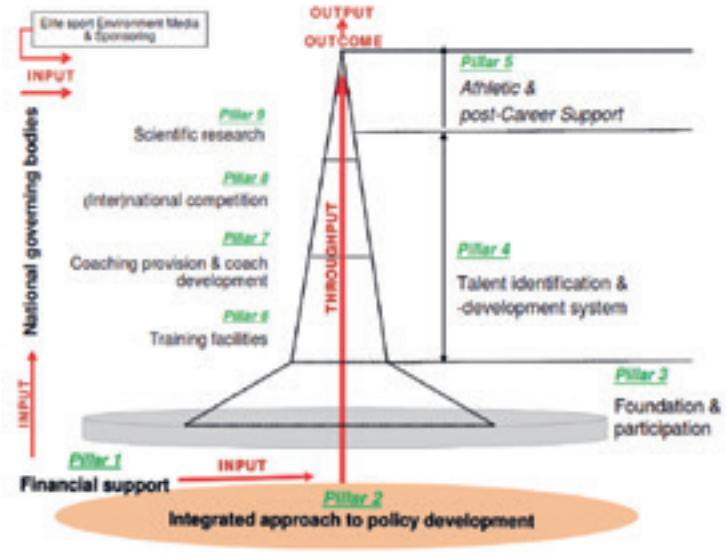


Figure 3. *The nine pillars of sports policy factors influencing international success De Bosscher et al., (2006) Licensed under CC BY-NC 4.0*

The figure illustrates the SPLISS framework (Sports Policy factors Leading to International Sporting Success), which conceptualizes how national sports policies can contribute to international success. The model identifies nine policy pillars that interact through a process-oriented structure, moving from inputs, through throughputs, towards outputs and outcomes.

1. Input
Pillar 1: Financial Support
Financial investment is the foundation of any elite sports system. However, the model emphasizes that the size of the budget alone does not guarantee success; rather, the way financial resources are allocated and utilized is of greater significance.
2. Throughput (Policy Processes)
The throughput stage reflects the meso-level factors that can be shaped by national policies and sports governing bodies. These are operationalized into seven pillars:
Pillar 2: Organisation and Structure of Sport Policies – Clear governance structures and integrated policy frameworks.
Pillar 3: Foundation and Participation (Initiation) – Broad participation at grassroots level, including school physical education and non-organized sports, which serve as the basis for talent pools.
Pillar 4: Talent Identification and Development – Systematic mechanisms to detect and nurture young talent.
Pillar 5: Athletic and Post-Athletic Career Support – Support systems for athletes during their competitive careers (scholarships, psychological services, nutritional guidance) as well as after retirement (education, job opportunities).
Pillar 6: Training Facilities – Access to high-quality, modern, and specialized training infrastructure.
Pillar 7: Coaching Provision and Coach Development – Recruitment, education, and continuous professional development of qualified coaches.
Pillar 8: (Inter)national Competition – Strong domestic competitions and opportunities for athletes to gain international experience.
Pillar 9: Scientific Research and Innovation – Incorporation of sport science, research, and technological innovations to optimize athlete performance.
3. Output and Outcome
Output: Improved Climate
Effective implementation of the nine pillars fosters an improved climate for elite sports.
Outcome: International Sporting Success
Ultimately, the framework aims at producing athletes capable of winning medals and achieving success on the global stage.

Conclution

The evaluation of volleyball development in Yogyakarta through the CIPP model demonstrates that, while the program has been implemented sustainably and has produced promising young athletes, critical weaknesses persist in areas such as program objectives, facilities, funding, and implementation. The context evaluation revealed that coaching objectives remained unclear and insufficiently measurable, highlighting the need for stronger strategic direction. Input evaluation identified significant deficiencies in infrastructure and funding, which continue to hinder athlete performance despite satisfactory coaching and athlete quality. Process evaluation showed that program execution and incentives remained suboptimal, while monitoring has been relatively stronger. Product evaluation confirmed achievements at the regional level but underscored the challenge of achieving success nationally.

To overcome these barriers, improvements in strategic planning, increased financial investment, infrastructure development, transparent funding mechanisms, and stronger monitoring systems are essential. The SPLISS framework further emphasizes that elite sports success requires not only athlete talent but also systematic policy support across financial, organizational, developmental, and scientific domains. Therefore, for Yogyakarta volleyball to reach higher levels of achievement, particularly at the national and international stages, a comprehensive, well-coordinated, and thoroughly resourced development approach is indispensable.

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Exploring Learning Barriers and Student Participation in University Basketball Classes: A Preliminary Study

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Abstract: *This study aims to explore learning barriers and student participation in basketball practice courses within the Sports Science Study Program at Universitas PGRI Yogyakarta (UPY). A qualitative phenomenological approach was employed, utilizing observation and in-depth interviews with one lecturer and six students who had completed the basketball course in the 2024 academic year. The research was conducted in January 2025 and analyzed using a thematic analysis method. The findings reveal that the course was implemented in accordance with the Semester Learning Plan through a cooperative learning model. However, several barriers were identified, including lack of student focus, delayed task submissions, unexplained absences, and low learning motivation among students with limited interest in basketball. Differences in prior playing experience also influenced students' participation levels. The lecturer actively provided feedback and implemented game-based learning, yet further innovation toward more adaptive and engaging learning models is needed to enhance student motivation and learning outcomes.*

Keywords: *Sports Learning, Basketball, Learning Barriers, Student Participation, Qualitative Study*

Introduction

Sports education in higher education institutions plays a crucial role in developing students' overall competencies not only in the physical domain but also in cognitive, affective, and social aspects. Engagement in sports activities enables students to enhance coordination, self-confidence, teamwork, and strategic thinking in competitive situations. Practical sports courses in universities, particularly basketball, play a significant role in fostering students' technical skills, tactical understanding, and sportsmanship. However, in practice, student participation in such courses is not always optimal. Some students face challenges in mastering basic techniques, maintaining consistent attendance, or actively participating in class activities. A study by Wang et al. (2024) investigating students' motivation in basketball courses found that the integration of a tactical games–based learning model can improve students' motivation and participation.

Various inhibiting factors influence participation and the effectiveness of sports learning, particularly at the higher education level. Previous research (Alsubaie, 2021) suggested that students' participation in sports activities is influenced by motivation, available facilities, and the teaching methods employed. A systematic review by Ferreira Silva et al. (2022) found that university students often face barriers such as lack of time, low motivation, and limited access to appropriate facilities—factors that significantly reduce their physical activity levels. Similarly, a study conducted in Qatar by Chaabna et al. (2022) reinforced these findings, highlighting that external barriers such as inadequate facilities and internal barriers such as low motivation contribute to low levels of student participation in physical activities. In addition, recent studies on physical activity barriers among university students have identified academic workload, busy schedules, and inflexible class or training timetables as exacerbating factors (Brown et al., 2024).

Social and cultural aspects (e.g., gender perceptions, feelings of embarrassment, or social norms) can also pose challenges, particularly for specific student groups, indicating that proposed solutions should be sensitive to local contexts and learner characteristics. Qualitative studies in various university settings across different countries have emphasized the importance of environmental and cultural aspects as both barriers and facilitators of participation (Burton et al., 2021). Psychological factors such as low self-efficacy and limited pre-college sports experience are also critical determinants influencing student participation in basketball learning. Students who perceive themselves as technically incompetent or lacking prior experience in sports often tend to withdraw from activities due to fear of making mistakes or performing poorly in front of their peers.

The study by Ouyang et al. (2019) revealed that self-efficacy is closely correlated with students' participation in sports; individuals with low confidence tend to reduce their engagement in physical activities. Environmental factors also play a significant role. Su and Liu (2025) emphasized that support from physical education lecturers can enhance students' motivation to learn sports, which in turn strengthens their self-efficacy. Students who feel supported are more confident in attempting new skills, even when there is a risk of making mistakes.

In the context of sports activities in general, student participation is not merely about attendance but also involves how actively they engage in performing fundamental techniques, teamwork, mental involvement (strategy), and emotional engagement (motivation and appreciation for sports). Low levels of active participation can negatively affect learning outcomes in practical courses. Nevertheless, there has been limited research specifically exploring learning barriers and student participation in university-level basketball classes in Indonesia, particularly from a qualitative perspective. This preliminary study aims to explore the perceptions of lecturers and students regarding the barriers they experience in basketball learning and participation. The findings are expected to serve as a basis for designing more effective, engaging, active, and creative learning models.

Method

This study employed a qualitative phenomenological approach aimed at gaining an indepth understanding of the experiences of students and lecturers in conducting basketball courses within a higher education setting. This approach was chosen because it allows the researcher to explore the meanings and subjective experiences of participants related to the learning process, encountered challenges, and the dynamics of interaction occurring throughout the course. The research was conducted in the Sports Science Study Program at Universitas PGRI Yogyakarta (UPY).

The research subjects consisted of one lecturer who taught the basketball course and six students from the Sports Science Study Program at Universitas PGRI Yogyakarta (UPY) who had completed the course during the 2024 academic year. According to Guest et al. (2006), data saturation is typically achieved after six to twelve interviews; therefore, the number of participants in this study was considered sufficient to obtain rich and diverse qualitative data. The student sample comprised three male and three female students. Participants were selected using a purposive sampling technique, considering gender representation, level of participation in the course, and prior experience with basketball. Some participants had experience playing basketball since high school, while others had no prior experience and were introduced to the sport through this course. This variation in experience was intentionally included to provide a more comprehensive understanding of learning barriers and student participation in university-level basketball instruction.

Data were collected using three main techniques: participatory observation, semistructured in-depth interviews, and documentation. Observations were conducted directly during both theoretical and practical sessions to record patterns of interaction, participation, and learning dynamics. Interviews were carried out with the lecturer and students to explore their perceptions, learning experiences, and the challenges they encountered during the course.

Documentation was obtained from the Semester Learning Plan (RPS), lecturer's teaching notes, and students' reflective journals during the course.

Data were analyzed using thematic analysis as outlined by Braun and Clarke (2006). The analysis procedure included: (1) transcribing the results of interviews and observations,

(2) assigning codes to relevant meaning units, (3) grouping the codes into main themes, and

(4) interpreting the thematic meanings based on the research context and supporting theories. This process aimed to identify patterns of experience and meanings embedded in the practice of basketball learning at the higher education level.

To ensure data trustworthiness, this study employed source triangulation by comparing information obtained from both lecturers and students, conducting member checking by confirming the interpretation results with participants, and engaging in peer debriefing with fellow researchers to review the consistency and objectivity of interpretations. Through these procedures, the study is expected to provide a comprehensive and valid depiction of learning barriers and student participation in university-level basketball classes.

Results

1. Learning Process of the Basketball Course

Based on the observation results, the basketball course in the Sports Science Study Program at Universitas

PGRI Yogyakarta (UPY) was conducted face-to-face through a combination of theoretical and practical sessions. The course implementation followed the Semester Learning Plan (RPS), which emphasized mastery of basic techniques and understanding of basketball game rules. The learning model commonly applied was the cooperative model, utilizing lectures, demonstrations, and assignments. The lecturer explained concepts gradually, demonstrated the movements, and then guided students to practice according to the given instructions. When errors or limitations were identified among students, the lecturer immediately provided direct feedback, either individually or in groups.

This approach aligns with the principles of *active learning* (Bonwell & Eison, 1991), in which the lecturer acts as a facilitator who fosters students' active engagement in the learning process. Furthermore, the continuous provision of feedback reflects the practice of *formative assessment* (Black & Wiliam, 1998), which helps students understand their progress and identify areas for improvement. The course was conducted at the Mandala Krida Basketball Court, which was equipped with supporting facilities such as basketballs, cones, whistles, and strategy boards. Despite the availability of adequate facilities, several challenges were still identified during the learning process.

2. Lecturer's Perspective on Learning Effectiveness and Challenges

Interviews with the course lecturer revealed that the implementation of the basketball course had been carried out in accordance with the existing curriculum and the Semester Learning Plan (RPS). Assessment was conducted individually and continuously, taking into account each student's progress from the beginning to the end of the course. Thus, the evaluation process emphasized not only the final outcomes (outputs) but also the learning process and individual development.

However, several challenges were frequently encountered, including students' lack of focus during explanations, delays in submitting assignments, unexcused absences, and the presence of passive students during practical sessions. The lecturer also emphasized that student attendance had a significant impact on the effectiveness of the learning process. Students who were frequently absent tended to experience difficulties in following subsequent materials, thereby hindering the achievement of learning outcomes.

This condition highlights the importance of students' internal motivation in participating in coursework (Deci & Ryan, 2000). Students with low motivation tend to be less active and easily lose concentration during learning activities. These findings are consistent with the study by Sari and Nugroho (2021), which reported that learning motivation and attendance significantly contribute to students' learning outcomes in practical sports courses. The lecturer further emphasized that although the cooperative learning model was relatively effective, there is a need for more contextual and innovative instructional approaches to enhance motivation, engagement, and minimize challenges encountered during practical sessions.

3. Students' Perspectives on Learning Experiences

Interviews with students indicated that the basketball course was conducted in accordance with the course contract. Students perceived the learning process as systematic and aligned with the objectives outlined in the Semester Learning Plan (RPS). Most students felt that the cooperative learning model facilitated their understanding of basketball techniques and game strategies. However, several students were found to be less engaged in the course, particularly those without prior background or specific interest in basketball. These students reported difficulties in mastering basic techniques and understanding game strategies.

Interestingly, most students stated that game-based learning was the most enjoyable part of the course. The game-based approach was perceived as capable of enhancing enthusiasm, challenge, and learning motivation. This finding aligns with Metzler (2011), who explained that a game-centered approach can improve students' tactical awareness and emotional engagement in sports learning. Similarly, Wang et al. (2024), in their study on student motivation in basketball courses, found that the integration of tactical games–based learning models can enhance students' motivation and participation.

However, group activities were sometimes disrupted by the absence of team members, leading to an imbalance of tasks and delays in completing learning activities. This reinforces the findings of Rink (2010), who noted that the effectiveness of team-based learning in physical education is strongly influenced by the consistency of attendance and the active engagement of each group member.

The findings of this study indicate that the cooperative learning model currently implemented has functioned effectively in achieving the fundamental learning objectives. Nevertheless, further pedagogical innovation is required to make basketball learning at the university level more contextual—focusing not only on technical mastery but also on enhancing motivation, active participation, and meaningful learning experiences.

Discussion

The results of this study indicate that basketball learning at Universitas PGRI Yogyakarta (UPY) has been implemented systematically and oriented toward developing students' practical skills. The use of the cooperative learning model proved effective in enhancing student interaction and strengthening active engagement throughout the learning process. These findings support the theory of *active learning* proposed by Bonwell and Eison (1991), which emphasizes that students' direct involvement in learning activities can improve knowledge retention and skill acquisition.

The provision of direct feedback by the lecturer also reflects the effective application of *formative assessment* principles to optimize the learning process. Black and Wiliam (1998) emphasize that formative evaluation helps students understand their learning progress and provides direction for improvement in subsequent sessions. Effective learning in higher education involves careful planning, implementation, and evaluation, with an emphasis on student participation, appropriate teaching methods, and a conducive learning environment (Faizah & Kamal, 2024).

Nevertheless, the findings of this study also identified several obstacles in the learning process, particularly those related to student motivation and attendance. Students with low interest in basketball tended to be passive, unfocused, and less enthusiastic in participating in practical sessions. This aligns with the Self-Determination Theory proposed by Deci and Ryan (2000), which states that students' intrinsic motivation increases when their needs for competence, autonomy, and social relatedness are fulfilled. When the learning environment fails to support these needs, learning participation tends to decline.

Furthermore, the finding on the importance of student attendance supports the study by Sari and Nugroho (2021), which demonstrated that attendance and active engagement have a significant influence on learning outcomes in sports practice courses. Active learning can enhance students' engagement in attitudinal and skill-based aspects such as questioning, expressing opinions, and experimenting (Halifah et al., 2019). In this context, students who are frequently absent lose opportunities to receive feedback, rehearse skills, and collaborate with peers.

From the students' perspective, the most engaging instructional approach was *gamebased learning*. Light (2008) found that game-based learning models not only emphasize technical skill acquisition but also promote the cognitive, emotional, and social development of learners. This approach enhances students' enjoyment, motivation, and self-confidence in participation (Metzler, 2011).

Furthermore, both lecturers and students agreed that innovative teaching models need to be developed at the higher education level. The integration of *student-centered learning* (Biggs & Tang, 2011) and *experiential learning* (Kolb, 1984) represents a relevant alternative for sports education. Through these approaches, students learn from direct experience, engage in self-reflection, and connect theoretical concepts with practical applications. Murni (2021) emphasized that lecturers are not only required to prepare accurate teaching materials but also to optimally facilitate the implementation of the learning process. Similarly, Asyafah (2019) argued for the importance of developing effective learning models, noting that well-designed instructional models significantly support the achievement of learning objectives and provide meaningful learning experiences for students.

Thus, the findings of this study confirm that although the cooperative learning model currently applied has effectively supported the achievement of fundamental learning outcomes, there remains a need for adaptive, reflective, and contextual innovations in teaching practices.

Such innovations are essential to enhance students' motivation, participation, and overall learning achievement. García-Carrión (2022) emphasized that the diversity of learners is accompanied by equally diverse needs, thereby necessitating the development of learning models that are more inclusive and capable of accommodating different learning styles and needs. Similarly, Fung (2023) argued that instructional models should be continuously developed to promote active student engagement and motivation in the learning process, as these factors play a crucial role in determining learning outcomes.

Conclusion

Overall, the findings of this phenomenological study indicate that the implementation of basketball courses at Universitas PGRI Yogyakarta has been conducted in accordance with the established curriculum and intended learning outcomes. The cooperative learning model applied has effectively facilitated student engagement and the mastery of fundamental skills, although several challenges remain—particularly those related to motivation, attendance,

and uneven participation. Instructors play a crucial role in providing formative feedback and fostering a supportive learning environment, while students require more interactive and contextualized learning approaches. Therefore, the development of basketball learning models in higher education should focus on adaptive, experience-based, and enjoyable innovations that enhance students' cognitive, psychomotor, and affective learning outcomes in a balanced manner.

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Improving Gross Motor Skills in Early Childhood: Through Aquatic Games and Coconut Shell Stilt Walking in Terms of Balance

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Abstract: *This research is based on the low level of aggressive motor skills in early childhood. This research aims to analyze: (1) the comparative effects of aquatic games and coconut shell stilts on the improvement of aggressive motor skills in early childhood. (2) The comparative effects of children with high and low balance on the improvement of aggressive motor skills in early childhood. (3) The interaction between aquatic games and coconut shell stilts in terms of balance on the increase in aggressive motor skills in early childhood. The research method used was an experiment with a 2 x 2 factorial design. The results showed that: (1) There was a significant difference in the effect of aquatic games and coconut shell stilts on the increase in aggressive motor skills, with a significance value of p < 0.05. The aquatic play model group performed better than the coconut shell stilts play model group in improving aggressive motor skills, with a posttest average difference of 1.2. (2) There is a difference in the effect between children with high and low balance on the improvement of aggressive motor skills in early childhood, with a significance value of p < 0.05. Children with large balance abilities were better than children with low balance abilities, with a posttest mean difference in aggressive motor skills of 1.8. (3) There is an interaction between aquatic game models and coconut shell stilts in terms of balance (high and low) on the increase in aggressive motor skills in children aged dni, with a significance value of p 0.000 < 0.05. Finally, it shows that the aquatic game model is a more efficient game model for children with high balance, and the coconut shell game model is more efficient for children with low balance.*

Keywords: *games; aquatic; coconut shell; balance; gross motor skills*

Introduction

Learning plays a significant role in children's lives because the development of character, mental behavior, and intellectual skills is built in early childhood. The quality of early childhood, including preschool, is a reflection of the quality of the nation to come. Early childhood education is intended as a foundation for children's future learning (Williams et al., 2019). Early childhood education is also a focus in Indonesia because early childhood is a period when children absorb a lot of information easily, so the stimuli provided must be appropriate and easily accepted by children. Through early childhood education, games need to be provided to stimulate children's development and motor skills.

Early childhood is a period of physical and motor development in children (Nieminen & Sajaniemi, 2016; Wijaya et al., 2024). Physical development is closely related to motor development in children, as physical development affects their daily movements. Motor development is coordinated through the nervous system, nerves, and muscles to develop physical movement abilities (Honrubia-Montesinos et al., 2021). Children's motor development is divided into two categories: gross motor skills and fine motor skills. Gross motor skills are a child's ability to perform movements that involve large muscles, such as the torso, arms, and legs (Ghassabian et al., 2016; Webster & Ulrich, 2017). In contrast, gross motor skills are a child's ability to perform movements that involve large muscles with hand-eye coordination (Cohen et al., 2018; Lelong et al., 2021). Of these two types of motor skills, gross motor development is very important for early childhood (Veldman et al., 2016). Gross motor development refers to the progression of movements that involve balance and coordination between body parts, such as crawling, walking, and running. Therefore, balance is very important for early childhood to maintain overall motor skills (Jain et al., 2022).

Balance is very important for young children in various activities they try, so that with good balance, all physical activities they do will also be good. In line with the above opinion, balance has various very important aspects, so that

the aspect of balance here will play a very large role in children in carrying out various physical activities, both daily activities and branch activities according to their interests (Dobell et al., 2020; Edwards et al., 2017).

Therefore, it is very important to consider that a child's early development is primarily based on fundamental skills and abilities. The components of balance control include the sensory information system, synergistic postural muscle responses, muscle strength, adaptive systems, and joint range of motion (Hirata et al., 2018). The sensory information system is related to the visual, vestibular, and somatosensory senses. Visual input can influence human adaptation to changes in the immediate environment. Information received through the visual senses is processed in the brain, after which the musculoskeletal system works synergistically to maintain body balance (Faber et al., 2022). Having good gross motor skills at an early age is crucial for supporting children's movements in performing coordinated, controlled, and orderly reactions. Gross motor skills in children need to be trained and developed because, at an early age, these skills form the foundation for the development of other skills, such as sensory skills and cognitive skills.

However, based on preliminary observations conducted by researchers in March 2025 at the Dharma Yoga Santi landfill site from two kindergarten classes, it was found that children's aggressive motor skills were still low. This is evidenced by the average scores obtained from 15 children, who scored 1 for motor skills, meaning they have not yet developed, and 10 children who scored an average of 2 for motor skills, meaning they are beginning to develop. In contrast, the standard score at this school is 3. When viewed in terms of the normative information on early childhood motor skills, this certainly falls into the category of deficient.

This is because the educational methods used to train children's aggressive motor skills are still inefficient. The learning methods used to train aggressive motor skills are: morning exercises once a week, ball catching, and throwing exercises. Cases observed during the learning process are: (1) during free drawing activities, children have difficulty holding writing instruments, (2) children have difficulty drawing and coloring, (3) children have difficulty using writing instruments and eating utensils correctly, (4) the child still has difficulty cutting according to patterns, (5) the child still needs guidance from the teacher when writing, drawing pictures, and tracing shapes, (6) the child still has difficulty catching and throwing balls.

If this situation continues to be allowed to affect the development of children's aggressive motor skills, learning in this area must be more careful in observing the increase in the aggressive motor skills of students and strive to find the right solution to the problems experienced. If teachers want children's aggressive motor skills to develop in line with their age and abilities, they must design appropriate and enjoyable learning activities and use media that are suitable for the development of children's skills so that educational goals can be achieved effectively.

One educational model that is considered capable of improving aggressive motor skills and balance in early childhood is game-based education. In physical education, games can be used to enhance educational goals (Gümüşdağ, 2019). Play activities that can improve aggressive motor skills must include activities such as running, walking, and jumping, which require large muscles (Roach & Keats, 2018). Games are one of the means of improving aggressive motor skills and balance in early childhood.

One game to maximize aggressive motor skills and balance in early childhood is aquatic play. The aquatic module contains activities that are tried in the swimming pool, such as water games, swimming styles, water safety, and the development of relevant knowledge aspects and values contained therein (Juan et al., 2022). Not only that, but providing education with innovative, interesting, and exciting methods also influences students' descriptions of the education module (Aljawarneh, 2020).

Stimulating development and growth in children aged 5-6 years is attempted through games that provide opportunities for children to move freely. The concept of movement-based educational development in water games is to use water as one of the tools in the game process (Arhesa & Badriah, 2021). Water is used as an effective medium to stimulate children's growth, including building self-confidence, motor skills, hand-eye coordination, and improving physical fitness.

The aquatic game model to improve the aggressive motor skills of early childhood is expected to be a teaching material for teachers in the education process. The aquatic game model for physical education has been adapted to the growth stages of children. This model was created to train the aggressive motor skills of early childhood. Another game activity that is considered capable of improving motor skills and balance is the coconut shell stilts game. The coconut shell stilts game model is a game that uses a coconut shell that has been split into two parts. A hole is made

in the middle of the top part of the coconut shell to attach a rope, and the bottom part is reinforced with a board or plywood to prevent damage (Maryanti et al., 2021). Next, the child stands on the coconut shell while holding the rope, then walks forward by lifting the rope along with lifting their feet. While walking, the feet must not touch the ground. This egrang game can train balance and concentration.

Based on the explanation of the above issues, the researchers aimed to analyze the comparative effects of aquatic games and coconut shell stilts on the improvement of aggressive motor skills in early childhood from a balancing perspective. Thus, researchers can share the best solutions to improve the aggressive motor skills of early childhood, and this information can be used as further education for playgroup schools.

Materials and Methods

Research Design

This research is an experiment with a 2 x 2 factorial design. This experimental research uses two different treatment groups, namely aquatic games and coconut shell stilts, to test their effects on the aggressive motor skills of early childhood.

Research Procedure

The procedure for collecting information in this research was testing and measurement. Before the pretest and posttest measurements were taken, balance was measured first to identify high and low balance. To measure balance in this research, the Stork Stand Test was used with a measurement unit of seconds. The tests in this research used aggressive motor skills testing instruments. Aggressive motor skills tests included: (1) walking on a straight line for 5 meters, (2) running away from 5 obstacles for 15 meters, (3) standing on one foot for 10 seconds, (4) a test of jumping from a 15-centimeter-high block, (5) a test of jumping from a 15-centimeter-high block. The research process was conducted over 16 sessions, with 3 sessions per week. It ended with a final test and post-test to measure aggressive motor skills in early childhood to identify comparisons in children's aggressive motor skill scores after treatment.

Research Participants

The population in this study consisted of all 38 children enrolled in the Dharma Yoga Santi preschool program. This study applied inclusion criteria to ensure the validity of the research, based on certain criteria desired by the researcher, including: specifically young children, children who are actively exploring school, children who are not sick, willing to explore the educational process, able to explore all educational programs that have been prepared, and children aged 5-6 years. Conversely, the exclusion criteria in this research were things that caused the sample to not meet the criteria to be used as a sample, such as sick children. The sample grouping was taken from children who had high independence (27%) and children who had low independence (27%) from the information that had been ranked. Based on this, 10 children with high independence and 10 children with low independence were selected as examples, for a total of 20 children. This study has obtained approval from all participants who have filled out a statement of willingness to be research examples and have met the research code of ethics requirements.

Data Analysis

The method of information analysis used in this study, using SPSS type 25, is by using two-way ANOVA at a significance level of 0.05. Furthermore, to compare the treatment mean pairs, the Tukey test was used (Santoso, 2018). Before using two-way ANOVA, prerequisite tests must be carried out, including: (1) a normality test and (2) a homogeneity of variance test, and hypothesis testing.

Results

The research results and discussion chapter will be presented sequentially, including: (1) research results data, (2) prerequisite analysis tests, and (3) hypothesis tests. The hypothesis tests in this study will be presented sequentially, including: (a) the difference in the effect of aquatic games and coconut shell stilts on improving gross motor skills in children; (b) differences in the effects of high and low balance on improving children's gross motor skills; and (c) interactions between aquatic play and coconut shell stilts models and balance on improving children's gross motor skills. The complete presentation is as follows:

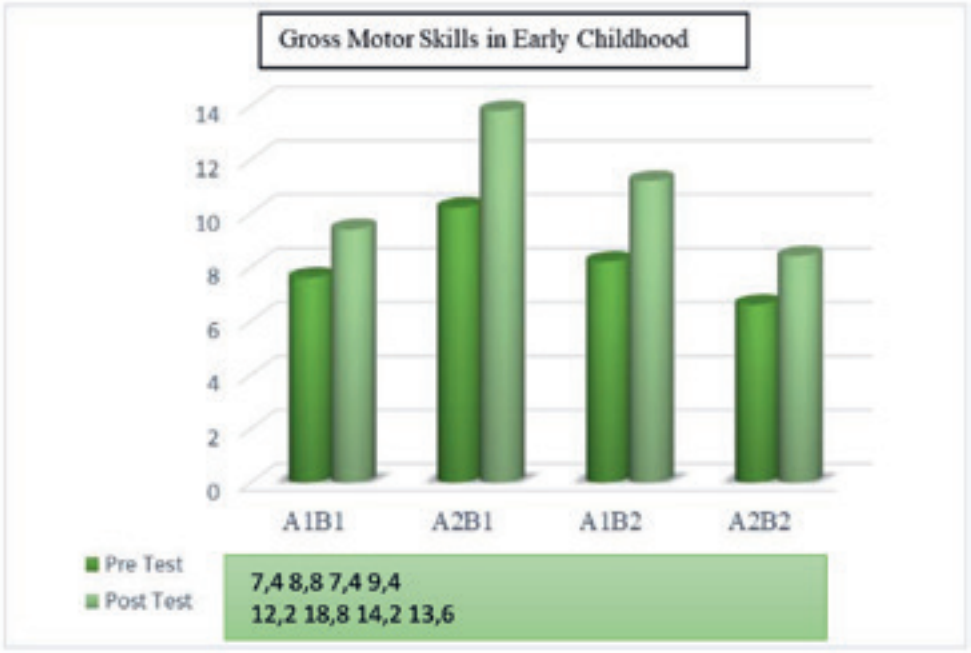

Figure 1. *Bar chart of children's gross motor skills pretest and posttest*

Description:
A1B1: A group of young children who were given aquatic games with a high level of balance.
A2B1: A group of early childhood children who were given a high-balance egrang batok game model.
A1B2: A group of early childhood children was given a low-balance aquatic game model.
A2B2: A group of early childhood children who were given a low-balance egrang batok game model.

Based on graph 1 above shows that the average pretest score for motor skills in the A1B1 group of early childhood children was 7.6, with an increase in the posttest score to 9.4. The average pretest score for the A2B1 group was 10.2, with an increase in the posttest score to 13.8. Group A1B2 had an average pretest score of 8.2 and an increase in the posttest score of 11.2. Group A2B2 had an average pretest score of 6.6 and an increase in the posttest score of 8.4.

1. Prerequisite Test Results

a. Normality Test

The Shapiro-Wilk method was used to test the normality of the data in this study. The normality test results for each analysis group were performed using SPSS version 24.0 for Windows software with a significance level of 5% or 0.05. The summary is presented in Table 1 as follows.

Table 1. *Summary of gross motor normality test results*

Group	*p*	Significant	Description
Pretest A1BI	0.814	0,05	Normal
Posttest A1B1	0.814		Normal
Pretest A2B1	0.421		Normal
Posttest A2B1	0.421		Normal
Pretest A1B2	0.421		Normal
Posttest A1B2	0.421		Normal
PretestA2B2	0.814		Normal
Posttest A2B2	0.201		Normal

Based on the statistical analysis of normality tests conducted using the Shapiro-Wilk test, all pretest and posttest data on gross motor skills in early childhood obtained from the normality test results had a significance value of $p > 0.05$, which means that the data were.

b. Homogeneity Test

The homogeneity test was conducted to test the similarity of several samples, namely, whether they were homogeneous or not. The homogeneity test was intended to test the similarity of the variance between the pretest and posttest. The homogeneity test in this study was the Levene Test. The results of the homogeneity test are presented in Table 2 as follows.

Table 2. *Summary of homogeneity test results*

Variable	F	df1	df2	*Sig.*
Motor skills	0.161	3	16	0.921

Based on the statistical analysis of homogeneity tests conducted using the Levene Test, the calculation results obtained a motor significance value of 0.921 ≥ 0.05, which means that the data groups have homogeneous variance. Thus, the population has similar variance or is homogeneous.

3. Hypothesis Test Results

The research hypothesis testing was conducted based on the results of data analysis and interpretation of the two-way ANOVA analysis. The sequence of hypothesis testing results was adjusted to the problem formulation, as follows.

a. Hypothesis: Differences in the Effects of Aquatic Games and Egrang Batok on the Improvement of Gross Motor Skills in Early Childhood

The first hypothesis states, "There is a difference in the effect between the aquatic game model and the coconut shell stilts on the improvement of gross motor skills in early childhood." Based on the analysis results, the data in Table 3 is as follows.

Table 3. *ANOVA test results for the difference between the aquatic game model and coconut shell stilts on the improvement of gross motor skills in children*

Source	Variabel	Type III Sum of squares	Df	Mean Square	F	Sig.
Game Model	gross motor skills	3.200	1	3.200	1.969	0.002

From the results of the ANOVA test in Table 3 above, it can be seen that the significance value for gross motor skills is p = 0.002, and the F value is 1.969. Because the significance value p = 0.002 < 0.05, H0 is rejected. Thus, there is a significant difference in effect. Based on the analysis results, it appears that the aquatic game model group had a gross motor variable of 10.3, which was better than the egrang batok game model group, which had a gross motor variable of 11.1, with a posttest average difference of 1.2. This means that the research hypothesis stating that "There is a significant difference in the effect between the aquatic game model and the coconut shell stilts model on the improvement of gross motor skills in early childhood" has been proven.

b. Hypothesis of the difference in effect between the high and low balance groups on the improvement of gross motor skills in early childhood

The second hypothesis states that "There is a difference in the effect between the high and low balance groups on the improvement of gross motor skills in early childhood." The calculation results are presented in Table 4 as follows.

Table 4. *Results of the ANOVA test of the high and low balance groups on the improvement of gross motor skills in early childhood*

Source	Variable	Type III Sum of squares	Df	Mean Square	*F*	*Sig.*
Balance	Gross motor skills	16.200	1	16.200	9.969	0.004

From the results of the ANOVA test in Table 4 above, it can be seen that the motor significance value p is 0.004 and the F value is 9.969. Because the significance value p is 0.004 < 0.05, H0 is rejected. Thus, there is a significant difference in influence. Based on the analysis results, it appears that the group of children with high balance in the

gross motor variable of 11.6 is higher than the group of children with low balance in the gross motor variable of 9.8, with a posttest average difference of 1.8. This means that the research hypothesis stating that "There is a significant difference in influence between the high and low balance groups on the improvement of gross motor skills in early childhood" has been proven.

c. The interaction between the aquatic and egrang batok game models and balance (high and low) on the improvement of motor skills in early childhood

The third hypothesis states that "There is a significant interaction between the game model (Aquatic and Egrang Batok) and balance (high and low) on the improvement of gross motor skills in early childhood." The calculation results are presented in Table 5 as follows.

Table 5. *Results of the ANOVA test of the interaction between the game model (Aquatic and Egrang Batok) and balance (high and low) on the improvement of gross motor skills in early childhood*

Source	Variable	Type III Sum of squares	Df	Mean Square	*F*	*Sig.*
Game Model	Gross motor skills	64.800	1	64.800	39.877	0.000

From the ANOVA test results in Table 5 above, it can be seen that gross motor skills obtained a significance value of p = 0.000 and an F value of 39.877. Because the significance value of p = 0.000 < 0.05, Ho is rejected. Based on this, the hypothesis stating that "There is an interaction between the game model (Aquatic and Egrang Batok) and balance (high and low) on the improvement of gross motor skills in early childhood" has been proven.

After testing the interaction between the game model (Aquatic and Egrang Batok) and balance (high and low) on the improvement of gross motor skills in early childhood, it is necessary to conduct a further test using the Tukey test. The results of the further test can be seen in Table 6 below:

Table 6. *Summary of post hoc tests for gross motor skills*

Group	Interaction	Mean Difference	Std. Error	Sig.
A1B1	A1B2	-3.5000*	0.82023	0.002
	A2B1	-1.2000	0.82023	0.48
	A2B2	1.0000	0.82023	0.616
A1B2	A1B1	3.5000*	0.82023	0.002
	A2B1	2.3000*	0.82023	0.036
	A2B2	4.5000*	0.82023	0
A2B1	A1B1	1.2000	0.82023	0.48
	A1B2	-2.3000*	0.82023	0.038
	A1B2	2.2000	0.82023	0.052
A2B2	A1B1	-1.000	0.82023	0.618
	A1B2	-4.5000*	0.82023	0
	A2B1	-2.2000	0.82023	0.052

Based on Table 6, the results of the Tukey test show that the pairs that have interactions or pairs that are significantly different are: (1) A2B1-A2B2, (2) A2B1, (3) A2B1-A1B2, (4) A2B2-A1B2, while the other pairs are declared to have no difference in effect: (1) A2B1-A2B2 (2) A2B1 – A2B2. (3) A1B1-A2B1.

Discussion

This review of the research results provides further insight into the results of the information analysis that has been presented. Based on hypothesis testing, three groups of analytical conclusions were drawn: (1) There is a significant comparison of the influence of the main research factors; (2) there is a comparison of the influence between the high and low control groups on the increase in children's aggressive motor skills; (3) there is a significant interaction between the main factors in the form of a two-aspect interaction. The review of the analysis results can be further explained.

1. The effect of aquatic games and coconut shell games on improving gross motor skills in early childhood.

Based on hypothesis testing, it is known that there is a significant effect of aquatic games and coconut shell games on improving gross motor skills in early childhood. This is supported by previous research conducted by (Akinola et al., 2019), which states that aquatic activities can develop gross motor skills in children. Other research data conducted by (Battaglia et al., 2019) reveals that there is a significant effect of aquatic activity programs on the gross motor skills of children aged 4-6 years. Aquatic activities influence children's gross motor skills because the process of implementing aquatic activities includes factors underlying motor skill components. Research results (Cook et al., 2019) confirm that water exercise programs are effective in improving gross motor skills in preschool children. Additionally, improvements in gross motor skills were also observed through the implementation of the egrang batok game model. This finding aligns with previous studies by Mujtahidin & Rachman, (2022), who stated that they developed a method for playing egrang that can improve children's balance. These findings are consistent with previous findings (Sari et al., 2022), which explain that playing egrang for 4 weeks is an effective method for improving balance. This is because when playing egrang batok, children must walk on a shell with a diameter of about 10 cm, which requires a balanced body reaction to play it. Not only that, when playing coconut shell stilts, the muscles of the lower extremities and abdomen contract, resulting in muscle growth. Thus, the traditional game of coconut shell stilts can be used as a balance training program (Nugroho et al., 2023).

However, based on the results of information analysis, it was found that the aquatic game model group performed better than the coconut shell stilts game model group in terms of improving aggressive motor skills in young children. This is supported by research findings (Tyas & Phytanza, 2019), which prove that aquatic programs can increase muscle strength in children. According to (Siega et al., 2021) Aquatic activities are activities carried out in water that aim to train children to improve their gross motor, cognitive, affective, and social skills. Aquatic activities are activities carried out in water that aim to train children to achieve progress in gross motor skills, cognition, affective, and social development. Aquatic activities or water media can provide a unique and exciting atmosphere for all children with disabilities, including the deaf. The purpose of water games is to build their courage in performing activities in water, provide movement enrichment for them, especially their gross motor skills, and reduce psychological, physical, and social disorders or deviations.

Water games designed to improve the gross motor skills of deaf children are expected to be used as teaching materials for teachers in the educational process. Water games for physical education have been adapted to the growth stages of deaf children in special elementary schools.

2. Differences in the effects of high and low balance groups on the improvement of gross motor skills in early childhood

The results of the analysis show that there is a significant difference in the influence of children with high and low balance on the improvement of gross motor skills in early childhood. The group of children with high balance is better than the group of children with low balance in terms of the improvement of gross motor skills in early childhood. One aspect that influences children's gross motor skills is balance (Giolanda, 2025). This is in line with the results of previous research conducted by (Faizah et al., 2024), which reported that children with high balance performed better than children with low balance in terms of the improvement of children's gross motor skills.

This balance is very important to try when children are young because it greatly affects the activities that children try every day. However, this exercise must be tried repeatedly because when children learn new movements, they cannot immediately perform them. It takes time and guidance so that children can hold their bodies to prevent falling and can move the large muscles in their bodies. (Fitri & Imansari, 2020) Argue that children with balance disorders tend to have poor nerve function and structure, such as in cases of vision, hearing, bone disorders, and so on. The appropriate method for training children's balance is through games.

3. Interaction between aquatic models and coconut shell stilts and their balance on improving gross motor skills in early childhood

Based on the results presented in this study, there is a significant interaction between aquatic models and coconut shell stilts and their balance on improving gross motor skills in early childhood. The research results show that aquatic game models are more efficient for children with high levels of balance, while coconut shell models are more

efficient for children with low levels of balance. Water activities have a buoyancy style that can work as a boost to reduce body weight or as resistance (Barbosa et al., 2019). The floating style can act as resistance if the movements that occur in the water are movements that push against the bottom or into the water; this resistance can be used as muscle strengthening. Activities that are attempted against gravity can strengthen and support muscles and connective tissue because muscles can generate force to move or hold weight. From the results of the interaction, it can be seen that the main factors of the research in the form of two aspects show a significant interaction. In the results of this study, the interaction has meaning in that each cell or group has a comparison of the influence of each group that is paired.

Conclusion

Based on the results and reviews that have been found, the following conclusions can be drawn: 1) There is a significant difference in the effect of aquatic games and coconut shell stilts on the increase in aggressive motor skills in early childhood. The aquatic game model group performed better than the coconut shell stilts group in terms of improving the aggressive motor skills of early childhood. 2) There is a significant difference between children with high and low balance in terms of improving the aggressive motor skills of early childhood. Children with high balance performed better than children with low balance in terms of improving the aggressive motor skills of early childhood. 3) There is a significant interaction between the game model (Aquatic) and (Egrang Batok) on the increase in aggressive motor skills in early childhood. The research results show that the game model (Aquatic) is a more efficient model for children with high balance, and the game model (Egrang Batok) is more efficient for children with low balance.

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Conflict of Interest

We acknowledge that there are no conflicts of interest related to this publication, and there has been no significant financial support for this work that could influence the results. As the corresponding author, I confirm that the manuscript has been read and approved for submission by all authors mentioned.

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Improving Physical Fitness of Pencak Silat Athletes Through Circuit Body Weight Training

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Abstract: *Pencak Silat, a traditional Indonesian martial art, requires athletes to demonstrate a combination of strength, muscular endurance, agility, and cardiovascular endurance. While skill acquisition and tactical drills have traditionally been the focus of training, physical conditioning remains a critical component for optimal performance. This study aimed to evaluate the impact of a circuit bodyweight training program on the physical fitness components of Pencak Silat athletes. A total of 64 participants completed a 16-session high-intensity interval training (HIIT) program designed to improve strength, endurance, agility, and cardiovascular fitness. Pre- and post-test assessments were conducted using leg dynamometer tests for strength, push-up tests for muscular endurance, a fleximeter for agility, and an 800-meter run for cardiovascular endurance. The results demonstrated significant improvements in strength ($p < 0.001$), muscular endurance ($p < 0.001$), and agility ($p = 0.022$), with large effect sizes. However, cardiovascular endurance showed a slight decrease ($p < 0.001$), which may reflect a shift in focus toward anaerobic conditioning. The findings suggest that circuit bodyweight training can effectively enhance athletic performance in Pencak Silat by improving strength, muscular endurance, and agility while complementing traditional skill-based training. These results highlight the value of integrating circuit training into Pencak Silat conditioning programs, providing a balanced physical foundation for athletes. The study provides empirical evidence for coaches and sports practitioners to implement evidence-based training methodologies in combat sports to ensure optimal athlete development.*

Keywords: *Pencak Silat; Circuit Training; Bodyweight Exercise; Physical Fitness; Endurance*

Introduction

Pencak Silat, as a traditional martial art originating from Indonesia, has evolved into an internationally recognized combat sport (Ediyono et al., 2022; Mulyana et al., 2024). It incorporates a unique blend of physical strength, mental discipline, tactical strategy, and spiritual values. Athletes are required to exhibit high levels of physical fitness to perform effectively across various aspects of the sport, such as speed, agility, strength, endurance, and coordination (Akbar et al., 2022; Yao & Niu, 2024). These physical attributes are essential not only to execute complex movements, counters, and attacks but also to sustain performance throughout bouts and tournaments (Rahayuni et al., 2023). Therefore, structured and scientifically grounded training methods are vital to improving the physical fitness of Pencak Silat athletes. The dynamic nature of Pencak Silat, which includes rapid offensive and defensive techniques, explosive power in kicks and punches, as well as continuous movement, requires athletes to possess high levels of anaerobic and aerobic fitness (Lubis et al., 2024). Traditional training methods often emphasize skill acquisition and tactical drills, which are essential. However, without a solid foundation of physical conditioning, the effectiveness of these skills may be compromised. Circuit body weight training offers a comprehensive approach to developing multiple components of fitness simultaneously (Agostini et al., 2023; Ramos-Campo, 2021). When structured appropriately, it can serve as both a conditioning and preparatory phase for more intensive sport-specific training. Therefore, managing body composition is also an essential consideration in their training. Circuit body weight training, due to its high-intensity interval nature, can help in fat reduction and muscle toning, contributing to optimal body weight maintenance without compromising strength or performance (BaiQuan et al., 2025; Ho et al., 2024; Minerva Medica, 2022; Oliveira-Junior et al., 2021). This becomes particularly important during the pre-competition phase, where athletes aim to reach peak physical condition while remaining within their weight class limits.

The structured and time-bound nature of circuit body weight training encourages mental discipline, focus, and perseverance. Athletes learn to push their physical and mental limits, which is essential in a high-pressure sport like Pencak Silat (Suprapto et al., 2024). By regularly engaging in high-intensity circuits, athletes also experience increased confidence and motivation, contributing to better performance in both training and competition (Suprapto et al., 2024). From a coaching perspective, circuit body weight training is relatively easy to design, monitor, and modify based on individual or team needs (Hughes et al., 2025). Coaches can adjust the intensity, duration, rest periods, and exercise selection according to the athlete's current fitness level, training phase, or specific goals. For instance, a coach may design a circuit focused on explosive power to enhance striking ability, or one that emphasizes endurance and recovery to support prolonged sparring sessions (Ruddock et al., 2021). The adaptability and scalability of circuit training make it a highly functional tool within a periodized training program. Despite its many advantages, circuit body weight training is not always integrated systematically into the training routines of Pencak Silat athletes. Some coaches and athletes may still rely heavily on traditional drills or overlook the importance of structured conditioning. There may also be misconceptions about the efficacy of body weight exercises compared to weight training. Therefore, it is essential to bridge this gap by demonstrating, through research and practical application, how circuit body weight training can significantly contribute to physical performance enhancements specific to Pencak Silat.

This study aims to explore and analyze the impact of circuit body weight training on the physical fitness components of Pencak Silat athletes. By implementing a structured circuit body weight training program over a determined period and measuring key fitness indicators such as cardiovascular endurance, muscular strength, agility, and body composition, we aim to provide empirical evidence of its effectiveness. Through this research, we also seek to contribute to the development of evidence-based training models that can be utilized by Pencak Silat coaches and sports practitioners to improve athlete performance sustainably and safely.

Materials and Methods

The research was conducted in Padang City in January 2025. The population of this study consisted of all pencak silat athletes, totaling 64 individuals. The sample was selected using a random sampling technique. All participants gave their consent by signing a statement of willingness to participate in the research. The instruments used in this study included a leg dynamometer to measure strength, push-up tests to assess muscular endurance, a fleximeter to evaluate agility, and an 800-meter run to measure cardiovascular endurance. This research employed a quasi-experimental design, specifically a one-group pre-test and post-test design. One group of athletes was given a circuit bodyweight training program as the treatment. Data collection was carried out through tests and measurements before and after the training intervention. The training program lasted for 16 sessions, conducted three times per week. The goal was to observe improvements in muscle strength, endurance, and agility following the training.

The circuit bodyweight training program was divided into two phases. During sessions 1 to 8, the exercises included Reclining Triceps Press, Lateral Plyo Squat, Floor Inverted Shoulder Press, Single Leg Dip, Split Jacks, Shuttle Run, Frog Jump, Side Jump, Half Squat, Lateral Run, and Bench Jump. Each exercise was performed for 2 sets of 10 repetitions with 20 seconds of rest between stations and 120 seconds of recovery after completing the full circuit. In sessions 9 to 16, the training intensity increased. The same exercises were performed, but with 3 sets of 12 repetitions each, maintaining the 20-second rest between exercises and a 120-second recovery after the circuit. The data collected were analyzed using the JASP software version 0.19.3 by applying a paired sample t-test to determine the differences between the pre-test and post-test results.

Results

The purpose of this study was to examine the effects of a structured physical training intervention on four critical components of fitness: strength, muscular endurance, agility, and cardiovascular endurance. A total of 64 participants completed both pre-test and post-test assessments, allowing for a within-subject comparison of performance before and after the intervention period. To explore the outcomes of the training program, a combination of descriptive and inferential statistical analyses was conducted. Descriptive statistics were used to provide a general overview of performance trends, while normality testing determined the appropriate statistical approach for hypothesis testing. Paired samples t-tests and non-parametric Wilcoxon signed-rank tests were employed to evaluate whether the observed differences between pre- and post-test scores were statistically significant. The following section presents the results of these analyses, beginning with a summary of descriptive data.

Table 1. *Descriptives Data*

Variable	Mean	SD	SE	CV
Strength (Pre-Test)	54.666	21.044	2.631	0.385
Strength (Post-Test)	58.250	22.345	2.793	0.384
Muscular Endurance (Pre-Test)	15.016	5.608	0.701	0.373
Muscular Endurance (Post-Test)	16.578	6.034	0.754	0.364
Agility (Pre-Test)	9.109	7.722	0.965	0.848
Agility (Post-Test)	6.915	3.119	0.390	0.451
Cardiovascular Endurance (Pre-Test)	4.748	0.819	0.102	0.172
Cardiovascular Endurance (Post-Test)	4.397	0.788	0.098	0.179

Table 1 presents the descriptive statistics for each fitness variable assessed before and after the training program. On average, participants showed improvements across most variables. Strength scores increased from a mean of 54.67 (SD = 21.04) to 58.25 (SD = 22.35), while muscular endurance rose from 15.02 (SD = 5.61) to 16.58 (SD = 6.03). These improvements suggest gains in both absolute strength and muscular capacity following the intervention. Agility scores demonstrated a meaningful improvement, decreasing from 9.11 seconds (SD = 7.72) to 6.92 seconds (SD = 3.12), indicating faster response and movement times. The coefficient of variation (CV) notably declined in agility scores, suggesting reduced variability and more consistent performance among participants after the intervention.

Interestingly, cardiovascular endurance scores showed a slight decrease from 4.75 (SD = 0.82) to 4.40 (SD = 0.79). While the decline is relatively small, it may reflect fatigue accumulation or a shift in training emphasis away from aerobic conditioning during the intervention phase. Further inferential analysis is required to determine the statistical significance of these changes. To determine the appropriate statistical tests, normality checks were conducted using the Shapiro–Wilk test. This test helps assess whether the data are normally distributed, which is a key assumption for parametric analysis. The results are presented table 2 below.

Table 2. *Normality Test*

Variable	W	p-value
Strength (Post-Test & Post Test)	0.884	< 0.001
Muscular Endurance (Post-Test & Post Test)	0.729	< 0.001
Agility (Post-Test & Post Test)	0.231	< 0.001
Cardiovascular Endurance (Post-Test & Post Test)	0.964	< 0.001

To assess whether the differences between pre-test and post-test scores were statistically significant, both parametric and non-parametric tests were applied. The paired samples t-test was used for variables that approximated normal distribution, while the Wilcoxon signed-rank test served as a non-parametric alternative for data that violated the assumption of normality. The following table presents the results of both tests for each measured variable, along with corresponding effect sizes to indicate the magnitude of change. For more details, please see table 3 below.

Table 3. *Results of Paired Samples t-Test and Wilcoxon Signed-Rank Test*

Measure	Test	Statistic	df	p-value	Effect Size	SE Effect Size
Strength (Post-Test & Post Test)	t-test	-14.715	63	< 0.001	-1.839	0.014
	Wilcoxon	0.000	—	< 0.001	-1.000	0.143
Muscular Endurance (Post-Test & Post Test)	t-test	-18.834	63	< 0.001	-2.354	0.021
	Wilcoxon	0.000	—	< 0.001	-1.000	0.143
Agility (Post-Test & Post Test)	t-test	2.353	63	< 0.001	0.294	0.153
	Wilcoxon	1.950.500	—	< 0.001	0.875	0.143
Cardiovascular Endurance (Post-Test & Post Test)	t-test	18.635	63	< 0.001	2.329	0.044
	Wilcoxon	2.080.000	—	< 0.001	1.000	0.143

The paired samples t-tests revealed significant differences between pre-test and post-test scores across all four variables. Strength and muscular endurance showed highly significant improvements with large effect sizes (d = -1.839 and -2.354, respectively). Agility also improved significantly ($p = 0.022$), with a small to medium effect (d = 0.294). Interestingly, cardiovascular endurance showed a significant decrease ($t = 18.635$, $p < 0.001$, d = 2.329), suggesting a potential regression post-intervention. The Wilcoxon signed-rank tests confirmed these findings, particularly for variables with non-normal distributions. All p-values were < 0.001, with strong effect sizes highlighting the robustness of the observed changes despite deviations from normality.

Discussion

This study is significant because it provides empirical insights into the impact of circuit body weight training on the physical fitness components of Pencak Silat athletes, a traditional martial art that has evolved into an internationally recognized combat sport. Pencak Silat requires athletes to demonstrate high levels of physical fitness, including strength, endurance, agility, and cardiovascular endurance. The findings from this research offer practical applications for enhancing the physical conditioning of Pencak Silat athletes through scientifically grounded training methods. Given the limited body of research focusing specifically on the effects of bodyweight circuits in the context of Pencak Silat, this study fills a crucial gap in our understanding of how such training can enhance athletic performance in this sport. Pencak Silat is a dynamic martial art that demands rapid offensive and defensive movements, explosive power, and sustained endurance. To execute complex techniques effectively, athletes must possess a combination of anaerobic and aerobic fitness. Therefore, physical conditioning is a critical aspect of performance. Circuit bodyweight training, which emphasizes high-intensity interval training, has been suggested to simultaneously improve multiple physical attributes, such as muscular strength, endurance, and agility. This study exploration of the benefits of circuit bodyweight training in improving the fitness levels of Pencak Silat athletes is vital as it supports the notion that structured conditioning plays a crucial role in enhancing athletic performance. Furthermore, the study highlights the importance of evidence-based training in improving athlete performance sustainably and safely. Traditionally, Pencak Silat training has focused heavily on skill acquisition and tactical drills, but this study demonstrates how structured conditioning, like bodyweight circuit training, can complement these skills to optimize overall performance. By analyzing the effects of this specific training method, the research contributes valuable knowledge to coaches, athletes, and sports practitioners in the Pencak Silat community.

This study aligns with and extends the findings of several other studies that have explored the effects of high-intensity circuit training on various athletic populations. For instance, a study by (Vasconcelos et al., 2020) on combat athletes showed that circuit training, specifically high-intensity interval training (HIIT), significantly enhanced aerobic fitness, strength, and muscular endurance. This is consistent with the findings of the present study, which demonstrated improvements in strength, muscular endurance, and agility following a circuit bodyweight training regimen. Additionally, (Herranz-Gómez et al., 2022) found that high-intensity exercise, including circuit training, can improve both aerobic and anaerobic fitness in athletes. Although the cardiovascular endurance in the present study slightly decreased, it is worth noting that other research indicates such fluctuations can occur due to shifts in the focus of the training, from aerobic conditioning to anaerobic, power-based exercises, as observed in this study. This aligns with (Stone et al., 2022), who emphasized that the specificity of training must align with the demands of the sport. For Pencak Silat, anaerobic power and strength are likely more critical than cardiovascular endurance during short bursts of combat.

Furthermore, the meta-analysis by (Yuniana et al., 2024) demonstrated that bodyweight training, especially when used in a circuit format, is highly effective for improving athletic performance across a range of sports. This strengthens the case for integrating bodyweight circuits into the training regimens of combat athletes like those practicing Pencak Silat. The present study not only corroborates these findings but also addresses a specific gap by focusing on Pencak Silat athletes, who have unique demands in terms of agility, explosive power, and endurance. The findings of this study have several important implications for Pencak Silat training and athletic conditioning. First, the significant improvements in strength, muscular endurance, and agility underscore the importance of integrating circuit bodyweight training into the training programs of Pencak Silat athletes. Coaches can use this method to complement traditional skill-based training and tactical drills, leading to well-rounded athletes who are physically prepared to perform complex movements, execute powerful strikes, and maintain performance over extended bouts.

Moreover, this research suggests that circuit bodyweight training can be a viable option during the pre-competition phase, where athletes are seeking to optimize their body composition, strength, and endurance without adding the bulk often associated with traditional weight training. The high-intensity nature of circuit training allows athletes to achieve fat reduction and muscle toning, maintaining a lean physique without compromising performance. This is crucial for athletes who need to meet specific weight class requirements while maximizing their power output and overall athleticism.

While the study offers valuable insights, there are some limitations that should be considered. First, the sample size of 64 participants, although adequate for initial analysis, could have been larger to enhance the generalizability of the findings across different populations of Pencak Silat athletes. Additionally, the study relied on a single group pre-test and post-test design, which, while useful for detecting changes within the group, does not allow for comparisons with a control group. Without a control group, it is difficult to rule out other factors (e.g., natural progress over time, external training variables) that might have contributed to the observed improvements. Another limitation is the duration of the training program, which lasted for only 16 sessions. A longer training period would allow for a deeper exploration of the long-term effects of circuit bodyweight training on various fitness components. Furthermore, the study's focus on only four specific fitness components (strength, muscular endurance, agility, and cardiovascular endurance) means that other important factors, such as flexibility, injury prevention, and mental toughness, were not evaluated. Lastly, the slight decrease in cardiovascular endurance observed in the study warrants further investigation. While this result might be attributed to the specific emphasis on anaerobic conditioning, it may also point to a potential trade-off between different fitness components. A more balanced training approach, integrating both aerobic and anaerobic exercises, could be explored in future studies to determine the optimal training protocol for combat athletes.

Future research could address several aspects to build on the findings of this study. One recommendation is to conduct a longitudinal study to assess the long-term effects of circuit bodyweight training on the physical fitness of Pencak Silat athletes. This would help determine whether the observed improvements are sustained over time and if the training has any lasting impact on performance. Additionally, future studies could explore the effects of circuit bodyweight training on other fitness variables, such as flexibility, reaction time, mental toughness, and injury prevention, which are equally important in combat sports. Investigating the relationship between physical conditioning and mental preparation could offer a holistic understanding of how circuit training can contribute to a Pencak Silat athlete's overall performance. Lastly, comparing the effects of bodyweight circuit training with other types of training, such as traditional weight training or sport-specific skill drills, could provide insights into the relative benefits of each method. This would help coaches design more effective and balanced training programs tailored to the unique demands of combat sports like Pencak Silat.

This study underscores the value of incorporating circuit bodyweight training into the conditioning programs for Pencak Silat athletes. The significant improvements in strength, muscular endurance, and agility suggest that this training method can be a highly effective means of enhancing athletic performance. Despite the limitations of the study, its findings contribute to the growing body of evidence supporting the use of high-intensity circuit training in combat sports. By integrating such training into their regimens, Pencak Silat athletes can achieve a more comprehensive and balanced physical conditioning, improving not only their technical skills but also their overall athleticism.

Conclusion

This study has demonstrated that circuit bodyweight training significantly improves key physical fitness components in Pencak Silat athletes, including strength, muscular endurance, and agility. The structured, high-intensity nature of circuit training appears to be highly effective in enhancing these attributes, which are essential for optimal performance in Pencak Silat. The improvements in strength and endurance are particularly notable, supporting the idea that such training can complement traditional skill-based drills and provide athletes with a more well-rounded physical foundation. While the study found a slight decrease in cardiovascular endurance, the improvements in strength, endurance, and agility suggest that the focus of the training on anaerobic conditioning may have been more aligned with the specific demands of Pencak Silat. These findings align with other studies on circuit training, reinforcing the value of this training method for combat sports that require explosive power, agility, and muscular endurance. Overall, the results of this study highlight the importance of integrating circuit bodyweight training into

the training programs of Pencak Silat athletes. It offers a practical, adaptable, and effective approach to developing athleticism, ensuring that athletes are not only skilled in the technical aspects of the sport but also well-conditioned physically. These findings provide valuable insights for coaches, sports practitioners, and athletes looking to optimize performance and ensure sustainable physical development in the sport of Pencak Silat.

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Metric Characteristics of a Short Scale for Self-assessment of Students' Quality of Life during the COVID-19 Pandemic

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Abstract: *With the aim of determining the metric characteristics of the adapted research instrument, applied in the process of detecting students' perception of the quality of life after the period of closure of cities, institutions, schools, institutions of different profiles, i.e. measures to restrict movement and "live" social interaction during the pandemic caused by the SARS-CoV-2 corona virus, its statistical valorization was performed. The questionnaire, which is based on the assessment scale for the quality of life among the student population (PQL-S), was tested through two statistical procedures: (1) checking its internal agreement (Scale Reliability Analysis) based on Cronbach's Alpha coefficient values; and (2) factor analysis (Principal Components Analysis, with the Direct Oblimin method of rotation). The research sample consisted of students of the Academy of Applied Studies in Belgrade (n = 1260). The results indicate good metric characteristics for the short twelve-item scale, demonstrating satisfactory reliability (Cronbach's α = .806). The scale also showed good validity, supported by a Kaiser-Meyer-Olkin measure of .805 and a significant Bartlett's test of sphericity (p < .001). Furthermore, application of the validated scale revealed a significant decline in students' self-assessed quality of life in the post-pandemic period (p < .001). Statistical conclusions were made with a significance level of 0.05 (p < .05). The application of the validated scale revealed a significant decline in students' quality of life perceptions in the post-pandemic period. The good metric characteristics of the instrument represent a quality basis for its possible application within the student population.*
Keywords: *scale, validity, quality of life, students*

Introduction

The determinism of the modern understanding of the quality of life refers dominantly to its essential multidimensionality. It includes several synergistically related factors related to the individual, among which the following stand out: physical health, psychological state, status of economic independence, social relations, personal beliefs, attitudes and value orientations, relation to existential aspects of the immediate environment, etc. (Nešić & Srdić, 2021). According to the still dominant definition of the World Health Organization (WHOQOL group, 1996) on the foundation of standards for the perception of quality of life, it is about a person's individual perception and perception of his own life position experienced through the context of the cultural and value system in which he lives. The key element in this complex process refers to the alignment of individual goals, expectations and interests, within the set and generally accepted social norms and standards (Nešić, 2016).

The view that the concept of quality of life is primarily perceived at the individual level through the personal set of values of a certain person has a solid foundation in the fact that, essentially, it is about the overall general well-being of each individual, which implies the existence of objective factors (mainly from the external environment), with subjective evaluation of physical, material, social and emotional well-being (Nešić et al., 2018).

When considering the quality of life of young people, especially the student population, it is necessary to think through the aspect of the influence of the environment as its integral component. Depending on how young people perceive their current quality of life, their attitude towards identifying, valuing, and adopting a certain lifestyle will also depend. In the search for their own identity, the feeling of adequate quality of life can represent a significant determinant of their social connection, preferences, aspirations, and/or distancing (Nešić et al., 2015). The period of study (the so-called student life) is a specific part of a young person's life, characterized by numerous challenges, but also opportunities. It is about a period in a young man's life that is characterized by adjustment processes. First of all, it implies a significant number of changes of cognitive, emotional and social character that occur in every young per-

son, and are conditioned, among other things, by significant changes in the period of time devoted to the study of the chosen field of study. Starting from information to developing a systematic and critical opinion about various facts and data essential for the development of lifestyle and habits, which is followed by the adoption of new (specific) norms of behavior in the conditions of a new living environment and relative separation from parents and family.

Although periods of great crises (such as the COVID-19 pandemic) most often condition changes in the experience of the quality of life (individuals, but also society as a whole), the very context of the experience of the quality of life, essentially, remains based on two key factors: (1) subjectivity (primarily understandable from the individual's perspective) and (2) multidimensionality (assessment of several different dimensions of an individual's life) (Slavuj, 2012; Nešić, 2016; Joković et al., 2017). In general, the perception of the quality of life during the pandemic period, as well as during the so-called post-covid regressed significantly, especially in the context of psychological and social factors that contribute to the individual sense of quality of life in the non-pandemic period (Leong Bin Abdullah et al., 2021; Stella Epifanio, 2021; Fiqueroa-Quiñones et al., 2022; Višnjić, Kok, Višnjić, Jovanović & Marković, 2023).

Self-assessment of quality of life is one of the important aspects of most population studies, including among the student community. It can be based on a different set of indicators, depending on research and social needs, scientific coverage, regional affiliation of the population, economic conditions, etc. Therefore, the appropriate selection of questionnaires is an important segment of research operations. Also, the individual experience of the quality of life represents for the individual the most authentic attitude towards this issue in the concrete living environment. In this regard, scalar-type survey instruments, based on the identification of respondents' self-assessment, proved to be very practical and reliable enough for a relatively clear identification of certain segments of the quality of life.

The aim of this research was twofold. The first, primary aim was to examine the metric characteristics (validity and reliability) of a short scale for the self-assessment of students' quality of life, constructed based on the PQL-S instrument, in order to verify its suitability for use in this population. The second aim, achieved by applying the validated scale, was to identify and analyze changes in the students' perception of quality of life after the period of the COVID-19 pandemic, compared to the period before its outbreak. In this way, the research strives to provide both a practical assessment tool and empirical insight into the well-being of the student population during a crisis.

Material and Methods

Sample of respondents

The research was conducted within the framework of a broader research project at the Academy of Applied Studies Belgrade, as a transversal study (survey method), with the aim of identifying the perception of quality of life among students in the period after the COVID-19 pandemic.

The sample of respondents consisted of a total of 1260 students of the Belgrade Academy of Applied Studies. Subsampling was carried out according to the criteria of being infected with the corona virus: (1) had been infected with covid-19 and (2) had not been infected with the corona virus.

Sample of measures

A five-point short scale for self-assessment of quality of life was used as a research instrument. The construct of this scale was based on the PQL-S instrument (Nešić, 2016), which was redesigned on this occasion and reduced to a short twelve-item Likert-type scale.

The item indicators included the following areas that determine the quality of life: (1) the level of daily physical activities, (2) the regularity of engaging in sports and recreational activities (SRA), (3) opportunities for exercising sports recreation in the place of residence, (4) general work capacity, (5) quality and regularity of daily meals, (6) sleep and rest, (7) self-confidence, (8) social relationships and environmental support, (9) relationships with friends, (10) contacts on social networks, (11) atmosphere at work/school and (12) family environment. As it is a reconstructed version of the validated scale for the student population, in the process of analyzing the results, its reliability was determined by calculating the Cronbach's Alpha coefficient.

Statistical analysis

Statistical procedures of a descriptive and comparative type were applied in the process of processing the empirical material. Basic descriptors were determined by calculating frequency distributions, standard deviation, arithme-

tic mean, as well as contingency analysis. In the area of comparative statistics, factor analysis (Principal Component Analysis with Direct Oblimin rotation) was applied. The suitability of data for factor analysis was assessed prior to the analysis, with the Kaiser-Meyer-Olkin measure confirming sampling adequacy and Bartlett's test of sphericity indicating that correlations were appropriate for factoring. Statistical inferences were conducted at a significance level of 0.05 ($p < .05$). The data analysis involved utilizing the Statistical Package for Social Sciences (SPSS) version 26.0 by SPSS Inc. in Chicago, IL, USA.

Results

The procedure that preceded the analysis and explanation of the results of the empirical material included the determination of the internal agreement of the applied scale. Reliability was identified by calculating the Cronbach's Alpha coefficient, which in this case was $\alpha = 0.806$, which significantly exceeds the recommended theoretical level of 0.7 (DeVellis, 2003; Hair et al., 1998) (Table 1).

Table 1. *Results of scale reliability analysis (n = 1260)*

Item	Indicator	Cronbach's Alpha if Item Deleted	Mean	Standard Deviation
1	Level of daily physical activities	0.780	3.36	0.978
2	Frequency of engaging in sports and recreational activities	0.788	2.97	1.197
3	Sleep and rest	0.798	3.65	1.074
4	Quality and regularity of meals	0.788	3.60	1.049
5	General work capacity	0.785	3.58	1.010
6	Self-confidence	0.782	3.88	0.983
7	Social relationships and support from the environment	0.777	4.15	0.881
8	Relationships with friends	0.781	4.43	0.814
9	Contacts on social networks	0.792	4.07	0.970
10	Atmosphere at work	0.781	3.85	1.013
11	Family environment	0.785	4.48	0.816
12	Opportunities for recreation in the place of residence	0.785	3.95	1.098
	Cronbach's Alpha for the Entire Scale	0.806	3.74	0.557

As the scale showed appropriate reliability and good internal agreement of item indicators, conditions were created that enable research capacity and its applicability for further processing. By applying factor analysis, an attempt was made to determine the latent structure of the space of self-assessment of the quality of life among students. The scalar average of the scale as a whole was at the level of moderate satisfaction with the quality of life (3.74), while the values within the item indicator ranged from 2.97 to 4.48. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (0.805) and Bartlett's Test of Sphericity, $\chi^2 = 4092.627$, $p < .001$, indicated the data were suitable for factor analysis.

The analysis of the main components obtained after oblique rotation (Direct Oblimin method of rotation) revealed the presence of three components with characteristic values (eigenvalues) over one, which explain 32.28%, 13.45% and 10.31% of the variance (Table 2), which explains a significant percentage of the total variance (56.076%) and indicates the stable factorability of this scale. These values also support the recommendations on the interpretation of factor analysis results (Pallant, 2009).

Table 2. *Total variance explained for the self-report scale*

Component	Total	% of Variance	Cumulative %
1	3.874	32.281	32.281
2	1.618	13.458	45.766
3	1.237	10.310	56.076

All 12 variables gave the appropriate factor weight to the extracted components in isolated factors (Table 3), additionally confirming that the short scale of self-assessment of the quality of life among students has appropriate

validity, which creates perspectives that it can be applied as an appropriate scale for assessing some aspects of the quality of life among students.

Table 3. *Results of the factor analysis of the short self-assessment scale (Pattern Matrix)*

Variable	Factor I		Factor II		Factor III	
	Factor weight	Communality	Factor weight	Communality	Factor weight	Communality
Relationships with friends	0.862	0.683				
Social relations and support from the environment	0.844	0.683				
Contacts on social networks	0.663	0.430				
Family environment	0.631	0.447				
Self-confidence	0.503	0.391				
Atmosphere at work	0.408	0.371				
Opportunities for recreation in the place of residence	0.369	0.328				
Frequency of engaging in sports and recreational activities			0.882	0.725		
Level of daily physical activities			0.859	0.725		
General working capacity			0.614	0.463		
Sleep and rest					0.882	0.754
Quality and regularity of meals					0.818	0.728

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.805
Bartlett's Test of Sphericity, $\chi^2 = 4092.627$, $p < .001$

The hierarchical structure of the assembly matrix (Pattern Matrix) indicates the hierarchical structure of the extracted factor. Projections on the first main component are realized by seven items (relationships with friends, social relations and environmental support, contacts on social networks, family environment, self-confidence, atmosphere at work/school and opportunities for recreation at the place of residence). It is noticeable that this factor includes indicators related to factors of the students' living environment and which can greatly influence the quality of their life. Respecting the semantics of the included items, this factor can be named as the factor of the *external environment*.

The second single factor includes three item indicators (regularity of engaging in physical activities, level of daily physical activities and general work capacity). It is unequivocally observed that this factor is saturated with items related to habits and attitude towards physical activities and recreation, and their consequence on the general working capacity of students, which is very important for the overall experience of the quality of life. Based on the semantic context, this factor is called the *physical activity* factor.

Although the saturation of only two items (sleep/rest and quality of daily meals) can be observed in the third single factor, their contextuality in a broader sense has the capacity for significant implications on the overall quality of life. Therefore, this factor was retained within the construct of the latent structure of the researched area of perception of the quality of life among students. Bearing in mind the wording of the items in the instrument as a logical terminological framework for this factor, the *lifestyle* factor was imposed.

The determined results of the empirical material in the space of the latent structure can be logically interpreted and connected with the expressed self-assessment of the quality of life of the respondents. The item indicators, which tried to determine how students perceive their overall quality of life in the period before the outbreak of the COVID-19 pandemic and the current living conditions (conditionally post-COVID period), showed that there are significant differences in the perception of the quality of life. It is clearly observed that, evaluating the quality of life before the outbreak of the pandemic, the largest percentage of respondents (60.9%) perceived their life as above average, while an almost negligible number (2.2%) were those who declared that they lived below the usual average for this part of our population. This was expected, given that the majority of respondents were those who were not infected with COVID 19 (70.7%) (Table 4).

Table 4. *Self-assessment of quality of life before the pandemic by COVID-19 infection*

Quality of life before the pandemic	COVID-19		Total
	Yes	No	
Below average	14	14	28
	1.1%	1.1%	2.2%
Average	124	341	465
	9.8%	27.1%	36.9%
Above average	231	536	767
	18.3%	42.5%	60.9%
Total	**369**	**891**	**1260**
	29.3%	70.7%	100.0%

$\chi^2(2) = 7.598, p = .022$

However, after a two-year period of living in a pandemic environment (with all the social restrictions, changes in the way of social and individual functioning, etc.) the experience of the quality of life has changed significantly. There is a noticeable decrease in the number of those who rate the current quality of life as above average (22%), while the number of respondents who now (according to their opinion) live average, has increased significantly (66.3%). Also, there is a noticeable increase in the percentage of those who think that they are living much worse now, i.e. below the average (11.7%) (Table 5), which is also detected in respondents who were not infected with the virus that causes the COVID-19 infection.

Conversely, in the post-pandemic period, the difference in quality of life assessments between infected and non-infected students was not statistically significant, $\chi^2(2) = 3.136$, $p = .208$.

Table 5. *Self-assessment of quality of life in the post-pandemic period by COVID-19 infection status*

Quality of life in the post-pandemic	COVID-19		Total
	Yes	No	
Below average	52	96	148
	4.1%	7.6%	11.7%
Average	242	593	835
	19.2%	47.1%	66.3%
Above average	75	202	277
	6.0%	16.0%	22.0%
Total	369	891	1260
	29.3%	70.7%	100.0%

$\chi^2(2) = 3.136, p = .208$

All this points to the fact that the pandemic had a significant impact on the respondents' perception of a decrease in the general quality of life. The significance of the observed empirical differences is also confirmed by the results of the contingency analysis, which revealed a statistically significant difference between the pre-pandemic and post-pandemic periods, $\chi^2(4) = 140.924$, $p < .001$ (Table 6).

Table 6. *Contingency analysis of self-assessed quality of life before and after the pandemic*

Self-assessment of quality of life	n	%
Before COVID-19	1260	100
Post-COVID period	1260	100

$\chi^2(4) = 140.924, p < .001$

The identified values of the empirical results can be considered as corresponding with similar recent studies that determined that the feeling of the quality of life among the student population changed significantly after the

pandemic period (Aristovnik, 2020; Aucejo et al., 2020; Vrdoljak, 2021; Farnell, Skledar-Matijević & Šćukanec-Schmidt, 2021; Bekić & Malčić, 2022).

Discussion

This study sought to develop and validate a concise instrument for assessing student quality of life in the context of the COVID-19 pandemic and to employ this tool to capture shifts in quality of life perceptions following this global crisis. The findings, interpreted against the study's dual aims, provide clear evidence of the scale's robustness and reveal a significant pandemic-related decline in student well-being.

Specifically, in relation to the first aim of examining the scale's metric characteristics, the results unequivocally show that the short scale possesses satisfactory metric characteristics. Its good degree of internal consistency (Cronbach's $\alpha = 0.806$) and clear three-factor structure explaining 56.07% of the variance confirm that the scale is a reliable and valid instrument suitable for the rapid assessment of quality of life in the student population. Concerning the second aim of identifying pandemic-related changes, the application of the scale revealed a dramatic and statistically significant decline in students' perception of their quality of life in the post-pandemic period. This finding clearly indicates that the COVID-19 pandemic and its psychosocial context had a significant negative impact on all three identified dimensions of well-being: the external environment, physical activity, and lifestyle.

Interpretation of Findings

The obtained Cronbach's alpha coefficient value of 0.806, which is higher than the recommended theoretical threshold of 0.7 (DeVellis, 2003), indicates solid internal consistency of the scale. This result is consistent with the reliability of the original PQL-S questionnaire (Nešić, 2016) on which the scale is based, as well as with other short instruments constructed to assess specific aspects of quality of life (Nešić et al., 2018). This suggests that the shortened version, despite the reduction in the number of items, successfully retained its reliability as a measurement instrument, which is crucial for its practical applicability.

The results of the factor analysis (Principal Components Analysis) confirmed the multidimensional nature of the quality of life concept, revealing a clear three-factor structure. This structure, comprising the factor of external environment (social relations, family, self-confidence), the factor of physical activity (activity level, sports, work capacity), and the factor of lifestyle (sleep, nutrition), is partially consistent with broad definitions of quality of life that emphasize physical, psychological, and social well-being as key dimensions (WHOQOL group, 1996; Nešić & Srdić, 2021).

Comparison with Recent Studies

Although the number and content of factors may differ from some more general models, the presence of factors related to social relations and physical activity consistently emerges as a critical component of student well-being in research conducted during the pandemic (Leong Bin Abdullah et al., 2021; Figueroa-Quiñones et al., 2022). Our results thus emphasize that these areas were particularly sensitive to the disruptions caused by the crisis.

The most striking finding of this study is the dramatic decline in students' self-assessed quality of life after the pandemic. The percentage of students rating their life as "above average" fell from 60.9% to just 22.0%, while the percentage of those rating themselves as "below average" increased from 2.2% to 11.7%. The confirmed dramatic decline in students' quality of life was statistically significant ($p < .001$). This finding is compellingly consistent with the results of numerous global studies that have documented the difficulties faced by the student population. Our data directly support the research of Aristovnik et al. (2020), who found a significant deterioration in the mental health, social, and academic well-being of students on a global sample. Similarly, Aucejo et al. (2020) reported a large decrease in satisfaction with education and life in general, which directly relates to our finding of a reduced rating of overall quality of life.

It is particularly interesting that the decline in quality of life was also recorded among students who had not been infected with the virus. This highlights that the psychosocial context of the pandemic itself – restrictive measures, social isolation, changes in the academic environment – had a more crucial impact on the experience of quality of life than the individual's health status alone. This assertion aligns with the findings of research by Farnell et al. (2021), who emphasize the loss of daily routines and reduced social contacts as key stress factors. Additionally, the study by

Višnjić et al. (2023) on students in Serbia also linked increased social media use during the pandemic with higher levels of anxiety, depression, and stress, indirectly supporting our finding that aspects of the "external environment" were critical.

The identified factors in our study provide even deeper insight. The decline in the domain of physical activity (Factor 2) directly reflects the closure of sports facilities and movement restrictions, which was a constant finding during the lockdown period (Bekić & Malčić, 2022). The reduction in social support and quality of family atmosphere (Factor 1) was also expected given the disruption of "live" interactions, which is also confirmed by the research of Epifanio et al. (2021) in the Italian population. Finally, the disruption of sleep patterns and eating habits (Factor 3, lifestyle) represents another universal consequence of disrupted daily routines during the crisis (Leong Bin Abdullah et al., 2021).

Implications of the Study

This study has dual implications. Theoretical implications lie in contributing to the validation of a short yet reliable quality of life assessment instrument that can serve as a basis for future comparative research in the region. Practical implications are more direct: the identified key areas of deterioration (social relationships, physical activity, sleep and eating habits) provide clear guidelines for universities and student services to design targeted support programs and interventions aimed at preserving the mental health and well-being of the student population in times of crisis. Finally, the good metric properties of the scale and the clear factor structure we obtained make this instrument a useful tool for future research. It enables a quick and efficient assessment of key quality of life domains among students, which is of particular importance for monitoring the long-term effects of the crisis and evaluating support programs.

Limitations of the Study

The application of this modified scale was tested on the population of students of the Academy of Applied Studies in Belgrade, which can be a relative limitation of this study. In this sense, it is recommended that in subsequent research it be additionally checked on a wider student sample, given that it showed correct metric characteristics. It is realistic to expect that the questionnaire/scale will prove to be reliable and applicable in the practice of quality of life research in the wider student population.

Conclusion

This research confirmed that the short self-assessment quality of life scale has satisfactory metric characteristics, demonstrating good reliability and a clear three-factor structure encompassing the dimensions of external environment, physical activity, and lifestyle. The application of the scale revealed a dramatic decline in students' perception of their quality of life after the COVID-19 pandemic, indicating the profound impact of the crisis on their well-being. These findings have immediate practical implications: the scale can be used as a quick and reliable tool for assessing the well-being of the student population in times of crisis, and the identified sensitive areas (physical activity, social ties, lifestyle) provide clear guidelines for designing targeted support programs and interventions by university services.

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Physical Activity and Cognitive Development: The Mediating Role of Body Awareness in Academic Achievement

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Abstract: *The relationship between physical activity, body awareness, and academic success has become an emerging focus of educational and cognitive research. Building on the theoretical framework of embodied cognition, this study examined whether structured physical activity enhances students' body awareness and academic performance. A quasi-experimental design with pre- and post-intervention assessments was implemented with 260 university students enrolled in Sport Sciences. Participants were divided into an experimental group (n = 130), which completed a 12-week physical activity program (two 60-minute sessions per week), and a control group (n = 130), which continued regular academic activities. Outcomes were measured using the Body Awareness Questionnaire (BAQ) and official academic grades. Statistical analyses included Confirmatory Factor Analysis (CFA), ANCOVA, t-tests, and Pearson's correlations. The intervention produced significant improvements in both body awareness and academic performance. ANCOVA results indicated medium-to-large effects (BAQ: partial $\eta^2 = 0.16$; grades: partial $\eta^2 = 0.13$), and independent t-tests confirmed significant group differences ($p < .001$). A positive correlation ($r = .44$, $p < .001$) was found between BAQ scores and academic grades, suggesting that higher body awareness is associated with better academic achievement. The findings demonstrate that structured physical activity enhances students' bodily self-awareness, which in turn supports cognitive focus, self-regulation, and academic success. These results highlight the importance of embodied education as a pedagogical approach that integrates physical and cognitive dimensions of learning. Incorporating mindful movement practices into university curricula may thus represent an effective strategy to promote both academic excellence and holistic student well-being.*

Keywords: *physical activity; body awareness; academic achievement; embodied education; higher education*

Introduction

In recent years, the relationship between physical activity and academic achievement has become a focal point of interdisciplinary research at the intersection of education, psychology, and the life sciences (Monacis et al., 2022, 2025). A growing body of evidence suggests that movement and cognition are not separate domains but deeply intertwined aspects of human development (Diamond, 2015; Pesce et al., 2021). This theoretical shift has prompted scholars to explore how the body, far from being a passive instrument, actively shapes cognitive processes, emotional regulation, and learning outcomes. Within this emerging framework, *body awareness*, the capacity to perceive, interpret, and regulate one's bodily sensations and movements, has been increasingly recognized as a crucial mediator linking physical activity and academic success (Mehling et al., 2012; Custers & Van den Berg, 2020).

Physical activity has long been acknowledged as a determinant of physical health, with well-established benefits for cardiovascular function (Nurzynska et al., 2013), metabolic efficiency, and musculoskeletal integrity (Farì et al., 2021). However, recent research has expanded this view by demonstrating that regular engagement in physical exercise exerts profound effects on brain structure and function (Hillman, Erickson, & Kramer, 2008). Aerobic and coordinative exercises stimulate neurogenesis, synaptic plasticity, and cerebral blood flow, particularly in regions associated with executive functions, attention, and memory (Best, 2010; Voelcker-Rehage & Niemann, 2013). These neurobiological adaptations are mirrored by improvements in academic performance, suggesting that movement-based interventions can serve as effective educational strategies (Donnelly et al., 2016). Yet, the mechanisms underlying this relationship are multifaceted and not entirely reducible to physiological effects. Among the psychosomatic pathways proposed, body awareness emerges as a particularly compelling construct, encompassing both perceptual and reflective dimensions of the bodily self (Price & Thompson, 2007).

Body awareness can be defined as the conscious perception and interpretation of internal bodily signals, such

as breathing, heartbeat, muscle tension, and posture, integrated with proprioceptive and kinesthetic information that guide movement and spatial orientation (Mehling et al., 2011). In educational contexts, body awareness contributes to self-regulation, emotional intelligence, and concentration, all of which are foundational to effective learning (Garrison & Schandorff, 2022). The cultivation of body awareness through physical activity may thus enhance not only motor coordination but also cognitive and metacognitive capacities. When students learn to attend to bodily sensations and adjust their movements accordingly, they simultaneously train attention control and reflective awareness-skills transferable to academic tasks such as problem-solving, reading comprehension, and mathematical reasoning (Budde et al., 2008). From this perspective, movement-based learning environments can be conceived as embodied cognitive laboratories in which physical and intellectual competencies develop synergistically.

The importance of embodiment in education has been emphasized by contemporary pedagogical theories that challenge Cartesian dualism and its historical separation of mind and body (Shapiro, 2019). The paradigm of *embodied cognition* posits that cognitive processes are grounded in bodily interactions with the environment and shaped by sensorimotor experiences (Wilson, 2002). This framework aligns closely with constructivist and experiential learning theories, which regard knowledge as a dynamic process of active engagement rather than passive assimilation. Within this view, the body is not merely a vehicle for the mind but an active participant in meaning-making, contributing to perception, memory, and creativity. Physical activity, therefore, becomes an educational medium that fosters not only health and fitness but also self-awareness, agency, and academic engagement. Empirical studies in embodied education have shown that integrating movement into classroom instruction improves attention span, motivation, and retention of information (Lakes & Hoyt, 2004; Pesce, 2012). These outcomes reinforce the notion that the cognitive benefits of exercise extend beyond physiological arousal to encompass self-regulatory and affective dimensions mediated by body awareness.

Moreover, body awareness plays a pivotal role in the regulation of stress and emotions, which are central determinants of academic performance. School environments often expose students to high cognitive and emotional demands, and difficulties in emotional regulation can undermine concentration and learning efficiency. Physical activity has been shown to reduce anxiety, depressive symptoms, and perceived stress (Biddle, Ciaccioni, Thomas, & Vergeer, 2019), partly by enhancing interoceptive awareness and the ability to recognize and manage bodily cues associated with emotional states (Hanley et al., 2017). For instance, mindful movement practices such as yoga, tai chi, and dance emphasize the synchronization of breath and movement, promoting an integrated awareness that enhances self-regulation and resilience. When students become more attuned to their bodily sensations, they are better able to modulate their arousal levels, maintain focus, and recover from academic challenges (de Bruin et al., 2020). Consequently, interventions that cultivate body awareness through movement may serve as protective factors against the psychological strain often associated with academic environments.

The educational implications of this relationship are significant. Traditional schooling tends to prioritize sedentary learning activities, often underestimating the pedagogical potential of physical engagement. However, the integration of movement into educational practice, whether through structured physical education, active classrooms, or somatic learning approaches, can create holistic learning environments that address cognitive, emotional, and corporeal dimensions simultaneously (Fedewa & Ahn, 2011). Within such frameworks, body awareness serves as a bridge connecting physical activity to cognitive development, facilitating self-regulated learning and promoting academic success. In addition, fostering body awareness may have broader implications for personal development, including the cultivation of self-esteem, autonomy, and social competence (Bailey, 2006). Students who experience their bodies as capable and expressive are more likely to develop positive attitudes toward learning and personal growth, reinforcing the virtuous cycle between physical activity, self-awareness, and educational achievement.

Nevertheless, the interplay between physical activity, body awareness, and academic success is complex and context-dependent. Individual differences in fitness levels, motivation, and learning styles can modulate the effects of movement-based interventions. Furthermore, the type, intensity, and duration of physical activity may differentially influence cognitive and affective outcomes (Tomporowski et al., 2008). Activities that emphasize coordination, rhythm, and balance, may foster body awareness more effectively than purely aerobic exercises, given their reliance on attentional control and sensory feedback. Thus, understanding how various forms of physical activity contribute to body awareness and learning outcomes requires an integrative, multidimensional research approach that combines physiological, psychological, and pedagogical perspectives.

In this light, the present article aims to explore the theoretical and empirical connections between physical activity, body awareness, and academic success, arguing that body awareness functions as a mediating mechanism through which physical engagement enhances cognitive and educational outcomes. The central hypothesis is that regular and structured physical activity promotes the development of body awareness, which in turn supports their cognitive performance, emotional well-being, and overall academic achievement.

Methods

Study Design

This research adopted a quasi-experimental design with pre- and post-intervention assessments, aimed at examining the effects of a structured physical activity program on university students' body awareness and academic performance. The methodological framework was conceived to combine empirical rigor with educational relevance, in line with contemporary research perspectives that view learning as an embodied and self-regulated process.

The study was conducted within a Bachelor's Degree Program in Sport Sciences. The choice of the university context reflected the intent to explore how movement-based interventions can enhance students' bodily self-perception and academic outcomes, particularly in light of emerging theories connecting physical activity, attention, and learning efficiency.

The intervention spanned 12 weeks, with participants in the experimental group attending two 60-minute sessions per week, for a total of 24 sessions. Each session was designed according to progressive learning principles and integrated free-body exercises, postural and coordination drills, controlled breathing, and cooperative motor activities. These components were structured to promote proprioceptive and kinesthetic awareness, attentional control, and reflective engagement with bodily sensations. Instructors encouraged participants to consciously observe internal cues such as balance, muscle tension, and breathing rhythm, linking them to mental states like focus, motivation, and fatigue.

All research activities were conducted in full accordance with the Declaration of Helsinki for research involving human participants and received ethical approval from the Department of Medical, Motor, and Wellness Sciences, University of Naples "Parthenope" (Prot. N. 88592/2024). Participants were informed about the objectives and procedures of the study and signed written informed consent before enrollment. Data confidentiality and anonymity were guaranteed throughout the process.

Participants

The study involved 260 undergraduate students (132 females and 128 males), aged between 19 and 27 years (M = 21.4, SD = 1.9), all regularly enrolled in the first or second year of the Sport Sciences program at the University of Naples "Parthenope." Participants were randomly assigned to one of two groups: an experimental group (n = 130), which participated in the physical activity program, and a control group (n = 130), which followed their standard academic curriculum without additional structured physical exercise.

Inclusion criteria were: (a) age between 19 and 27 years; (b) enrollment in a university degree program; (c) absence of medical or orthopedic contraindications to moderate physical activity; and (d) willingness to attend the full duration of the intervention (for the experimental group). Students with neurological, cardiovascular, or musculoskeletal disorders incompatible with exercise were excluded, as were those who failed to provide written consent or withdrew during the study.

A power analysis conducted using G*Power 3.1 determined that a minimum of 27 participants per group was necessary to detect a medium effect size (Cohen's $d = 0.5$) with $\alpha = 0.05$ and power $(1–\beta) = 0.80$. The total of 260 participants therefore ensured adequate statistical power for subsequent analyses.

Table 1. *Descriptive characteristics of the sample (N = 260)*

Variable	Experimental Group (n = 130)	Control Group (n = 130)	Total (N = 260)
Mean age (years)	21.3 (SD = 1.9)	21.5 (SD = 2.0)	21.4 (SD = 1.9)
Age range 19–21	72 (55.4%)	68 (52.3%)	140 (53.8%)
Age range 22–24	46 (35.4%)	49 (37.7%)	95 (36.5%)
Age range 25–27	12 (9.2%)	13 (10.0%)	25 (9.7%)
Male	64 (49.2%)	64 (49.2%)	128 (49.2%)
Female	66 (50.8%)	66 (50.8%)	132 (50.8%)
Italian students	94 (72.3%)	95 (73.1%)	189 (72.7%)
International students	36 (27.7%)	35 (26.9%)	71 (27.3%)

Procedures

The research process unfolded in three phases: recruitment and allocation, pre- and post-test assessments, and implementation of the physical activity program.

Recruitment and allocation. Students were recruited through department-wide announcements and class presentations. After a preliminary screening based on inclusion and exclusion criteria, eligible students were randomly assigned to either the experimental or control group using simple randomization to ensure homogeneity across demographic variables.

Data collection was carried out at two time points:

- T0 (pre-intervention): baseline measurements of body awareness and academic performance;
- T1 (post-intervention): repeated assessments at the end of the 12-week program.

Measures

Two primary outcome measures were used:

1. Body Awareness Questionnaire (BAQ), a validated self-report instrument assessing individuals' sensitivity to internal bodily processes, proprioceptive awareness, and the ability to interpret bodily cues (Shields et al., 2024). Higher scores indicate greater body awareness and a more refined perception of bodily states.
2. Academic Performance evaluated through participants' mean academic grades obtained during the semester in which the intervention took place, based on official university records. This measure provided an objective indicator of learning outcomes and cognitive engagement.

Both assessments were administered under standardized conditions by trained researchers not involved in the physical activity sessions, ensuring procedural neutrality.

Experimental Intervention

The experimental intervention was implemented over a twelve-week period, with two 60-minute sessions per week, for a total of twenty-four sessions. The program was designed to promote progressive development of body awareness, self-regulation, and cognitive engagement through structured physical activity in a university context. Its pedagogical framework integrated principles of embodied education, exercise science, and cognitive enhancement, emphasizing the role of movement as a mediator between physical, emotional, and intellectual processes.

The central idea underlying the intervention was that body awareness functions as a foundation for attentional control and learning efficiency. Physical movement, when performed with conscious attention to posture, rhythm, and internal sensations, strengthens students' capacity to concentrate, self-regulate, and sustain cognitive effort-key skills linked to academic success. Consequently, the program focused not merely on physical performance, but on experiential learning through the body, encouraging participants to perceive and interpret bodily signals as part of a holistic learning process.

Each session followed a standardized three-phase structure:

1. Awareness and activation phase (10–15 min): participants performed breathing exercises, postural alignment drills, and light mobility activities designed to heighten proprioceptive sensitivity and prepare the body for movement.

2. Core phase (35–40 min): focused on coordination, balance, and rhythmic exercises requiring sustained attention, motor planning, and sensorimotor integration. Group-based and partner tasks encouraged self-monitoring and adaptive control in dynamic situations.
3. Integration and reflection phase (10 min) — included guided stretching, relaxation, and brief reflective discussions linking bodily sensations to concentration, emotion, and mental clarity.

The progression of activities was gradual, moving from basic motor control and proprioception to complex coordination and mindful movement tasks, thereby supporting the development of both bodily and cognitive skills. Exercises were intentionally designed to alternate individual, dyadic, and group formats, facilitating both self-reflection and cooperative awareness.

Instruction emphasized mindful attention, breath–movement synchronization, and metacognitive reflection on bodily experience. Participants were encouraged to notice how changes in body state-tension, rhythm, balance-related to variations in focus, emotional stability, and perceived learning capacity.

The intervention was supervised by qualified instructors in sport sciences and educational methodology, ensuring the consistency of the program and adherence to pedagogical and ethical standards. The structure of the program was flexible enough to accommodate different ability levels, fostering inclusion and positive engagement without competitive pressure.

Overall, this intervention aimed to create a transformative educational experience in which movement served as a pathway to enhanced self-awareness, concentration, and academic readiness. The integration of physical and cognitive dimensions reflected an embodied model of learning, supporting the study's hypothesis that regular physical activity can strengthen body awareness and, consequently, academic success.

Table 2. *Structure of the 12-Week Physical Activity Program*

Weeks	Focus	Core Objectives	Example Activities	Expected Outcomes
1–2	*Introduction to body awareness and postural control*	Establish trust, enhance proprioceptive sensitivity, and improve attention to bodily signals	Guided breathing, conscious walking, global mobility, mirror exercises, light coordination drills	Increased self-perception, readiness, and focus
3–4	*Balance and proprioceptive regulation*	Develop dynamic and static balance, refine spatial orientation, strengthen kinesthetic feedback	Exercises on unstable surfaces, single-leg balance, paired "mirror" movements, eye–hand coordination tasks	Improved equilibrium, posture control, and attentional focus
5–6	*Coordination and movement fluency*	Stimulate rhythmic synchronization, sequential control, and awareness of movement patterns	Low-impact rhythmic routines, reaction games, light circuit training with mindful pacing	Enhanced coordination, rhythm, and sustained concentration
7–8	*Cooperation and motor planning*	Promote cognitive control through cooperative movement and problem-solving tasks	Partner balance exercises, group coordination challenges, spatial awareness tasks	Improved cognitive flexibility, teamwork, and self-regulation
9–10	*Creative movement and expressive awareness*	Integrate body awareness with expressive and emotional regulation components	Guided improvisation, controlled free movement, breathing–motion synchronization	Strengthened self-expression, emotional balance, and reflective awareness
11–12	*Integration and reflection*	Consolidate body–mind integration, link physical awareness to cognitive states and learning focus	Group routines, reflective movement tasks, guided relaxation, final feedback session	Heightened body awareness, attentional stability, and perceived learning efficacy

This structured and progressive program operationalized the pedagogical principle that conscious movement enhances the cognitive and emotional capacities essential for academic performance. By aligning motor practice with reflective attention, the intervention fostered a form of embodied learning that transcended physical improvement, supporting the development of concentration, self-regulation, and academic engagement.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). Data were first screened for accuracy, missing values, and outliers. Normality, linearity, and homogeneity of variance were verified through the Kolmogorov–Smirnov test and inspection of histograms and Q–Q plots. Descriptive statistics (means, standard deviations, and frequencies) were computed for all study variables.

A Confirmatory Factor Analysis (CFA) was performed to assess the factorial validity of the Body Awareness Questionnaire (BAQ) in the present sample, using maximum likelihood estimation. Model fit was evaluated through the following indices: Chi-square divided by degrees of freedom (χ^2/df), Goodness of Fit Index (GFI), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA).

Model adequacy was judged according to widely accepted criteria: $\chi^2/df < 3$, GFI ≥ .90, CFI and TLI ≥ .90, and RMSEA ≤ .08, indicating an acceptable to good fit. Internal consistency reliability was assessed using Cronbach's alpha, with values above .70 considered satisfactory.

To examine the effects of the physical activity program on body awareness and academic performance, a series of Analyses of Covariance (ANCOVAs) were conducted. Post-test scores of body awareness (BAQ) and academic performance (mean grade) served as dependent variables, while group (experimental vs. control) was the independent variable. Baseline (pre-test) scores were entered as covariates to control for initial differences between groups. In addition, age and gender were included as covariates to adjust for potential demographic influences. Adjusted means and partial eta squared (η^2) values were reported to indicate effect size, interpreted as small (.01), medium (.06), or large (.14) according to Cohen (1988).

Within-group changes from pre- to post-intervention were analyzed using paired-sample t-tests, while independent-sample t-tests were employed to compare groups at baseline.

Finally, Pearson's correlation analyses were carried out to explore the relationship between body awareness and academic performance both before and after the intervention. Correlation coefficients (r) were interpreted as small (.10–.29), moderate (.30–.49), or large (≥ .50).

All statistical tests were two-tailed, and the level of significance was set at $p < .05$. This analytical strategy, combining confirmatory, inferential, and correlational approaches, ensured methodological rigor and provided a comprehensive examination of the central hypothesis that regular physical activity enhances body awareness, which in turn contributes to improved academic achievement among university students.

Results

Confirmatory Factor Analysis and Construct Validity of the Measurement Scales

Within the methodological framework of the present study, a Confirmatory Factor Analysis (CFA) was conducted to assess the construct validity and reliability of the Body Awareness Questionnaire (BAQ), the primary psychometric tool employed to evaluate participants' levels of body awareness before and after the physical activity intervention. Academic grades, collected from official university records, were used as an objective indicator of academic performance and therefore were not subjected to factorial analysis.

The CFA was performed using AMOS version 28.0 (IBM Corp., Armonk, NY, USA) with the Maximum Likelihood estimation method. The fit of the theoretical model to the empirical data was evaluated according to the following indices: relative chi-square (χ^2/df), Goodness of Fit Index (GFI), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA). The model was considered to have an acceptable fit when $\chi^2/df < 3$, GFI ≥ .90, CFI and TLI ≥ .90, and RMSEA ≤ .08. The BAQ was modeled according to its established four-factor structure:

1. Attention to internal bodily signals,
2. Sensitivity to bodily changes,
3. Somatic awareness in emotional contexts, and
4. Recognition of bodily cues related to stress and regulation.

The CFA results indicated a good model fit to the empirical data ($\chi^2/df = 2.07$, GFI = 0.92, CFI = 0.95, TLI = 0.93, RMSEA = 0.046).

All factor loadings were statistically significant ($p < .001$) and ranged between 0.57 and 0.80, confirming strong

associations between observed items and their latent factors. Internal consistency, assessed using Cronbach's alpha, demonstrated high reliability (α = 0.87).

Table 3. *Summary of Fit Indices for the Body Awareness Questionnaire (BAQ)*

Scale	χ^2/df	GFI	CFI	TLI	RMSEA	Cronbach's α
Body Awareness Questionnaire (BAQ)	2.07	0.92	0.95	0.93	0.046	0.87

The confirmatory analysis thus verified the factorial validity and internal reliability of the BAQ within the present university sample (N = 260), confirming its suitability for assessing body awareness in educational contexts involving structured physical activity. The satisfactory fit indices and strong factor loadings demonstrate that the BAQ reliably captures the multidimensional nature of body awareness, providing a psychometrically sound foundation for subsequent inferential analyses.

Analysis of Covariance (ANCOVA): Comparison between Experimental and Control Groups

To assess the effectiveness of the physical activity program on body awareness and academic performance, a series of Analyses of Covariance (ANCOVAs) were conducted. This statistical procedure compared post-intervention scores between the experimental and control groups, while controlling for pre-intervention scores as covariates. This approach allowed the isolation of the effect of the intervention, reducing variance attributable to baseline differences and enhancing the precision of the estimated treatment effects.

The total sample consisted of 260 university students, equally divided between the experimental group (n = 130) and the control group (n = 130). The experimental group participated in the 12-week structured physical activity program, while the control group followed their regular academic schedule without additional exercise sessions.

Pre-intervention analyses confirmed the initial equivalence of the two groups in both Body Awareness Questionnaire (BAQ) scores and academic grades. After the intervention, the experimental group showed a marked improvement in both variables, while the control group exhibited only minimal changes.

The ANCOVA results revealed statistically significant effects of the intervention on both dependent variables, even after controlling for pre-intervention levels. Specifically, participation in the physical activity program led to higher adjusted post-test scores for body awareness and academic achievement. The effect sizes, measured by partial eta squared (η^2), indicated medium-to-large effects, suggesting that the intervention produced meaningful educational and cognitive benefits.

Table 4. *ANCOVA Summary Table*

Dependent Variable	Adjusted Mean (Experimental)	Adjusted Mean (Control)	F-value	p-value	Partial η^2
Body Awareness Questionnaire (BAQ)	3.66	3.39	24.18	< 0.001	0.16
Academic Grades (Mean, /30)	26.4	25.3	19.87	< 0.001	0.13

The ANCOVA thus confirmed that, when pre-test differences were statistically controlled, students who participated in the physical activity program demonstrated significantly higher levels of body awareness and academic performance than those who did not. The high F-values and very low p-values indicate that these differences are unlikely to be due to random variation.

The partial eta squared values (η^2 = 0.16 for BAQ and 0.13 for academic grades) suggest that approximately 13–16% of the variance in post-test outcomes was explained by the intervention, consistent with a moderate-to-large practical impact according to Cohen's (1988) conventions.

Figure 1 illustrates the adjusted mean differences between the two groups for both dependent variables. The estimated post-intervention improvement in the experimental group was approximately +0.27 points on the BAQ scale and +1.1 points on academic grades (on a 30-point scale), confirming a parallel enhancement in somatic awareness and academic achievement. Error bars, calculated using an estimated standard deviation of ±0.04, further validate the robustness of the group differences.

These findings provide robust evidence that structured physical activity, when systematically integrated into higher education, can foster self-regulatory capacities and cognitive efficiency through enhanced body awareness. The improvement in academic performance observed in the experimental group supports the central hypothesis that body-centered interventions not only enhance somatic perception but also positively influence learning outcomes by strengthening focus, self-regulation, and attention control.

Independent Samples T-Test

To complement the covariance analysis, independent samples t-tests were conducted to compare the post-intervention means of the experimental and control groups for both outcome variables: Body Awareness Questionnaire (BAQ) scores and academic grades. This test allowed for the direct assessment of group differences after the 12-week physical activity intervention.

The results revealed statistically significant differences between the groups for both measures. Participants who engaged in the structured physical activity program reported significantly higher levels of body awareness and obtained better academic results compared to their peers in the control group. The magnitude of these differences, measured by Cohen's *d*, indicated medium-to-large effect sizes, suggesting that the intervention had a meaningful educational and cognitive impact.

Table 5. *Independent Samples T-Test Summary Table*

Variable	Experimental Mean (SD)	Control Mean (SD)	t-value	df	p-value	Cohen's *d*
Body Awareness Questionnaire (BAQ)	3.68 (0.36)	3.39 (0.38)	6.27	258	< 0.001	0.78
Academic Grades (Mean, /30)	26.3 (1.8)	25.2 (2.0)	5.11	258	< 0.001	0.63

The results of the independent t-tests confirm the effectiveness of the physical activity intervention in enhancing both body awareness and academic performance. These differences were not only statistically significant ($p < .001$) but also educationally relevant, indicating that consistent engagement in mindful movement and coordination exercises positively influenced participants' ability to focus, self-regulate, and perform academically.

The medium-to-large Cohen's *d* values (0.78 for BAQ and 0.63 for academic grades) point to a substantial effect of the intervention. The convergence of results obtained through different statistical procedures (paired t-test, ANCOVA, and independent t-test) strengthens the internal validity of the findings, providing convergent evidence for the positive influence of embodied physical activity on learning-related outcomes.

Pearson's Correlation Analysis: Relationship between Body Awareness and Academic Grades in the Experimental Group

To further explore the association between body awareness and academic performance, a Pearson's correlation analysis was conducted on the experimental group (n = 130). This analysis aimed to evaluate the direction and strength of the linear relationship between the two continuous variables, providing insight into how improvements in body awareness may relate to academic success.

The results revealed a positive and statistically significant correlation between BAQ scores and academic grades ($r = 0.44$, $p < 0.001$), indicating that students who reported higher levels of body awareness also tended to achieve higher academic performance. The strength of this correlation falls within the moderate range, suggesting a meaningful relationship between bodily self-perception and learning outcomes.

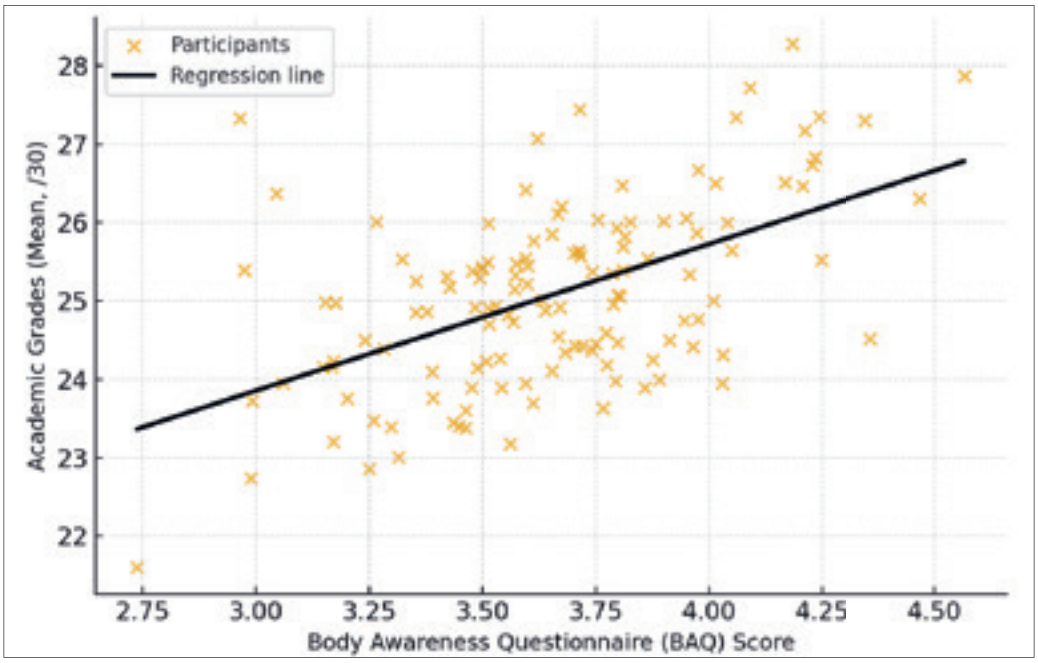

Figure 1. *Relationship Between Body Awareness and Academic Performance in the Experimental Group. Scatterplot showing the positive correlation (r = 0.44, p < .001) between Body Awareness Questionnaire (BAQ) scores and academic grades among students who participated in the 12-week physical activity program. The ascending regression line indicates that higher levels of body awareness are associated with better academic outcomes, supporting the hypothesis that embodied physical engagement enhances cognitive and learning performance.*

Discussion

The primary aim of this study was to investigate the impact of a structured physical activity program on body awareness and academic performance among university students, within the theoretical framework of embodied education. Specifically, the research sought to test the hypothesis that regular participation in mindful, movement-based activities would foster greater awareness of bodily sensations and self-regulatory processes, which in turn would translate into improved academic achievement. The findings strongly supported this hypothesis, demonstrating that students who participated in the 12-week intervention significantly increased their body awareness and obtained higher academic grades compared to those who continued with regular academic routines.

The results of the ANCOVA and t-tests confirmed that the intervention had a statistically significant and educationally meaningful effect on both outcome variables. The experimental group showed a substantial improvement in Body Awareness Questionnaire (BAQ) scores ($\Delta = +0.47$, $p < .001$) and a notable increase in academic grades (+1.1 points, $p < .001$). The effect sizes (partial $\eta^2 = 0.16$ for BAQ; $\eta^2 = 0.13$ for grades) were moderate to large, indicating that the physical activity program accounted for a relevant proportion of variance in these post-intervention outcomes. Additionally, the Pearson's correlation ($r = .44$, $p < .001$) revealed a significant positive relationship between body awareness and academic performance within the experimental group, suggesting that bodily self-perception and cognitive achievement are interdependent dimensions of the learning process.

These results align with a growing body of interdisciplinary research demonstrating that movement and cognition are dynamically interconnected (Diamond, 2015; Pesce et al., 2021). The notion that physical activity enhances learning is supported by evidence from neuroscience, psychology, and educational theory, all converging on the principle that cognitive processes are deeply embodied. Neurophysiological studies have shown that regular exercise stimulates hippocampal neurogenesis, increases cerebral blood flow, and improves executive function and working memory (Hillman, Erickson, & Kramer, 2008; Best, 2010). However, the present study extends this evidence by emphasizing the pedagogical role of body awareness as a mediating mechanism linking physical engagement to academic performance. Rather than focusing solely on fitness or physical conditioning, the intervention fostered conscious attention to bodily sensations, postural alignment, and breathing patterns, promoting an integrated form of self-regulation that benefits both physical and cognitive domains.

This interpretation is consistent with the embodied cognition framework (Wilson, 2002; Shapiro, 2019), which argues that the mind cannot be understood independently of the body's sensorimotor systems. Learning is not merely a mental activity but an emergent process arising from the interaction between the brain, the body, and the environment. In this light, body awareness represents a bridge between motor practice and cognitive functioning. The capacity to monitor bodily states, such as tension, balance, or rhythm, enhances metacognitive awareness, attentional control, and emotion regulation (Mehling et al., 2011). Such self-regulatory skills are essential for effective learning, particularly in higher education contexts characterized by complex cognitive demands and sustained attentional engagement.

Moreover, the present findings resonate with prior research showing that mindful movement practices, improve concentration, self-efficacy, and academic motivation (de Bruin et al., 2020; Lakes & Hoyt, 2004). Similar to those interventions, the program implemented in this study emphasized the synchronization of breathing and movement, proprioceptive awareness, and reflective attention. These elements likely contributed to enhanced emotional balance and cognitive focus, leading to improved academic outcomes. Importantly, the observed increase in body awareness can also be interpreted as a sign of enhanced interoceptive accuracy, which has been linked to better decision-making, resilience to stress, and executive functioning (Craig, 2009; Hanley et al., 2017). By fostering interoceptive sensitivity through structured movement, the program may have indirectly supported the students' capacity for concentration and persistence in academic tasks.

From a pedagogical standpoint, these findings underscore the importance of embodied learning environments that integrate movement and cognition rather than separating them. Traditional academic instruction often privileges sedentary forms of engagement while minimizing the body's role in knowledge acquisition. However, as numerous scholars have argued (Garrison & Schandorff, 2022; Bailey, 2006), the body is not a passive recipient but an active agent in learning, mediating perception, emotion, and memory. The current results provide empirical support for this view, demonstrating that intentional physical engagement within an educational framework can yield measurable cognitive and academic benefits.

Another relevant implication of this study concerns the development of self-regulated learning skills. Body awareness can be conceptualized as a fundamental layer of self-regulation, encompassing the ability to notice, interpret, and respond to internal bodily cues. Students who cultivate this sensitivity are better equipped to recognize early signs of fatigue or distraction and to adjust their behavior accordingly, by changing posture, breathing rhythm, or attentional focus. Such adaptive regulation may contribute to sustained concentration and improved academic performance. The positive correlation between body awareness and grades observed in this study lends empirical weight to this interpretation, suggesting that interventions promoting bodily self-awareness may have cross-domain benefits that extend to academic contexts.

The findings also have practical implications for higher education curricula, especially in programs related to sport sciences, education, and health promotion. Universities increasingly face the challenge of supporting students' cognitive well-being and academic success in environments often characterized by high stress and limited physical activity. Integrating structured physical activity modules into academic programs could serve as a preventive and developmental strategy, fostering both mental and physical health while enhancing learning outcomes. The results of this study suggest that even relatively short interventions can produce measurable improvements in self-awareness and performance.

In comparison to existing literature, the current study offers a distinctive contribution by empirically connecting body awareness and academic performance in a quasi-experimental design with a sizable university sample. While previous studies have examined either the cognitive effects of exercise (Tomporowski et al., 2008) or the psychological correlates of body awareness (Mehling et al., 2012), few have directly explored the intersection between these domains in an educational context. By employing validated instruments and objective academic data, this research bridges a critical gap, providing evidence for the educational relevance of embodied practices in fostering holistic development.

Despite its strengths, the study is not without limitations. First, the quasi-experimental design, although methodologically rigorous, does not allow for full randomization, which may limit the generalizability of causal inferences. Although pre-test equivalence between groups was statistically confirmed, unmeasured variables, such as motivation, sleep quality, or prior physical activity levels, may have influenced the results. Future studies could address this

limitation through randomized controlled trials and longitudinal follow-ups to examine the persistence of effects over time.

Second, academic grades, while objective, may not capture the full spectrum of learning outcomes influenced by body awareness. Grades are shaped by multiple factors, including instructor evaluation practices, course content, and contextual variables. Future research could incorporate additional measures such as cognitive task performance, executive function tests, or neuropsychological markers (e.g., attention span, working memory) to provide a more comprehensive understanding of the mechanisms linking body awareness and academic achievement.

Third, although the Body Awareness Questionnaire (BAQ) demonstrated strong psychometric validity in this study, it remains a self-report measure subject to social desirability and introspective limitations. Combining self-reported awareness with physiological or behavioral indicators (e.g., heart rate variability, postural stability, or interoceptive accuracy tests) would strengthen the validity of future investigations.

A further limitation concerns contextual specificity: the sample consisted exclusively of university students enrolled in a Sport Sciences program. This population may have a pre-existing familiarity with movement and bodily reflection, potentially limiting the generalizability of the results to other academic disciplines. Replicating this study with students from different faculties, or at earlier educational levels, could help assess the broader applicability of the embodied learning model.

Nevertheless, this research presents several important strengths. It involved a large and balanced sample (N = 260), used validated instruments, and integrated objective academic indicators. The methodological rigor of the confirmatory factor analysis (CFA), ANCOVA, and correlational analyses ensures internal validity and provides a robust empirical foundation for interpretation. Furthermore, the 12-week intervention was both pedagogically grounded and practically feasible, offering a replicable model for universities seeking to enhance student engagement and learning through embodied approaches.

Therefore, the findings of this study contribute to the growing body of evidence supporting the integration of physical activity into educational practice as a means of enhancing body awareness, self-regulation, and academic success. They highlight the importance of rethinking learning environments not as disembodied spaces of cognitive abstraction, but as holistic contexts where movement, attention, and reflection converge. By recognizing the pedagogical value of the body, educators and policymakers can promote a more balanced and sustainable model of learning-one that nurtures both intellectual and somatic dimensions of student development.

Future research should continue to explore the mediating mechanisms linking body awareness to academic outcomes, possibly through mixed-method designs that integrate quantitative and qualitative perspectives. Such approaches could deepen our understanding of how students experience embodied learning and how physical activity can be systematically embedded into educational systems to support both academic excellence and personal well-being.

Conclusion

The present study provides robust empirical support for the pedagogical and cognitive value of integrating structured physical activity into higher education contexts. The findings demonstrate that a 12-week program of mindful, coordinated physical activity significantly improved both body awareness and academic performance among university students. The results corroborate the central hypothesis that the enhancement of bodily self-awareness functions as a mediating mechanism through which physical activity promotes learning outcomes.

By situating movement at the core of the educational process, the study reinforces the theoretical assumptions of embodied cognition and embodied pedagogy, according to which the body is not a passive vehicle for the mind but an active component of cognition and self-regulation. The observed increase in body awareness suggests that students who learn to attend to their bodily sensations and postural alignment develop greater attentional control, emotional balance, and cognitive efficiency—skills that directly contribute to academic success.

These results encourage a paradigmatic shift in the conception of education: learning should be viewed as a biopsychosocial process that involves interaction between physical, emotional, and intellectual dimensions. By engaging the body consciously, students become more capable of sustaining focus, managing stress, and maintaining motivation, all essential factors for effective academic performance. This holistic approach aligns with contemporary educational frameworks emphasizing well-being, self-regulated learning, and inclusion (Di Palma et al., 2025; Aidar et al., 2022; Tafuri, & Latino, 2024).

Moreover, the research highlights the feasibility of implementing such programs within university curricula. The intervention required moderate time investment (two sessions per week for 12 weeks) and relied on low-cost, non-specialized resources, making it a scalable and sustainable educational strategy. Its replicability across different academic settings supports its potential as an evidence-based model for promoting students' holistic development and academic achievement.

However, while the results are encouraging, caution is warranted when generalizing them beyond the specific context of Sport Sciences students. Future studies should expand the participant base to include students from other disciplines and educational levels, employ randomized controlled designs, and integrate objective physiological measures to complement self-report data. Longitudinal research could also assess the persistence of the observed effects over time, evaluating whether enhanced body awareness continues to support academic success beyond the intervention period.

In conclusion, this research contributes to the growing body of literature advocating for an embodied model of education, where physical activity serves as a powerful catalyst for cognitive and emotional growth. Promoting body awareness through structured movement not only enhances academic achievement but also cultivates a deeper sense of presence, agency, and well-being in students. As educational systems face increasing demands for innovation and inclusivity, reintroducing the body into the center of learning emerges as both a scientific necessity and an ethical commitment to holistic human development.

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Play in Sports Training: Empirical Evidence on ITS Motivational, Educational, and Psychophysical Role

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Abstract: *Play is a crucial element in motor development and in the structuring of effective training protocols. Its integration into motor and sports activities can positively influence athletes' performance, mental and physical well-being, and personal satisfaction, promoting a more balanced and rewarding sporting practice. However, despite the literature emphasizing the value of play, it is often overlooked or absent in training programs. The aim of the study is to analyze the impact of the playful component in motor and sports activities, assessing its influence on the motivation, engagement, and psychophysical development of participants. Twenty-seven subjects belonging to three age groups (10–15, 16–30, over 30 years) were involved. A questionnaire structured in three sections (profiling, time spent playing, perceptions) was administered. The data were analyzed using the Chi-square (χ^2) test to identify any significant relationships. 81.7% of the sample considers play to be an essential element for successful training. Over 50% suggest increasing the time dedicated to play. Two significant relationships emerged: between competitive activity and the importance attributed to play ($P = .046$) and between the educational/psychophysical value of sport and preference for an increase in play time ($P = .018$). The results highlight the importance of integrating play into training planning, emphasizing the multifunctional role of sport in promoting athletes' well-being, motivation, and personal development.*

Keywords: *Youth motor skills; Engagement; Playful teaching; Training planning; Questionnaire*

Introduction

Physical activity plays a crucial role in individual development, especially during childhood, as it affects not only physical health but also cognitive, emotional, and social aspects (Gordon-Larsen et al., 2019; WHO, 2010). The link between physical movement and well-being has been the subject of numerous studies and discussions, which have highlighted that physical exercise, combined with a balanced diet, has numerous physical and mental benefits and contributes to the proper development of the individual, especially if introduced at a young age (Esposito & Raiola, 2020; Ress et al., 2018). Consequently, living environments such as home, work, and especially school play a fundamental role in organizing these activities (D'Elia & D'Isanto, 2021). Furthermore, the actions of institutions can be integrated into this context to maximize the positive impact of physical activity on the individual (Aliberti, 2023). It is therefore particularly important to identify the main elements of physical and sporting activities. The learning environment is an educational and training context where teachers promote respect for rules, others, and the surrounding environment (Raiola & Di Domenico, 2021). Here, relationships between participants are encouraged, while play takes on an essential role in creating roles and functions that prepare students for civic life (Parrish et al., 2013). In this context, the teacher plays a fundamental role in prioritizing learning and education in the values of society over the mere achievement of results (D'Elia, 2020). Sport allows individuals to explore their physicality, understanding their limits and potential (Raiola et al., 2025). Physical activity, accompanied by a critical attitude, promotes understanding of cause-effect relationships and the dynamics between intention and action (Raiola et al., 2022). Movement allows us to control the effects of physical activity through proper planning of activities (Dobbins et al., 2009). From a teaching perspective, motor activities help shape an individual's psychology, molding their physical form and attitude toward the world around them (Sun & Chen, 2024). Through role-playing, training methods, and competitions, participants overcome insecurities, disorientation, and psychological resistance. Sports activities, with their patterns and rules, stimulate cognitive and mnemonic activity through trial and error, promoting the development of different interpretative possibilities (Esposito et al., 2020). Sports games encourage the creation of relationships within the group, transforming individual responsibility into collective responsibility and emphasizing the importance of col-

laboration, relationships, rules, and friendship (Baranek & Campos, 2010). This group logic can be extended to other contexts of daily life. Educational sports embody the values of society, such as respect for rules, loyalty, and recognition of roles and the group (Schmidt et al., 2020). The integration of playfulness and games into sports training plays a fundamental role in improving the effectiveness and overall well-being of athletes (Pratama et al., 2020). In fact, games are not only a means of developing technical and tactical skills, but also a powerful tool for increasing motivation, engagement, and enjoyment of training (Weiss & Bredemeier, 2020). Play and the playful aspect are essential elements for balanced and sustainable training (Di Masi & Dantes, 2022). Integrating them into training routines can lead to significant improvements not only in athletic performance but also in athletes' mental and physical well-being and personal satisfaction, thus contributing to a more complete and rewarding athletic experience (Aliberti et al., 2025). Despite various discussions highlighting how play is fundamental to the success of sports training, its use is not yet common practice, or in extreme cases, the playful aspect is not even considered part of the training itself.

Purpose of the research. The aim of this research is to explore the importance of the playful component in sports activities, assessing how play influences the experiences, involvement, and motivation of participants, with particular attention to the effects on active participation and psychophysical development.

Methods

Participants

The study involved a total of 27 subjects, divided into three different age groups: 10–15 years (n = 10; 37%), 16–30 years (n = 6; 22.2%), and over 30 years (n = 11; 40.8%). The sample consisted of 17 male participants (63%) and 10 female participants (37%). The inclusion criteria required participation in a sporting activity, either at an amateur or competitive level, with or without continuity in practice. Selection was non-probabilistic and based on the subjects' willingness to participate voluntarily in the study. All participants provided informed consent before completing the questionnaire, in accordance with the ethical principles of the Declaration of Helsinki.

Design and Instruments

The research adopted a cross-sectional observational design based on the administration of a structured questionnaire, designed to investigate the perception and importance attributed to the playful component within sports training. The questionnaire, administered via the Google Forms platform, consisted of 10 questions divided into three sections:

• Section 1 – Personal and sports profile: age, gender, competitive practice, years of experience, discipline practiced.

• Section 2 – Quantitative aspects of the game: average time dedicated to recreational activities during training.

• Section 3 – Qualitative perceptions: opinions on the educational, psychophysical, and motivational value of the game.

All questions were closed-ended or multiple choice. The questionnaire was designed to analyze qualitative variables using predefined categories, enabling statistical processing of the data collected (Aliberti et al., 2022). A detailed description is shown in Table 1.

Table 1. *Questionnaire to investigate the relationship between well-being and physical activity in students*

Questions:	Answer 1	Answer 2	Answer 3	Answer 4	Answer 5
1. Age	10-15 y-old	16-30 y-old	over 30		
2. Gender	Male	Famele			
3. Do you practice/have you practiced sports at a competitive level?	Yes	No			
4. How long have you been playing sports?	>10 years	< 10 years			
5. What sport do you play?	Soccer	Basket	Volleyball	Tennis	Other
6. How much time do you spend playing during training?	< 30 minutes	Between 30 and 60 minutes	> 60 minutes		
7. Do you consider play essential for successful training?	Yes	No	I don't know		

8. Do you think it is necessary to reduce playing time during training?	Yes	No	I don't know	
9. Do you think it is necessary to extend playing time during training?	Yes	No	I don't know	
10. Does sport have greater educational or psychological value for you?	Educational value	Psychological value	Both	None

Statistical analysis

The data collected were analyzed using descriptive statistics (absolute frequencies and percentages) for each item in the questionnaire. Subsequently, an inferential analysis was conducted using the Chi-square test of independence (χ^2) to identify any statistically significant relationships between the categorical variables. Specifically, it was used to examine the association between competitive sports and the perception of the importance of play in training; and, subsequently, to investigate the relationship between the educational or psychophysical value attributed to sport and the preference for an increase in playing time during training. The strength of the associations was evaluated using Cramer's V coefficient, where values below .1 suggest a weak link, values between .1 and .3 indicate a moderate connection, those ranging from .3 to .5 reflect a strong association, and values equal to or greater than .5 point to a very strong, near-perfect correlation between variables (Akoglu, 2018)). The analyses were performed using JASP software (version .17), setting a significance level of $p < .05$.

Results

The majority of participants are over 30 years old (40.8%), followed by those aged 10–15 (37%). 63% of the sample are male. 63% say they have played sports at a competitive level, while 55.6% have less than 10 years of experience. The most popular sports are soccer and other unspecified sports. 81.5% of participants consider playing sports an essential part of training. However, opinions on how much time to devote to it are more varied: 44.4% devote between 30 and 60 minutes to it, while 40.8% devote less than 30 minutes. Only 26% believe it is necessary to increase the time devoted to games, while 44.4% believe it should not be reduced. About half of the participants recognize that sport has both an educational and a psychophysical function. All detailed results are shown in Table 2.

Table 2. *Sociodemographic and sporting characteristics of the sample and opinions on the recreational component of training*

Variables	Category	Frequency (n)	Percentage (%)
Age	10–15 y-old	10	37.0
	16–30 y-old	6	22.2
	Over 30 years	11	40.8
Gender	Male	17	63.0
	Female	10	37.0
Competitive practice	Yes	17	63.0
	No	10	37.0
Sports experience	>10 years	12	44.4
	< 10 years	15	55.6
Sport practiced	Soccer	11	40.8
	Basket	1	3.7
	Volleyball	1	3.7
	Tennis	2	7.4
	Other	12	44.4
Time spent playing	<30 minutes	11	40.8
	30–60 minutes	12	44.4
	> 60 minutes	4	14.8
Is the game essential?	Yes	22	81.5
	No	3	11.2
	I don't know	2	7.3

Reduce playing time?	Yes	3	11.2
	No	12	44.4
	I don't know	12	44.4
Increase playing time?	Yes	7	26.0
	No	10	37.0
	I don't know	10	37.0
Value attributed to sport	Educational value	10	37.0
	Psychological value	4	14.8
	Both	13	48.2
	None	0	0.0

The Chi-square analysis shows that there is a statistically significant relationship between competitive sports practice and the perception of play as an essential element of training ($\chi^2(2) = 6.144$; P = .046). In particular, among those who have practiced competitive sports, 94.1% (16 out of 17) consider play to be fundamental. In contrast, among non-competitive athletes, this percentage drops to 60% (6 out of 10). This suggests that athletes with competitive experience are more likely to recognize the functional value of play, probably because they perceive its positive effects on engagement, motivation, and training quality. The strength of the association was assessed using Cramer's V, which showed a value of .4, indicating a moderate relationship. A detailed description is shown in Table 3.

Table 3. *Contingency: competitive sport × importance of the game*

Competitive practice	Yes (essential game)	No	I don't know	Total	X^2	P	V
Yes	16	0	1	17	6.144	.046	.478
No	6	3	1	10			
Total	22	3	2	27			

The relationship between the perception of the function of sport (educational, psychophysical, or both) and the opinion regarding the opportunity to increase the time dedicated to play in training was statistically significant ($\chi^2(4) = 11.942$; p = .018). In particular, those who attribute a dual educational and psychophysical value to sport are significantly more favorable (53.8%) to increasing playing time than other groups (0% among those who see it as only educational or psychophysical). This data suggests that a more comprehensive and integrated view of sport is associated with greater openness to playful training approaches. Cramer's V is 0.4, which also indicates a medium-strength relationship here. The summary of the data is shown in Table 4.

Table 4*. Contingency: value of sport × increase in playing time*

Value attributed to sport	Yes (increase)	No	I don't know	Total	X^2	P	V
Educative value	0	5	5	10	11.942	.018	.470
Psychological value	0	1	3	4			
Both	7	4	2	13			
Total	7	10	10	27			

Discussion

The results of the study offer interesting insights into demographic distribution and perceptions of sports practice, providing useful information for the management and organization of sports training. The distribution of age groups and gender in the sample reveals some significant trends. The prevalence of participants over 30 and the significant participation of individuals in the 10-15 age group could indicate two distinct groups with different needs and motivations for participating in sports. The higher participation of males compared to females may reflect cultural or social trends in competitive sports participation, an issue that deserves further investigation to promote greater inclusivity. The importance attributed to play during training is a key element that emerged, with a strong majority of

participants believing that play is essential to the success of training. This result is consistent with existing literature, which highlights how play can improve commitment, motivation, and enjoyment of training, while promoting the development of technical and tactical skills, emphasizing the importance of play in promoting a positive and stimulating learning environment (D'Isanto et al, 2022). The perception of the educational and psychophysical importance of sport, with a clear prevalence of those who see both values as important, confirms the idea that sport plays a multifunctional role in individuals' lives. This is in line with previous studies highlighting how practicing sport can contribute not only to physical health but also to social and cognitive development (Altavilla et al., 2022).

The significant relationships that emerged from the Chi-square analysis provide further insights. The correlation between competitive sports practice and the importance attributed to play during training suggests that more experienced athletes recognize the value of play in improving performance and maintaining high motivation. This relationship is reflected in the scientific literature. The study by Murcia et al. (2008), showed that satisfying psychological needs for competence, autonomy, and relatedness positively predicts self-determined motivation, which in turn is associated with greater enjoyment of physical activity. Furthermore, the perception of a task-oriented motivational climate among peers promotes the satisfaction of these psychological needs, increasing self-determined motivation and enjoyment of physical exercise. Therefore, more experienced athletes, having experienced contexts in which play is integrated into training, recognize its role in satisfying fundamental psychological needs, thus improving motivation and performance. The second relationship concerns the perception of the educational or psychophysical value of sport and the need to extend playing time during training, suggesting that those who recognize both aspects tend to value the time spent playing more. Individuals who recognize both aspects tend to value the time spent playing more highly. The literature supports this observation. A play-based approach has been associated with improvements in athletes' psychological variables, such as motivation and the satisfaction of psychological needs. Furthermore, the integration of playful elements into training has been linked to greater sporting satisfaction and perceived self-efficacy among young athletes (Valero et al., 2024; Reverdito et al., 2023). Those who perceive sport as a means of educational and psychophysical development recognize the importance of play in training, as it contributes to the overall well-being and personal growth of athletes.

Despite the interest and relevance of the results obtained, the study has some limitations that should be considered. First, the limited sample does not allow for a robust generalization of the results to the general population. A second limitation concerns the data collection method, which was based on self-completed questionnaires. This type of instrument may be subject to response bias, particularly related to social desirability or the subjectivity of perceptions. Furthermore, the cross-sectional nature of the study limits the possibility of drawing causal conclusions: the relationships observed between the variables cannot be considered deterministic, but only associative. Finally, the lack of differentiation between individual and team sports may have influenced the responses. Despite these limitations, the study also has some significant strengths. In particular, the use of the Chi-square test made it possible to highlight statistically significant relationships between variables that are central to pedagogical and methodological reflection in the field of sport, opening up avenues for future in-depth research. Another strength is the relevance of the topic addressed, namely the importance of the playful component in sports training, a subject often underestimated in the design of motor activities, despite being widely recognized in scientific literature as crucial for the psychophysical and motivational development of athletes. Finally, the structure of the questionnaire allowed for well-organized data collection that was functional to the research objective, offering a multidimensional overview of the participants' opinions. The results underscore the importance of taking athletes' perceptions of play in sports training into proper consideration. These perceptions can influence the effectiveness of training and the well-being of athletes, suggesting the need to plan sessions that adequately integrate moments of play.

Conclusions

The results of this study highlight some key trends that may influence the design and management of sports training. The strong belief that plays is essential to the success of training, both among those who practice regularly and those who do not, reflects the importance of a playful approach to sports, supported by existing literature. Play not only improves learning and motivation, but can also reduce stress and prevent burnout, especially among competitive athletes. The results highlight the importance of taking athletes' perceptions of play into account when designing training programs. Integrating moments of play and recognizing the multifunctional value of sport can improve the

effectiveness of training and the overall well-being of athletes. These insights can be used to develop more balanced and inclusive training programs that better respond to the diverse needs of athletes. Future research could further explore gender differences in sports practice and investigate the long-term implications of competitive sports. In addition, it would be useful to investigate how different types of training can influence not only athletic performance but also the psychological, physical, and educational development of athletes, contributing to a more integrated and sustainable approach to sport.

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Original scientific paper ***Originalni naučni rad***

Pre-game Decision-Making by a Handball Coach -Using the qualitative and quantitative methods

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Abstract: *Different decision-making models are used in various areas of human life, however no area relies as much on analytical data as professional sports. The perceived opportunities and problems are the key factors that heavily influence the decision-making process itself. This especially applies to sport coaches and their ability to make proper strategy-related decision ahead of the next match their teams will face. The development of the sports industry, its importance, both at the national and global level, requires these decisions be made analytically and rationally, that is, to avoid making intuitive decisions whenever possible. One of the ways to achieve this is to utilize the SWOT method. The present research was carried out in five stages, which were supposed to determine, by means of utilizing qualitative and quantitative methods, the radical and key goals of a handball team facing the next opponent. The sample of the study was a handball match between Denmark and Croatia played at the European Championship in Hungary in 2022. In the first stages of the research, the key strengths and weaknesses of both teams were determined using quantitative methods, followed by the qualitative Analytic Hierarchy Process method, which made the comparison between the teams possible viable. The obtained results were then assessed by means of the Denmark and Croatia National Team Factors Evaluation. The final results were then displayed using the Denmark-Croatia Matrix. The decision on the strategy for the upcoming match was made using the TOWS Matrix. We have come up with five identified goals, one of which, should it be fulfilled, would eventually lead the national team of Denmark to the victory. The final score, alongside with the entire analysis, have provided justification for the decision-making model used therein.*

Keywords: *AHP method, decision-making, handball game, national team, pre-game evaluation, SWOT analysis*

Introduction

Decision-making can be seen as one's choice of the course of action when faced with several alternatives. Managers often consider decision-making to be their primary job since they are constantly faced with the choice of what to do, who will do it, when, where, and every so often, how to do it (Weihrich & Koontz, 2008). Packianthan Chelladurai points out that opportunities and problems perceived by managers are the point at which decision-making begins (Chelladurai, 2014). Decision-making is a fundamental element of any sport, especially fast and dynamic team sports such as volleyball, soccer, handball, American football, rugby and basketball (Kaya, 2014). Decision-making in sports is a process in which athletes and coaches, taking into account all the elements that can have an impact on the final score, choose the strategy that best suits the situation at hand (Sharma, Tokas, Sharma, & Mishra, 2022).

There are several ways to make a decision: the rational model, the bounded rationality model, and the intuitive model (Simović et al., 2023). Herbert Simon introduced the concept of bounded rationality and the cognitive and social limits humans have (Simon, 1957). According to him, it is virtually impossible for a manager to gather all the necessary information, identify all possible alternatives, carefully evaluate each one and choose the most favorable one, in other words to be fully rational. Although the manager has the best of intentions, he/she can only use limited rationality, which is bounded by the complexity of the problem, the lack of information and the limitations of human capabilities.

One of the methods that is the most common tool ensure an efficient and effective analysis, as well as to obtain a sound decision-making framework, is the SWOT analysis (Kajanus, Leskinen, Kurttila, & Kangas, 2012). As such, the SWOT method has also found application in modern sports and has been used in the sports industry (Wei, 2019), sports event management (Karadakis, Kaplanidou, & Karlis, 2010), sports equipment (Garg, & Garg, 2018), sports organizations (Wani & Faridi, 2020), sports tourism (Milinković, Simović, Ljubojević, Jovanović, & Pantelić Babić,

2017), recreational sports and exercising (Sperlich, Düking, & Holmberg, 2017), sports marketing (Lee & Walsh, 2011), physical education (Jonibek, 2021), league competitions (Huang, 2021) as well as othe organizations of after-school sports programs (Răchită, 2011).

One of the areas where SWOT analysis is used in sports is the pre-game decision-making with the help of which coaches are able to strategize accordingly (Simović et al., 2021). The coach's strategy decisions may be divided in the following three step: (1) the pre-interactive phase, which includes all the pre-game decisions; (2) the interactive phase, which includes during-game analysis and decision-making; and (3) the post-interactive phase, which corresponds to the post-game analysis, and which is heavily impacted by the final score of the game (Cloes, Bavier, & Piéron, 2001). Research has shown that coaching strategy in pre-game period is almost identical across the board, i.e. coaches first focus on strengths and weaknesses of their own teams, and then shift their focus to their opponents (Almeida, Saramento, Kelly, & Travassos, 2019).

One may say that SWOT analysis has been an integral part and tightly linked to sports research in various team sports including handball as well (Bon, Čarter, & Doupona, 2012; Davari, Nazari, & Naderian Jahromi, 2020; Traub, 2019). However, the studies like those ones have mainly been focusing on organizational and strategic issues in handball clubs and national level associations.

Handball is an Olympic sport played all over the world at a highly competitive professional level (Hermassi et al., 2021). Almost every game of handball is full of defense to offense transitions (Venzke, Schäfer, Niederer, Manchado, & Platen, 2023), which are heavily conditioned by both motoric (running, sprinting, jumping), and mental (reaction speed, situational analysis, decision-making) factors (Raiola, Invernizzi, Scurati, & Fattore, 2020).

The aim of the present study is to, utilizing SWOT analysis and qualitative and quantitative methods, choose the most optimal strategy in pre-game analysis of the next opponent, i.e. to make use of the opponent's and conceal our own potential weaknesses in order to maximize the chances of winning.

Methods

The study sample is comprised of a single game in the main stage of the competition at the 2022 European Championship played in Budapest (Hungary), between the national teams of Denmark and Croatia. These two teams have widely been regarded as the powerhouses of European and world handball. This sample game has been randomly chosen.

The research has been conducted in five separate stages, as indicated in Figure 1.

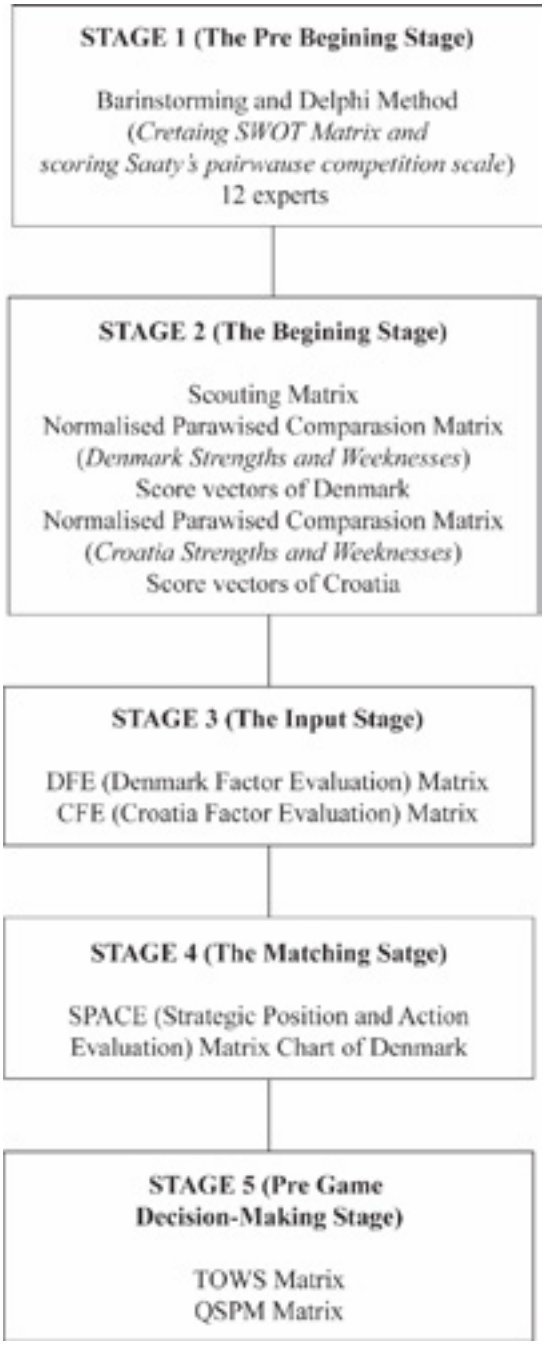

Figure 1. *Game-Decision Strategy Determining Stages*

In the Pre Beginning Stage, two qualitative methods were used to form the SWOT Matrix and the Matrix of Absolute Numbers. First we used the Individual Brainstorming method in which selected experts, each for himself, determined the strengths and weaknesses of both national teams. Based on their proposed findings, the study authors formed SWOT Matrix. Once the SWOT Matrix has been complete, the experts used a standardized comparison scale with nine levels (Albayrak & Erensal, 2004). Then, the Delphi Method was used so that the authors could synthesize and extract the average of the experts' opinions, i.e. their comparison of the weaknesses and strengths of the examined national teams.

When it comes to the selected experts, they are all former handball players who played in national teams and renowned European clubs, and then pursued coaching careers.

In The Beginning Stage, using mathematical quantitative methods, each average entry a_{jk} represented the value of the *j* criterion in relation to *k* criterion. If $a_{jk} > 1$ then *j* criterion is more significant than *k* criterion, and vice versa if $a_{jk} < 1$. If two criteria are of equal importance, then we entered 1 for the value of a_{jk}. Entries a_{jk} and a_{kj} have to satisfy the following constant $a_{jk} \, x \, a_{kj} = 1$. At the same time, $a_{jj} = 1$ for all categories.

$$A = \left(\bar{a}_{jk}\right)_{mxm} = \begin{bmatrix} a_{11} & a_{12} \dots a_{1n} \\ a_{21} & a_{22} \dots a_{2n} \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ a_{n1} & a_{n2} \dots a_{nn} \end{bmatrix}$$

When the Pairwise Comparison Matrix was formed, it was possible to perform a Normalized Pairwise Comparison Matrix so that in each column of the table the sum is equal to 1, i.e. $\overline{a}_{jk}$ from the second matrix is calculated as:

$$\tilde{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{lk}}$$

or

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & \tilde{a}_{nn} \end{bmatrix}$$

In fact, relative weights are found through the normalization of the matrix. Those relative weights w (relative weights, which were later entered in the DFE and CFE Matrix) correspond to the largest eigenvalue λmax as:

$$A_w = \lambda_{max} \times W$$

Finally, the Criteria weight vector (vector of m-dimensional columns) was derived based on the average of the entries of each row of the Normalized Pairwise Comparison Matrix (Banihashemi & Rejaei, 2016) i.e.

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m}$$

The DFE and CFE Matrices were calculated in the third stage, or the Input Stage. The CFE Matrix was formed by entering the values obtained in the Score Vector of Croatia, where a weight was calculated for each key factor representing Croatian national team, and shown in the numerical range from 0 (not important) to 1 (very important), and where, of course, the sum of the weights must be 1. This weight shows the relative effect of each factor on the team's success or failure. Then a score was assigned to each factor (Ratio). The numbers vary from 4 to 1, where 4 means - *a big impact of the Croatian national team on the final result*, 3 – *an above average impact*, 2 – *an average impact,* and 1 – *a small impact*. Finally, the weights of each factor were multiplied with its score (Ratio) and we obtained the weighted score of each factor. We added the obtained results to get the Sum Total Weight Scores. The same procedure was applied for DFE Matrix the only difference being in determining the result of each factor (Ratio). To be more specific, value 1 was assigned for *major weakness observed,* value 2 for *minor weakness,* value 3 for *minor strength,* and value 4 for *major strength*. As a logical result, the strength results should be represented by either value 3 or 4, whereas weakness results should be 1 or 2 (David, David, & David, 2023).

In the Matching phase we compared the intensity of the key factors in Danish and Croatian national teams and their impact onto the final score. By doing so we obtained an indication what the most optimal choice of future strategy (Strategic Positioning) is. More specifically, we created a SPACE Matrix diagram. The entire procedure included

calculation of weight scores of DFE and CFE matrices and their graphic representation in the range of 1 to 4. DFE results were presented on the x-axis whereas CFE results were presented on the y-axis.

In the final stage of The Pre Game Decision Making, and based on the previously obtained results, a TOWS matrix was formed and it included a clear guidelines towards formulation of the goals of the future strategy and their importance on proper strategizing ahead of a new game (Fadillah, Dewi, & Hardjanto, 2013; Koontz, Weihrich, & Cannice, 2020). We also left some space for a possible QSPM Matrix (Quantitative Strategic Planning Matrix) in case we came up with some significant findings relative to the other strategic options and their possible outcomes, i.e. should DFE and CFE intersection points be close on either *x* or *y* axis.

Results

Table 1. *SWOT Matrix (Denmark vs Croatia)*

Strengths (Denmark) S_{Den}	Weaknesses (Denmark) W_{Den}
s1D – organized positional attack s2D – attack segmenting with proper preparation-execution transition s3D - „attacking versatility"(achieved through all-round scoring positions and balanced scoring efficiency) s4D – well-organized transition attacks (fastbreaks and counterattacks) s5D – well-balanced first and second attempt attacking s6D – current form s7D – two goal keepers s8D – team line-up s9D – disciplined and stable defensive formation s10D - disciplined defensive formation including offense-to-defense transition	w1D – attacking deep defensive zones w2D – reckless ball possession w3D – dips in form and performance w4D – performance problems in slow pace related games w5D – goalkeeper dependency w6D – heavy reliance on one defensive formation with multiple defending flaws
Strengths (Croatia) S_{Cro}	Weaknesses (Croatia) W_{Cro}
s1C – adjusting the defense to the opponent (deep and shallow zone switching) s2C – transition to defense s3C – motivation and defensive aggression s4C – improvisation in attack (quality ball possession awareness, goal-to-goal play, patience in offensive setting, etc.) s5C – individual characteristics SB s6C – offensive efficiency of inner position players	w1C - Covid-19 protocol w2C – two goalkeepers w3C - turnovers w4C – playing experience and change of generations w5C – right and left back players' performance w6C – team line-up w7C – media and public pressure w8C – defense-to-offense transition w9C – attacking patterns w10C – defensive turnovers

Table 1 shows SWOT Matrix which was formed right after the initial brainstorming delivered by the 12 handball experts who took part in our study. The total of 10 strengths and 6 weaknesses of the Danish national team and 6 strengths and 10 weaknesses of the Croatian national team were recorded. A code was assigned to each strength and weakness so that we could use the research results more easily in our study. The strengths and weaknesses of the Danish national team would correspond to the internal environment in a classic SWOT analysis, whereas the strengths and weaknesses of Croatian national team would correspond to the external environment, with the side note that one team's strengths would be seen as the other team's threats – same holding true for one team's weaknesses and the other team's opportunities.

Using the Analytic Hierarchy Process mathematical method, we compared each of the obtained key elements for the Danish and Croatian national teams with other strengths and weaknesses and thus formed the Parawise Comparisons Matrix of Denmark Factors Evaluation (Strengths & Weaknesses) and the Parawise Comparisons Matrix of Croatia Factors Evaluation ($Weaknesses_{Opportunities}$ & $Strengths_{Threats}$). We added each vertical column of the matrix, and then divided each individual cell of the vertical column with the obtained vertical result and entered the obtained re-

sult into the matrix. Then we added those results horizontally across the rows of the matrix, and divided the obtained results by the total number of strengths and weaknesses in both national teams. We obtained tables Score Vectors Denmark and Score Vectors Croatia as the result of the foregoing procedure. Figure 2 shows the impact of each of the key factors on the final score. The results are presented in percentages, i.e. we multiplied the values obtained in the Score Vectors tables by 100. In this way, you can see how each recorded strength and weakness of both national teams affected their overall performance quality.

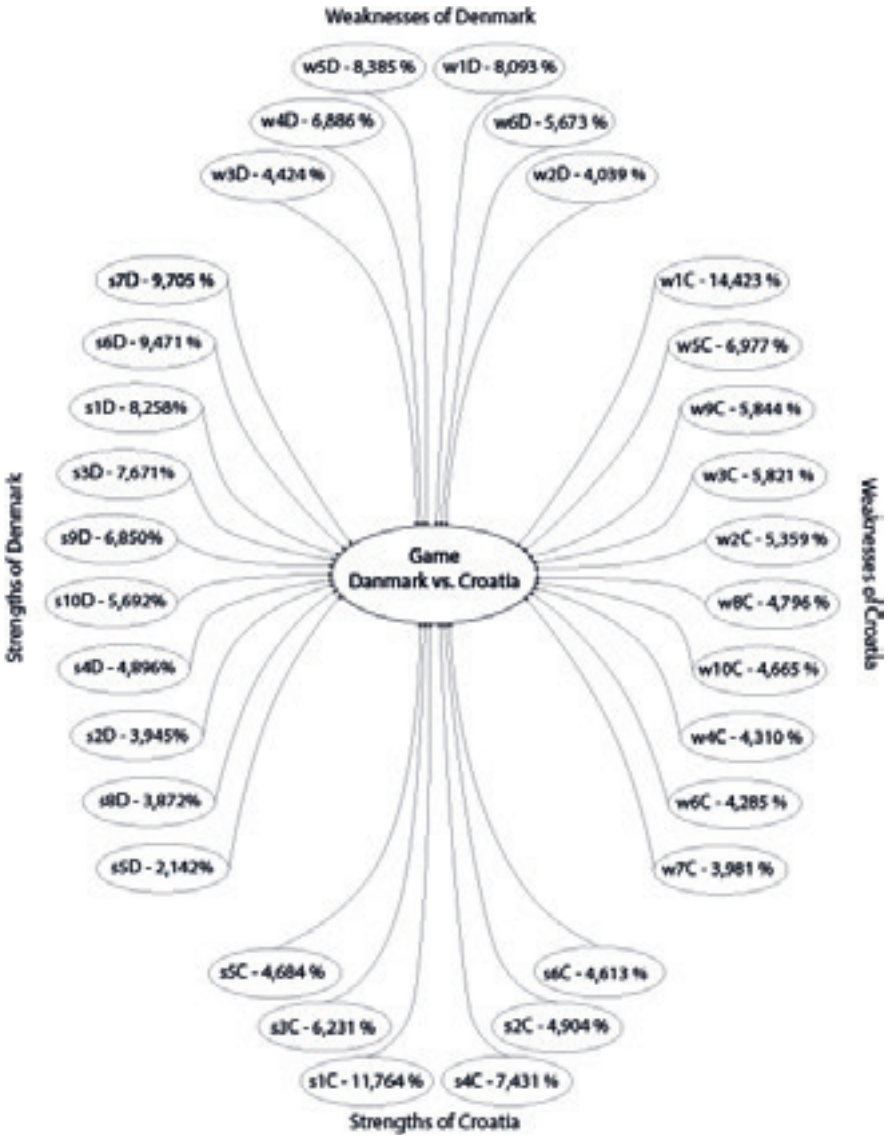

Figure 2. *Weight of Kay Factors Strengths and Weakness Team Denmark and Team Croatia*

The results obtained at the Beginning stage were entered into the HFE (Home Team Factors Evaluation) Matrix and the VFE (Visitor Team Factors Evaluation) Matrix. The HFE matrix represents the strengths and weaknesses of the Danish national team, and the VFE Matrix represents the strengths (or threats) and weaknesses (or opportunities) of the Croatian national team. The results of the third stage, The Input Stage, are presented in Table 2.

Table 2. *IFE and EFE Matrix for team Denmark*

IFE Matrix team Denmark					EFE Matrix team Denmark			
Kay Internal Factors	**Weight**	**Ratio**	**Weighted Score**		**Kay External Factors**	**Weight**	**Ratio**	**Weighted Score**
Strengths Denmark					*Opportunity Denmark (Weaknesses Croatia)*			
s7D	0,097	4	0,388		o1D (w1C)	0,146	4	0,577
s6D	0,095	4	0,379		o5D (w5C)	0,070	4	0,279
s1D	0,083	3	0,248		o9D (w9C)	0,059	2	0,118
s3D	0,077	4	0,307		o3D (w3C)	0,058	3	0,175
s9D	0,068	4	0,274		o2D (w2C)	0,054	4	0,214
s10D	0,057	4	0,288		o8D (w8C)	0,048	2	0,096
s4D	0,049	3	0,147		o10D (w10C)	0,047	3	0,140
s8D	0,039	4	0,155		o4D (w4C)	0,043	4	0,172
s2D	0,039	3	0,118		o6D (w6C)	0,043	4	0,171
s5D	0,021	3	0,064		o7D (w7C)	0,040	4	0,159
Weaknesses Denmark					*Threats Denmark (Strengths Croatia)*			
w5D	0,084	2	0,168		t1D (s1C)	0,118	3	0,353
w1D	0,081	1	0,081		t4D (s4C)	0,074	2	0,149
w4D	0,069	1	0,069		t3D (s3C)	0,062	4	0,249
w6D	0,057	1	0,057		t2D (s2C)	0,049	3	0,147
w3D	0,044	2	0,088		t5D (s5C)	0,047	2	0,094
w2D	0,040	1	0,040		t6D (s6C)	0,046	1	0,046
	1,000		2,811			1,001		3,139

The results of the HFE (2,811) and VFE (3,139) evaluation are plotted in the Denmark-Croatia Matrix, which we have shown in Figure 3.

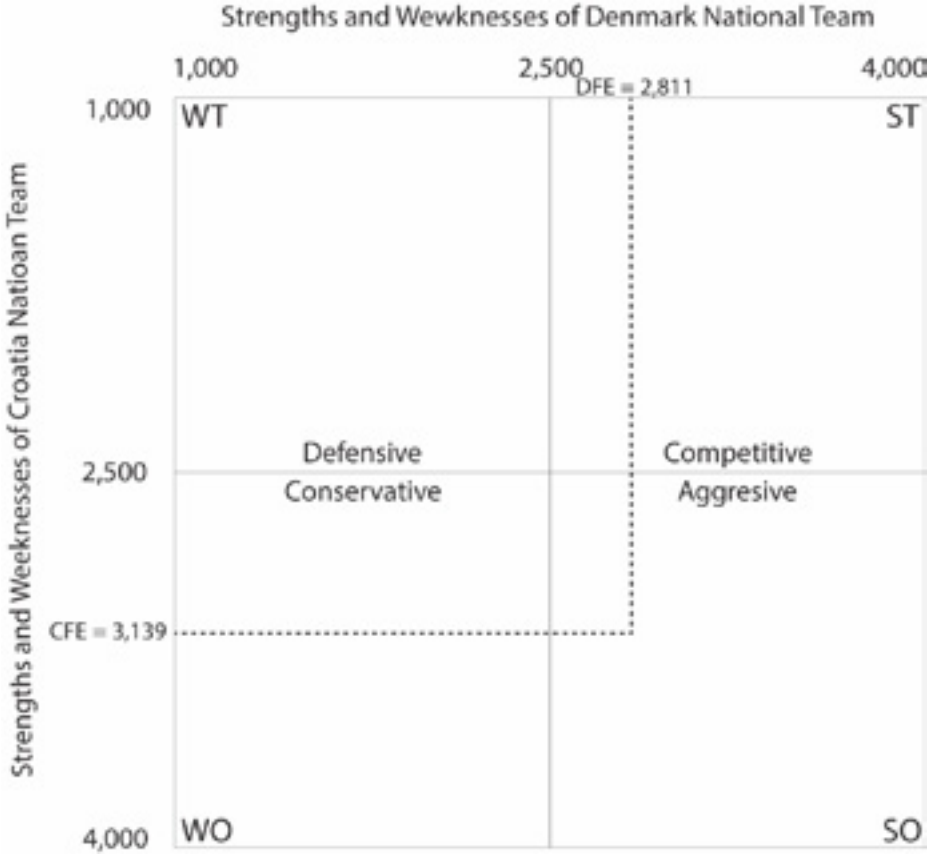

Figure 3. *SPACE Matrix Plot for team Denmark*

The diagram showed that the choice of Denmark's strategy for the match with Croatia should be an SO, i.e. an aggressive strategy. In other words, Denmark should use its strengths and opportunities, or play on Croatia's weaknesses, in order to win this match.

Based on the results obtained in the final stage of the research, the Game-Decision Stage, the TOWS Matrix was created and it outlined the specific goals setting pertaining to the upcoming game, as shown in Table 3.

Table 3. *TOWS Matrix – strategic goals*

		TEAM DENMARK (Strengthts and Weaknesses)	
		s1D (0,083) s2D (0,039) s3D (0,077) s4D (0,049) s5D (0,039) s6D (0,095) s7D (0,097) s8D (0,039) s9D (0,068)	w1D (0,081) w2D (0,040) w3D (0,044) w4D (0,069)
TEAM CROATIA (Weaknesses$_{Opportunities}$ and Strengthts$_{Thretas}$)	o1C (0,146) o3C (0,058) o4C (0,043) o5C (0,070) o6C (0,043) o7C (0,040) o8C (0,048) o9C (0,059) o10C (0,047)	<u>SO strategy</u> 1. disciplined and compact defense in line with all major defensive principles (s6D s7D s8D s9D vs o1C, o3C, o5C, o6C, o8C´, o9C´) = 0´,926 2. transition with certain elements of positional attack (s1D, s2D, s3D, s4D, s5D, s6D, s8D vs o1C, o6C, o10C) = 0,639 5. peaking in form through continuity in competitive matches (s6D, s8D vs o1C, o4C, o6C, o7C) = 0,406	<u>WO strategy</u>
	t1C (0,118) t2C (0,049) t3C (0,062)	<u>ST strategy</u> 3. neutralize polyvalence of the defending team by delivering segmented attacks (s1D, s2D, s3D, s4D, s5D, s6D, s8D vs t1C, t2C, t3C) = 0,632	<u>WT strategy</u> 4. adjusting the offensive system formation to the opponent's defense (w1D, w2D, w3D, W4D vs t1C, t2C, t3C) = 0,463

According to the results shown in Table 3, we see that, should Denmark want to beat Croatia, it must set five specific goals in pre-game preparation stage. The goals have been ordered by priority, of which the first goal is crucial for Danish national team, i.e. if this goal fails to be met, it would be highly unlikely for Denmark to win the match.

Although our research plan envisioned a QSPM Matrix for this particular matter, it was later decided not to provide one since the point where the HEF and VEF intersect in the SPACE Matrix is far from both the x and y axes, so there was no need to evaluate the choice of strategy in this respect.

Discussion

Making right decisions about the choice of tactics has proven to be a decisive factor in winning matches in team sports (Weigel, Raab, & Wollny, 2015). Handball is a team sport where game and offense time limitations, coupled with the tactical choices a team makes, have a very significant impact on the overall decision-making process on the players' part, and which, as a consequence, decide which team will eventually come victorius (Nicolosi, Quinto, Lipoma, & Sgro, 2023). The process of decision-making is heavily dependent on the appropriate set of information on one's own and the opposing team.

The use of modern technologies enables the process of data collecting to be ever more efficient (Torres-Ronda & Schelling, 2017). To analyze both teams has become an indispensable part of pre-game preparations at the professional level in handball (Trunić & Milovanović, 2022). At the same time, the amount of information that the coach receives creates the phenomenon of information overload, therefore it is necessary to filter them and extract the most relevant pieces of information (Bawden & Robinson, 2020).

While selecting the most appropriate strategy in pre-game preparation stage, we could consider utilizing certain approaches that have been applied in business management (*Peatling, 2005)*. SWOT analysis is one such strategy, which enables a certain group of individuals to perform 60% better than their opponents (*Kessler, 2013)*. However, one might argue that sports and business management do not have much in common - „as the outcome would be that 'oil and water mix' - sports on the field/court/ice are not the same as business in the workplace" (*Grant, McKechnie, & Chint, 2008)*. But if there are strategies people use to beat their competition in a business environment, why wouldn't we use the same or similar set of tools to gain a competitive advantage over an opponent in sports (Ibid). The Scout Method (SM) is used in various team sports like football (Jamil & Kerruish, 2020), ice hockey (*Lignell, Rago, & Mohr, 2020)*, volleyball (Ciuffarella, Luca Russo, Masedu, & Valenti, 2013), tenis (Martínez-Gallego, Vives, Guzmán, Ramón-Llin, & Crespo, 2021), rugby (Zahidi & Ismail, 2018), basketball (Esteves, Mikolajec, Schelling, & Sampaio, 2021), waterpolo (Verlin, Gullikson, Mayberry, & Cliburn, 2019) etc. Handball is no exception in this regard (Ferrari, Sarmento, & Simões Vaz, 2019; Kumar & Chandrasekaran, 2017) The process that allows coaches to collect data which provide feedback on players' and team's performance is known as Match Analysis (Carling, Williams, & Reilly, 2005). It provides information on strengths and weaknesses of both teams and individual players (Costa, Garganta, Santos, & Teoldo, 2014). Advances in technology have exponentially increased the availability of data, but at the same time we have been witnessing an ever growing complexity in decision-making (Torres-Ronda & Schelling, 2017). The question now is – what is the most optimal way to interpret the plethora of information gathered in this process?

As the final result of our matrix calculation, we extracted Score Vectors of Denmark and Score Vectors of Croatia, which enabled us to see to what extent the key factors within each team's strengths and weaknesses affect the overall performance quality (Figure 2). Specifically, the most significant factors as far as the team Denmark is concerned are the following strengths: s7D "*two goalkeepers*" (9.705% of the total impact on the final score) and s6D „*current form*" (9.471%), followed by strength s1D "*organized positional attack*" (8.258%), weakness w5D "*goalkeeper dependency*" (8.385%) and w1D " *attacking deep defensive zones"* (8.093%). As far as the team Croatia goes, the most significant weakness is w1C "*Covid-19 protocol*" (14,423%), whereas the most significant strength is s1C „*adjusting the defense to the opponent*" (11,764%), which was also recorded as one of the greatest threats to the team Denmark.

DFE Matrix and CFE Matrix (Table 2) matrices are nothing less than IFE (Internal Factors Evaluation) and EFE (External Factor Evaluation) Matrix commonly used in economics and strategic management research (David et al., 2023). DFE Matrix and CFE Matrix results were 2.811 and 3.139 respectively. This indicates that the team Denmark had more observed strengths than weaknesses, whereas the same cannot be said about the team Croatia.

These two obtained results shown on the SPACE Matrix Plot for Denmark National Team (Figure 3) show that Denmark's strategy for this match is to be found in the SO quadrant. Situations like these are considered the most favorable ones for teams with multiple strengths when facing the opponent's weaknesses (Sikavica, Bahtijarević-Šiber, & Pološki Vokić, 2008). These kind of situations call for growth-oriented strategies, that is, an aggressive strategy in which the team Denmark must first put focus on its own strengths and set up an „aggressive" game plan.

The final stage of the study focused on specific goal setting based on the selected strategy form SO quadrant and the hierarchy of the goals set in TOWS Matrix (Table 3). The were 5 goals in total, out of which the first one was

considered radical in terms of its impact on the final score and a possible victory of the team Denmark. This goal was labeled „*disciplined and compact defense in line with all major defensive principles*". No other key factors should be disregarded whatsoever, the most notable ones being „*transition offense with certain elements of positional attack*" and „*neutralize polyvalence of the defending team by delivering segmented attacks*", and also two minor factors such as: „*adjusting offensive game plan to the opponent's defense*" and *„peaking in form through continuity in competitive matches"*.

There is a vast set of evidence that the following game segments have also a major impact on the final score: goal scoring position and its efficiency, number of goals scored by back positions (outside the 9 meter line) and its efficiency, 7 meter line (penalty throw) efficiency, and overall scoring efficiency (Ferrari, dos Santos, & Simões Vaz, 2014), as well as the total number of assists made (Popovich, Bezukladnova, Bezukladnov, & Goncharova, 2020). The offensive strategizing is recommended to be based on an increased number of fast attacks against unset defense, attacking the opponent *wide and deep* and with multiple individual actions (Rogulj, Vuleta, Milanović, & Čavala, 2011), whereas deep defensive zones should be attacked by well-set and organized offense actions Popovich et al., 2020). The national teams excelling in these regards have been the ones winning the games (Ferrari, Dias, Sousa, Sarmento, & Vaz, 2020). Indeed, the SWOT matrix formation in our study was highlighted by those characteristics as the key ones. For the team Denmark the key factors included: „*transition attack*" (s4D), *attacking efficiency* (s1D, s2D and s5D) and „*attacking versatility achieved through all-round scoring positions*" (s3D) and offensive weakness „*attacking inefficiency resulting from poor tactical solutions against seep defensive zones*" (w1D and w2D). The team Croatia was found to have one major attacking weakness, i.e. „*poor attacking solutions heavily dependent on right and left back performance*" (w5C and w9C).

As far as the defense solutions in modern handball are concerned, research show that compact defense with collective response is the preferred option since that is a highly adaptable formation, particularly when it comes to high pace and intensity games (Barreira, Musa, Morato, & Menezes 2021). The classic type of zone defense 6:0 is highly recommended since it is simpler to be formed than deep zone formations particularly in games with plenty of transitional attacks. The research on game-related statistics indicate that highly significant are technical mistakes made by the opponent (Antonis, Dimitris, ZacharoulaP, Vasilis, & Ioannis, 2019), as well as the total number of fouls committed, 2 minute suspensions, penalty throws and blocked shots (Rogulj et al., 2011). Also, the goalkeeper's efficiency is a strong predictor of a team's success on the professional level (Pavlinović, Foretić, Veršić, Uljarević, & Modrić, 2021). The experts involved in our study have found out that the team Denmark has „*strong, stable and disciplined defensive formation*" (s9D and s10D) coupled with phenomenal „*two goalkeepers*" (s7D), whereas their weaknesses include „*dependency on goalkeepers' performance*" (w5D) and „*tenacious 6:0 defense formation*" (w6D). As for the defense of the team Croatia, the following strengths were recorded: „*deep and shallow formation zone switching*" (s1C), „*swift offense-to-defense repositioning"* (s2C) and high „*motivation and defensive aggression*" (s3C). The team Croatia weaknesses were „*individual and team turnovers"* (w10C) and „*two goalkeepers*" (w2C). Also, one of the perceived weaknesses in the team Croatia was common line-up changes heavily affected by Covid-19 protocol and the change of generation in their national team (w1C, w4C i w6C).

It should mentioned of course that one of the main shortcomings of this research lies primarily in the fact that we did it only after this match had been completed. However, one of our main goals was to try to provide a theoretical framework for the Scout Method and decision-making about the proper strategy for the game (competition) by using qualitative and quantitative methods that have already been used in other scientific disciplines. We propose a similar study to be conducted before the actual game takes place, so that the further research provide an insight as to what extent such analyses may or may not be beneficial for coaching staff. Another problem is the applicability of this methodology in practice, primarily due to qualitative research relying brainstorming and the Delphi method, in which 12 of our research experts were involved. Scott Armstrong also emphasized the fact that it is necessary to involve 5-20 experts if we want to have a sound implementation of the Delphi method (Armstrong, 1985). Multiple research have proven the there is a high correlation between expert opinions in sports and results obtained by mathematical methods (Simović, Matković, Mijanović, & Vojvodić, 2019).

The match between Denmark and Croatia at the European Championship, played on January 22, 2022 in Budapest, ended with the final score of 27-25 in favor of Denmark. Shaping their game tactics around game-related statistics team Denmark gained an advantage at the very beginning of the game with their experienced players from

the starting line-up, many of which had already participated in numerous international level games of the highest caliber (s6D, s8D; w1C, w4C and w6C). Team Denmark managed to reach the „radical" goal, which was extracted in TOWS matrix and labeled as „*disciplined and compact defense in line with the basic defending principles and able to eliminate strengths of team Croatia and take advantage of the opponent's weaknesses",* which derives from SWOT analysis an the following items: s6D, s7D, s8D, s9D, o1C, o3C, o5C, o6C, o8C and o9C. Taking game-related statistic as the base of its tactics, the team Denmark managed to impose its standard defending formation, as highlighted in other research as well (Antonis et al, 2019), and force team Croatia to make more turnovers, whereas Danish players had three steals more than their opponents, higher goalkeeper's saves percentage particularly from left and right back positions. Team Denmark also managed to camouflage their potential weaknesses (w5D and w6D), by insisting on a disciplined approach in defense and thus reduce their „*goalkeeper dependency"* (w5D). By doing so they also managed to reduce the shortcomings of their „*tenacious 6:0 defense formation"* (w6D) despite the fact that the most efficient player from team Croatia was the pivot (center forward) position player. Team Denmark identified the offensive pattern in team Croatia's attacks, i.e. from center back (s5C) to other positions, and pressed these players with additional defending burden, which eventually resulted in team Croatia's reduced efficiency from center back position (only 30%). This tactical decision was a conscious effort to let team Croatia attack from right and left back positions. Some previous studies have highlighted team Denmark's tendency to let their opponent's center back take shots since their goalkeepers have had an increased efficiency while defending these shots (the numbers in that regard being 56% in 2019 and 67% in 2021) (Parthipan & Kalidasan, 2022). Team Denmark focused its attention on team Croatia's center back Luka Cindric and limited him only on two goals while allowing him to record 8 assists, which was in line with team Denmark's tactical decision to decrease his shot efficiency. Speaking of the team Denmark's 6:0 defense formation efficiency, let's just point out that the goalkeeper Niklas Landin Jacobsen had 45% efficiency (5/11 saved goal attempts). Furthermore, team Denmark's goal keepers had a high efficiency from back position shot attempts in the finals of the following World Championships: 2019 WC 67% (4/6) and 2021WC 78% (7/9) (Ibid). The TOWS matrix indicates that team Denmark should make advantage of "*transition offense with certain elements of positional attack"*, which derives from the the SWOT matrix and the following proposed items: s1D, s2D, s3D, s4D, s5D, s6D and s8D; o1C, o6C and o10C. They managed to use this particular strategy and neutralize team Croatia's strengths thus minimizing difficulties when attacking deep defensive zones – something team Denmark and other Scandinavian national teams have been known to have problems with. Game-related statistic points in the same direction since team Denmark was very efficient when it came to transition attacks – 82% (9/11). Goals scored in transitional attacks (counterattacks) have been known as one of the most impactful on the final score (*Hatzimanouil, Lola, Giatsis, & Skandalis, 2023)*. As far as the positional attacks are concerned, team Denmark excelled in that aspect as well. Here are percentages for team Denmark back position players' efficiency: Mikkel Hansen 5/8 (62.5%), Mathias Gidsel 5/6 (83%) and Rasmus Lauge Schmidt 4/7 (57%). Also, left and right wing position players had remarkable efficiency percentages 88% (7/8). Their penalty throw efficiency was at 100% while at the same time team Croatia's goalkeepers recorded only 23% efficiency. This is to confirm that the third tactical goal of team Denmark was reached, i.e. „*neutralize polyvalence of the defending team by delivering segmented attacks*", as can be seen in the SWOT matrix s1D, s2D, s3D, s4D, s5D, s6D and s8D; t1C, t2C and t3C. Furthermore, team Denmark fulfilled the fourth tactical goal (TOWS matrix), i.e. „*adjusting the defense to the opponent*" – that specific goal was achieved by performing a cover-up of its own weaknesses and eliminating team Croatia's strengths (SWOT matrix: w1D, w2D, w3D, w4D and t1C, t2C i t3C). The fifth goal was also achieved, i.e. *„peaking in form through continuity in competitive matches",* as can be concluded from the SWOT matrix: s6D, s8D; o1C, o4C, o6C and o7C. This might be related to the fact that team Denmark was one of the rare teams at this championship without serious issue with their line-up and Covid-19 protocol. Regardless of that fact, every team still needs to have a coaching staff able to select the right players to deliver their tactical and strategic plans on the court and, by doing so to build the team's form so as to peak at the right time (Panagiotis, Konstantinos, & Ioannis, 2020). All the above confirms that team Denmark is at the very top of European and world handball (Pavliuk, 2022), and provides ample evidence that the prediction model we used in our study was accurate.

Every sport is abundant in uncertainties of potential outcomes, most probably due to the stochasticity of various game elements that require proper analysis, evaluation, prediction, and forecasting. To achieve reliable results in that respect, one must use the most appropriate analytical and methodological procedures and tools. There are no tools

to predict the exact final score of a game, which is basically very fortunate and innate to sports as it leaves plenty of room for speculation, biases, miscalculations and strategical mistakes, all of which are the essential parts of any sport and keep the spectators coming to sporting events. Every analytical forecasting is surely more than welcome, but there should always be a margin left for the uncertainties which can heavily influence the final score (Simović & Komić 2021).

Conclusion

SWOT analysis is a method that has been used in sports for a long time in order to provide coaches with a framework to strategize and plan tactical solutions before the actual game. SWOT analysis can be used by handball coaches on a regular basis, and can impact the viability of the decision-making process. This paper has used the most recent SWOT tools and procedures, i.e. qualitative, quantitative and mathematical methods, in order to set the right strategic goals for the game we researched. The key strengths and weaknesses for both teams were extracted using qualitative methods. The comparison of both teams' strengths and weaknesses was made by means of AHP mathematical method, and then through matrix calculation we were able to determine the importance of each factor on the final score of the game. Weight Scores were also calculated for each factor and each team separately (2.811 for team Denmark and 3,139 for team Croatia). The SPACE Matrix Chart indicated that the strategy for this game was best defined as the focus on the quality of team Denmark's two goalkeepers, peaking in form at the right time, and positional attacking pattern against the opponent and exploiting team Croatia's weaknesses heavily affected by the Covid-19 protocol. The TOWS method pointed out 5 strategic goals, one of which was *disciplined and compact defense.* Should the players be able to meet that goal and materialize the proposed strategic solutions set by the coaching staff, team Denmark is to come out as the winning team against the opponent.

Acknowledgement
The author wishes to dedicate this article to professor Branko Jankovic, a handball expert who was one among 12 researchers participating in our study, and who sadly passed away in the meantime.

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Sex-Based Differences in Body Composition Parameters Among 16-Year-Olds Using BIA

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Abstract: *This research analyzes the differences in body composition between adolescents aged 16 from Kosovo and the relationships between major anthropometric and physiological properties between boys and girls aged 16. In total, 84 females and 64 males were selected through a simple random sampling method to be part of the sample. Body composition was analyzed by performing a bioelectrical impedance analysis (BIA) on each member of the sample, while the statistical analyses included descriptive statistics, normality testing, Pearson correlation analysis, and independent samples t-tests. Findings from this study revealed substantial differences between sexes, confirming results from studies conducted globally, with boys having greater levels of lean body mass, whereas girls had greater levels of bodily fatness. Through the correlation analysis, a distinct difference between fat-related variables (body fat percentage, BMI, visceral fat, and vitality) was established to form a single cluster of closely related variables, whereas lean body mass indicators (muscle mass, bone mass, and BMR) formed another cluster. In addition, the independent sample t-tests established that males and females differed significantly for all variables (except for vitality), indicating that the differences seen in the study support the expected differences in physical and physiological development by gender at age 16 based on studies on males and females in similar age groups conducted recently in other parts of the world.*

Keywords: *Body composition, differences, adiposity, Physiological development*

Introduction

The adolescent phase of a child's life includes several important phases of growth and personal development. During this time, there are many biological changes taking place at an accelerated pace. Starting at around 16 years of age, the maturation process, along with hormonal fluctuations, will create a more pronounced variable in terms of fat distribution, skeletal muscle development, bone mineral density (bone mineral density), as well as hydration status between females and males. The physiological growth that occurs during the adolescent years will alter the ratio of total body weight, fat mass and lean mass to water; therefore, the female and male biological difference is one of the primary factors that significantly impacts the body composition of females and males aged 12–24. Traditional body weight measures, such as the body mass index (body mass index), cannot accurately measure an individual's body composition,thus, it is possible for a 12 to 24-year-old individual with a one BMI classification to have an excessive amount of fat but still maintain an adequate amount of lean mass. As a result, the nutritional and physiologic classification of the individual's health indicators would be incorrect. Various studies have demonstrated the numerous advantages that BIA has over traditional practices, as BIA can provide accurate estimates of fat mass, fat-free mass, lean mass, skeletal muscle mass, bone mass, total body water and many other body compartments. Studies completed with data generated from population samples using the BIA method indicate that males, generally speaking, have more fat-free mas, lean mass, total body water, bone density, and skeletal muscle than their female counterparts. In contrast, females have a lower percentage of fat mass, more indicators of fat mass than males, and have lower hydration status (Kaczmarek, Durda-Masny, & Hanć; Hu et al. All cited by Pavlovic et al., 2024). Additional research has provided confirmation of these findings regarding BMI as it relates to pediatric populations when BMI is analyzed as a method of determining the body composition of children aged 0–12 years, high rates of misclassification have been documented, indicating that the majority of children classified as having a healthy or normal BMI have excess fat. The rates of misclassification with traditional BMI measurements, in conjunction with the decline in motor competence among overweight children, suggest that traditional BMI measurements alone do not accurately reflect functional physique composition (Banjac & Kuscevic).The differences between males and females reach a peak around 16 years of age, therefore using BIA as a method of assess-

ing body composition in males and females is important and will improve our understanding of adolescent growth and development. Using BIA will assist healthcare professionals in identifying health conditions related to excessive adiposity and low muscle tone, ultimately, this evaluation will assist healthcare providers in developing targeted therapies and will strengthen the evidence base regarding the impact of weight on physical health and development.

Literature Review

During puberty, rapid biological, hormonal and morphological changes occur to the body in addition to becoming more different in both body composition and fat distribution for Boys versus Girls. A few examples of the body's maturation process include a divergence of body fat distribution, development of skeletal muscles, development of bone mineralization and an increase of hydration status during this time frame (16 years of age). In addition, many of these components are changing so rapidly, that standard Anthropometric measurements (e.g., BMI) have limited diagnostic value for adolescents because those measurements do not account for Lean Tissue vs. Adipose Tissue. This misclassification of Nutritional and Physiological Status across different countries was reported in many studies conducted worldwide (Ferozi et al., 2024; Pavlović et al., 2025). Bioimpedance Analysis (BIA) has emerged as a superior method of assessing the morphology of adolescents because BIA estimates the total amounts of fat and fat-free mass skeletal muscle mass, bone mass, and all of the major compartments of the body's water status. The consistent results of large-scale population studies indicate that boys have significantly higher fat-free mass, skeletal muscle mass, body cell mass and total body water, while girls show significantly higher percentages of adipose tissue. (Kaczmarek, 2025; Kaczmarek, Durda-Masny & Hanć, 2024). Longitudinal cohorts have demonstrated predictable developmental trajectories in fat-free mass, water compartments, muscle mass, and phase angle, thereby indicating that adolescence is a critical period for the examination of body composition (Hu et al., 2025). Intervention-based studies support the importance of the body composition component. The results of studies that utilize high-intensity and plyometrics-based training in adolescents show that muscle mass, body fat percentage and motor performance have a significant relationship with physical activity patterns (Domaradzki et al., 2025). Additionally, initiatives designed to monitor fitness and health, such as "Athletics for All!", have shown that differences between the sexes in strength, endurance and morphology exist, and these differences are consistent with previous literature (Baj-Korpak et al., 2024). The limitations of the use of BMI are made more apparent when conducting systematic analyses. A comprehensive review of the existing literature by Banjac and Kuscevic (2020) showed that BMI scores in the higher ranges for children and adolescents have a negative association with motor skills and performance, indicating that the BMI is not a true measure of functional body composition. Environmental factors also play a role in determining body composition in adolescents. In a study by Stankovic and colleagues (2024), it was shown that morphological and motor differences exist between rural and urban girls, indicating that body composition can be influenced by other environmental factors such as environment physical activity, nutrition, school and lifestyle. Research conducted by Požar et al., (2024) found that BIA is able to reliably detect changes in body composition as a result of nutrition counselling (fat mass, abdominal fat, muscle mass, and TBW). BIA is also suitable for monitoring physiological changes from population to population. Therefore, it is a relevant method for evaluating the body composition of adolescents. Large samples of youth have been analyzed in this area and findings point to a clear relationship between sex and developmental progress for the body. In research conducted by Nikšić et al., (2025) on primary- and secondary-school children, there were significant differences in the morphological characteristics and motor performance between boys and girls. This difference increases over the course of development and shows an exact match with the patterns found in BIA studies. Overall, literature suggests that the composition of the bodies of adolescents is determined by a combination of biological sex, environment, physical activity, and nutrition. In all studies, boys are consistently found to have a larger lean mass and lower %fat as compared to girls. Patterns of % fat and lean mass peak at age 16. Thus, to properly assess girls and boys and identify hidden low muscularity or hidden fat mass, utilizing both BIA and traditional anthropometry to evaluate differences between sexes is critical for early identification, accurate assessments, and the development of evidence-based interventions supporting healthy growth in adolescents.

Methods and materials

The purpose of this study is to evaluate the variances in body composition between men and women who are 16 years old, using BIA (bioelectrical impedance analysis), a common method employed by current researchers studying pediatrics and adolescents (for example: Hu and colleagues 2025 and Kaczmarek and colleagues 2024). Variables associ-

ated with Body Composition through BIA include the following: height, weight, %BF (percent body fat), muscle mass, bone mass, BMI (Body Mass Index), BMR (Basal Metabolic Rate), vitality, TBW (Total Body Water) and visceral fat.

Hypotheses

The development of the project and the methods used for statistical analyses of the data collected dictate the hypotheses developed to direct the study design of this research project.

H – Statistically significant differences in Body Composition between males and females exist between boys and girls 16 years old

The general hypothesis was split into three specific hypotheses.

H1 – Body composition variables will be normally distributed.

H2 – There will be significant and statistically significant bivariate correlations between the body composition variables for the significance level $p < 0.01$.

H3 – There will be statistically significant differences in body composition indicators between females (girls) and males (boys) at age 16 years.

Sample of population

The sample population for the study consisted of both males and females, age 16, recruited from the general source pool of the "population of age 16" using a simple random sample approach. The total sample of Adolescents (n = 149) included 65 males and 84 females in the following groups for purposes of this analysis.

All individuals that participated provided informed consent to participate in this study, met the age requirement for participation and currently were enrolled in school at the time of the study. There were no medical diseases/disorders that could impact Body Composition by the participants of this study.

Instruments and Procedures

In this study, the Bioelectrical Impedance Analysis (BIA) technique was used to assess differences in Body Composition by sex among 16-year-old Adolescents, as this is an accepted method of evaluating pediatric and adolescent PAI in the literature in recent years (e.g., Hu, Kaczmarek, et al. 2025 and Kaczmarek, et al. 2024).

Each measurement was taken and recorded in accordance with the BIA Assessment Manuals.

Statistical Procedures

Independent-samples T-test was used to examine for sex differences in body composition of 16-year-old adolescents. Descriptive statistics were computed to determine mean values and standard deviations for all variables derived from BIA as well as their normal distribution. The assessment of normal distribution determined the appropriate tests of correlation between variables. Key indicators of body composition correlation were investigated by means of Pearson's coefficient of correlation. Statistical significance was determined as $p<0.01$.

Results

Table. 1. *Descriptive Statistics for 16 Girls*

Descriptive Statistics[a]									
	N	Range	Min	Max	Mean	Std. Devi	Variance	Skewness	Kurtosis
Body height (cm)	84	25	153	178	165.93	5.994	35.923	-.026	-.719
Body weight (kg)	84	44	42	86	59.56	10.123	102.483	.438	-.128
Body fat percentage (%)	84	28	13	41	27.95	7.019	49.267	-.171	-.503
Muscle mass (kg)	84	16	33	49	40.20	3.535	12.495	.228	-.668
Bone mass (kg)	84	1	2	3	2.16	.184	.034	.342	-.625
BMI	84	14	16	31	21.75	3.429	11.756	.527	-.297
Basal metabolic rate (kcal)	84	877	1883	2760	2226.85	197.218	38895.024	.335	-.457
Vitality score	84	23	12	35	20.73	8.779	77.069	.328	-1.634
Total body water (%)	84	20	44	64	53.53	4.823	23.263	.093	-.521
Visceral fat level	84	4	1	5	1.77	1.134	1.286	1.476	1.369

The sample of 16-year-old female participants (N=84), had an average height of 165.93cm (SD=5.99) and an average body weight of 59.56kg (SD=10.12). The average body-fat % was relatively high at 27.95% (SD=7.02); however, skeletal-muscle mass was around 40.20kg (SD=3.53). Mean BMI values were within the normal range for adolescents (M=21.75 and SD=3.43). The average total-body-water for the study population was 53.53% (SD=4.82) which is consistent with what would be expected of female adolescents. Visceral-fat levels were low (M=1.77), and the average basal metabolic-rate of participants was 2226.85kcal (SD=197.22). The results show that the female study sample has the typical pattern for body composition (i.e., relatively high adiposity and low lean mass) when compared to males. All variables for females fell within the range of a normal distribution, such as height, weight, body fat % and skeletal muscle mass, as well as calorie expenditure and total body water. Vitality levels exhibited mild left skewness, however, visceral fat levels were positively skewed.

Table 2. *Descriptive Statistics for Boys*

	N	Range	Min	Max	Mean	Std. Dev	Variance	Skewness	Kurtosis
Body height (cm)	64	27	168	195	179.00	5.721	32.730	.498	.582
Body weight (kg)	64	57	51	108	72.94	13.536	183.226	.647	-.302
Body fat percentage (%)	64	28	8	35	16.60	5.476	29.990	.844	.818
Muscle mass (kg)	64	30	44	74	56.93	6.908	47.727	.151	-.623
Bone mass (kg)	64	1	2	4	2.99	.329	.108	.206	-.745
BMI	64	19	16	36	22.81	4.264	18.182	.967	1.044
Basal metabolic rate (kcal)	64	1721	2525	4246	3223	394.843	155900.962	.340	-.599
Vitality score	64	21	12	33	18.25	8.138	66.222	.916	-.798
Total body water (%)	64	33	47	79	63.31	6.357	40.406	-.189	.144
Visceral fat level	64	12	1	13	2.63	2.826	7.984	2.496	6.668

The boys' average height (179.00 cm) and average weight (72.94 kg) were significantly greater than their counterparts in this study (N=64). They had a lower body fat % (M=16.60%), greater skeletal muscle mass (M=56.93 kg), and higher bone mass density (M=2.99 kg) compared to girls. They also had a greater total body water percentage (63.31%), and an increased basal metabolic rate (kcal/MNT) when compared to females: (M=3223.92 kcal). In addition, they had more visceral fat (M/Avg=2.63) than girls did as well. These findings represent the expected norms for male adolescents, given that they have a predominance of lean body mass compared to females at this stage of development. For boys, all variables except for visceral fat where within the normal range of acceptable limits and as such, statistical analysis on this last variable should only be considered non-parametrically due to the extreme skewness and kurtosis observed.

Table 3. *Correlation matrix for Girls*

	BH	BW	BFP	MM	BM	BMI	BMR	VS	TBW	VFL
Body height (cm)	1									
Body weight (kg)	.406**	1								
Body fat percentage (%)	.291**	.907**	1							
Muscle mass (kg)	.502**	.883**	.639**	1						
Bone mass (kg)	.466**	.846**	.608**	.966**	1					
BMI	.035	.897**	.845**	.760**	.747**	1				
Basal metabolic rate (kcal)	.483**	.917**	.705**	.983**	.952**	.796**	1			
Vitality score	.217*	.855**	.886**	.623**	.575**	.809**	.693**	1		
Total body water (%)	-.257*	-.854**	-.979**	-.556**	-.527**	-.777**	-.630**	-.854**	1	
Visceral fat level	.104	.812**	.763**	.613**	.594**	.803**	.690**	.836**	-.750**	1

The correlation matrix demonstrated that there are biologically sensible and strongly associated relationships between body composition variables. Weight, %BF, muscle mass, bone mass, BMI, BMR and visceral fat were positively correlated with each other due to the common influences of total body size and fatness on all these variables. %TBW was also strongly negatively correlated with the fat-related variables, showing that a person with a greater

relative amount of fat has a lower amount of relative TBW. Muscle mass, bone mass and BMR were all very strongly positively correlated to each other, further indicating that lean mass is the strongest predictor of BMR. These patterns also conform to the physiological processes of adolescents and substantiate the accuracy of the BIA derived variables.

Table 4. *Correlation matrix for Boys*

	BH	BW	BFP	MM	BM	BMI	BMR	VS	TBW	VFL
Body height (cm)	1									
Body weight (kg)	.217	1								
Body fat percentage (%)	-.071	.847**	1							
Muscle mass (kg)	.385**	.868**	.603**	1						
Bone mass (kg)	.412**	.891**	.626**	.958**	1					
BMI	-.112	.933**	.898**	.750**	.764**	1				
Basal metabolic rate (kcal)	.379**	.932**	.690**	.962**	.988**	.819**	1			
Vitality score	-.011	.826**	.919**	.588**	.622**	.854**	.684**	1		
Total body water (%)	-.091	-.706**	-.866**	-.535**	-.563**	-.694**	-.610**	-.778**	1	
Visceral fat level	-.137	.812**	.843**	.495**	.517**	.887**	.588**	.839**	-.606**	1

In summary, the above correlation patterns reveal that adolescents with high body masses typically have a broader profile of increased fat, muscle mass, bone density, metabolic rate, and visceral fat levels. All of the adiposity variables (i.e., % body fat, BMI, visceral fat, vitality) are grouped together in one cluster, while all the lean-tissue variables (muscle mass, bone mass, and BMR) are included in another coherent cluster. The percentage of total body water exhibited an inverse mirror relationship with each of the adiposity variables, definitively demonstrating a physiological distinction between fat-dominant bodies and lean-dominant bodies in adolescents. This study demonstrates that the individual components of body composition in adolescents are highly interconnected and that they also reflect very distinct physiological patterns that are produced by the way in which fat is distributed and formed in the body as well as by the way lean tissues are formed and distributed in the body.

Sex Differences and Comparative Analysis

Independent Samples t-Test Comparing Girls and Boys (Age 16)

Table 5. *T-test*

Variable	Girls (M)	Boys (M)	t	p
Body Height (cm)	165.93	179.00	-13.49	< .001
Body Weight (kg)	59.56	71.69	-5.40	< .001
Body Fat %	27.95	16.96	9.94	< .001
Muscle Mass (kg)	39.76	57.42	-17.78	< .001
Bone Mass (kg)	2.41	3.00	-18.20	< .001
BMI	21.75	22.91	-2.43	.016
Basal Metabolic Rate	2226.85	3219.00	-18.55	< .001
Vitality Score	20.73	18.25	1.77	.079
Total Vitality Score	53.83	63.31	-9.45	< .001
Visceral Fat Level	1.77	2.63	-2.27	.026

The sex-based differences in body composition of 16-year-old adolescents were examined using independent samples t-tests. About 90% of the sex-based difference analysis results indicated large, statistically significant differences across all body composition variables measured. Therefore, it can be concluded that in the adolescent developmental stage, sex is responsible for a large portion of the physiological development. For example, in 16-year-old adolescents, boys were taller than girls ($t(df\approx139) = -13.49$, $p < .001$), and boys are heavier than girls ($t(df\approx113) = -5.40$, $p < .001$). The body fat percentage is significantly higher in girl adolescents ($M = 27.95\%$) than in boy adolescents ($M = 16.96\%$), $t(df\approx146) = 9.94$, $p < .001$ demonstrates one of the largest sex-based differences found in this study. Whereas boys have a much higher concentration of lean muscle mass than girls, boys have a significantly

higher weight of skeletal muscle mass (M = 57.42 kg) than girls (M = 39.76 kg), t(df≈88) = –17.78, p < .001; as well as bone weight, t(df≈93) = –18.20, p < .001. In addition, boys have a significantly higher average resting energy expenditure (i.e., basal metabolic rate (BMR)) than girls (M = 3219 kcal for boys and M = 2226 kcal for girls), t(df≈87) = –18.55, p < .001. Higher BMR in boys can be attributed to the higher concentrations of lean body mass than in girls. Body mass index (BMI) was only slightly higher for boys than girls (22.91 for boys vs. 21.75 for girls; t = –2.43, p = .016), which represents a small effect. Energy vitality scores were not significantly different between the sexes (p = .079). However, total vitality scores were significantly higher for boys than for girls, t = –9.45, p < .001. Visceral fat was modestly, but significantly, higher in boys than in girls (M = 2.63 for boys and M = 1.77 for girls), t(df≈79) = –2.27, p = .026. Although this is statistically significant, the difference between boys and girls in regard to visceral fat represent much smaller differences than the difference found in skeletal muscle and bone mass.

Discussion

Results of this research show that physical changes during adolescence in the sample population of 16-year-old boys and girls in Kosovo were closely aligned with the findings of other recent international studies. The female sample population had a significantly higher percentage of body fat and lower amounts of lean mass than the male sample population, which had higher levels of muscle, total mineral, total body water, and basal metabolic rates. Body fat distribution in females peaks earlier, while males see a rapid increase in fat- free mass starting at 16 years of age (Kaczmarek, Durda-Masny & Hanć, 2024). Our correlation analyses indicate that the relationships between the adiposity and the lean-mass variables form two separate clusters, which supports the findings of Hu et al., 2025, who state that there is a high degree of interdependence between fat (fat free mass), TBW and skeletal muscle indices. The variance in the relationship between BMI and the actual amount of adiposity in some study participants reinforces the findings of the Ferozi et al., 2024 study that the utilitarian value of BMI for diagnosing excessive body fat is limited. With regard to sex-related performance differences shown in the form of lean-mass advantages identified among our male participants and the indication of a physiological correspondence between lean tissue and other physiological variables listed in Keirns et al., 2025, it could be said that males and females between 14 and 20 years of age will have a marked difference in their rates of physical development as well as their relative amounts of adiposity and lean-body mass. As confirmed by the results of this & studies, it is apparent that adolescents in Kosovo are developing in much the same manner as adolescents worldwide.

Conclusion

Our study shows that sex is a strong determinant of body composition among male and female adolescents at age 16 years, and that there is a consistent sex difference between males and females in body composition during adolescent development. Males demonstrate a greater amount of lean body mass (muscle, mineral, total body water & basal metabolic rate) and females demonstrate a greater overall percentage of body fat due to the differences in hormonal and physiological characteristics between males and females in mid-adolescence. The correlations between fat (fat free mass) and lean body mass variables support the concept of the integrated nature of adolescent body composition and highlight the importance of using bioimpedance analysis over conventional anthropometric measures (BMI) to assess adolescent body composition. Our results are also consistent with the body composition patterns observed in adolescents in recent studies outside Kosovo. Accordingly, when evaluating the growth and potential health risks of adolescent males and females, use of measures that assess body composition should supplement measures of partial growth determined using BMI.

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Traditional Games in Physical Education and Beyond: A Systematic Review of Experimental Research

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Abstract: *This systematic literature review investigates the application of traditional games within school education. Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, the study analyzed 18 experimental research articles that utilized traditional games as the independent variable. Data was sourced from four prominent databases: Scopus, Web of Science, ProQuest, and ScienceDirect. Key findings reveal a broad implementation of traditional games across diverse subjects, extending beyond the commonly associated Physical Education domain to encompass Mathematics, Physics, Art, and Science education. This practice is evident in various countries such as Indonesia, Malaysia, the Philippines, Tunisia, Spain, Kazakhstan, and Macedonia. The research emphasizes the interplay between game selection, intervention duration, and participant characteristics in determining the effectiveness of traditional game interventions. While this review highlights the significant potential of traditional games in enhancing educational outcomes, it underscores the need for further research. Exploring the application of traditional games in higher education and broader community contexts is crucial to fully comprehend their impact across different age groups and sociocultural settings. By expanding the scope of inquiry, future studies can contribute to a more comprehensive understanding of the multifaceted benefits of traditional games and inform the development of effective educational strategies.*
Keywords: *traditional games, physical education, systematic review, PRISMA, experimental research*

Introduction

Education is very important to improve the ability of human resources. The phenomenon of 'learning loss' due to the Covid-19 pandemic continues to be felt even today. This phenomenon arose due to the disruption of educational activities during the pandemic (Jakubowski et al., 2023). Learning and teaching activities at schools had to be halted to prevent the spread of Covid-19, which was then gradually adjusted through online learning (Alhazmi, 2023). Online learning was not beneficial for developing countries (Vit, 2023), including Indonesia. The uneven access to the internet and communication devices in Indonesia caused some Indonesian students, especially in remote areas, to be unable to access education at all (Syaukani et al., 2023). In general, the decline in education in Indonesia as a result of the Covid-19 pandemic can be seen from the decline in PISA scores. In December 2023, the Organization for Economic Co-operation and Development (OECD) reported that the PISA scores of Indonesian students had declined compared to previous years (Ismawati et al., 2023). This indicates that education in Indonesia has declined due to the Covid-19 pandemic. Currently, as the Covid-19 pandemic ends and schools are opened for students and teachers to learn, it has had an impact on improving the educational conditions. However, there are still shortcomings that need to be immediately addressed, namely the low interest of students in learning. Several studies have revealed that several years after the Covid-19 pandemic, students' interest in learning is still relatively low (Blain et al., 2022; Manzoor et al., 2022). Emphasis on teacher and student motivation as important because through this game it can also cheer up the mood (S. Susanto et al., 2024).

If this is not taken seriously, then efforts to overcome this learning loss will not be optimal. One strategy that can be made to restore students' interest in learning is to create creative learning, both in terms of material and teaching methods. Traditional games, as a rich cultural heritage, have great potential to answer this challenge. Physical education fosters value-based learning, developing essential 21st-century skills for global competitiveness (Mardiyah et

al., 2024). Traditional games are not only fun but also contain educational values that can develop various cognitive, social, and emotional skills in students(Azlan et al., 2021). Although some studies have mentioned the benefits of traditional games in education, further research is still needed to systematically examine the effectiveness of their implementation. This research is presented to provide a broader picture to readers about the extent to which traditional games have been implemented in the context of learning in schools.

Traditional games are those that have been played for generations across different generations(Fauzi et al., 2023). These games are deeply rooted in the culture of the society that plays them, so it can also be said that traditional games are cultural products. Traditional games were very familiar to children in the past, but now, traditional games tend to be forgotten by the younger generation. The emergence of more modern and interactive games, especially those based on digital technology, has caused traditional games to lose their existence. Therefore, as an effort to improve the quality of education and preserve culture, the implementation of traditional games in schools has become the most strategic step. Structured learning activities in schools will inevitably make students take part in learning activities delivered by teachers. The implementation of traditional games by teachers in learning will certainly open up opportunities for students to learn more deeply about traditional games. The cultural values in traditional games will be a strong foundation for the formation of students' character who have a global perspective and are aware of the culture around them. These are the characters that students must have in 21st century skills(Nazarian et al., 2023).

Although several studies have investigated the implementation of traditional games in educational contexts, a comprehensive literature review reveals several shortcomings. Firstly, most studies have focused on qualitative aspects (Hananingsih et al., 2024), making it difficult to generalize the results. Secondly, some studies are descriptive and associative in nature(Adi et al., 2022; Kristanto & Wibowo, 2023), which can only describe or measure the relationship between variables, but cannot prove that one variable cause another. Thirdly, the contexts in which traditional games are implemented also vary, ranging from formal schools to informal communities, making it difficult to identify the factors that most influence the success of implementation (Suhra, 2023). Therefore, this study aims to fill this gap by conducting a systematic review of experimental studies that specifically test the effectiveness of traditional games in improving students' academic achievement in school settings. Thus, it is expected that this study can provide stronger causal empirical evidence regarding the potential of traditional games as an effective learning tool.

Based on the above background, this study aims to answer several research questions: (1) To what extent have traditional games been implemented in school learning? (2) What learning outcomes are produced from the implementation of traditional games in schools? (3) What is the most effective way to implement traditional games in the learning process? Through this literature review, it is expected that important information will emerge that can serve as a guide for teachers to adopt traditional games in their teaching activities.

Material and Methods

This Systematic Literature Review (SLR) aims to determine the extent to which traditional games have been adapted for use in school learning activities. This research collected articles from four prominent databases that index academic journals in the field of education: Scopus, Web of Science (WOS), ScienceDirect, and ProQuest. In conducting this investigation, the researcher adhered to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)(Page et al., 2021). The literature review protocol presented in PRISMA has been widely used in various social research studies and has proven effective in producing comprehensive, transparent, and easily understandable systematic literature reviews. Through the databases used in this study, the researchers searched for articles related to the implementation of traditional games in school curricula.

Search protocol

The search process began by determining the keywords used to form search strings for each database. Search strings were created by combining keywords and Boolean operators such as "AND", "OR", and "NOT" to find articles that matched the research objectives. Additionally, parentheses and quotation marks were used within the search strings to group keywords, and asterisks (wildcards) were used to search for variations of words. The search using the search strings yielded a total of 1064 articles. A breakdown of the results shows that 345 articles were obtained from Scopus, 362 from WOS, 256 from ScienceDirect, and 101 from ProQuest. In this study, there was no limit set on the publication year for the articles. Subsequently, the filtering feature was used in each database to simplify the number

of articles according to the research needs. Based on the search results using filters, 195 articles were obtained, which then entered the title screening stage. At this stage, each title was reviewed and matched against the inclusion criteria to be included in the abstract screening stage. At the title review stage, the number of articles decreased to 37, where most of the analyzed articles had titles that did not align with the research objectives. For example, there was the word "traditional" in the article title, but it did not refer to traditional games but rather to traditional teaching, traditional assessment, etc., which were not related to traditional games. The 37 articles that passed the title screening stage were then screened based on their abstracts. The authors were guided by the inclusion and exclusion criteria to determine the articles suitable for use in this study. There were a total of 28 articles that would then be analyzed in full-text. The remaining 9 articles did not meet the criteria because they were not experimental research (1), were not curricular activities in schools (3), and did not use students as research samples.

Data extraction

At the final stage of article selection, 28 articles were analyzed in full-text. This stage required the authors to read and scrutinize each article individually to determine the alignment between the data presentation and discussion in each article with the data needs of this SLR. A total of 10 articles were found to be ineligible and were excluded from this study. The reasons for exclusion included irrelevance to the context of implementing traditional games for students in schools (3 articles), as the traditional games were applied outside of a school setting and the subjects involved in the study were not students but teachers, parents, and the general public. Additionally, 3 other articles, while studying traditional games in schools, did not employ an experimental research design. Several other articles were not included in the final list of articles because they were still preliminary studies or were not open-access articles. At this final screening stage, Microsoft Excel software was used because it has a simple interface, is easy to operate, and can be used to categorize articles into smaller sections for more detailed analysis of their suitability. In the final stage, 18 articles were selected for further in-depth analysis to identify patterns and data congruence to answer the research questions. The overall flow of this SLR can be seen in Figure 1.

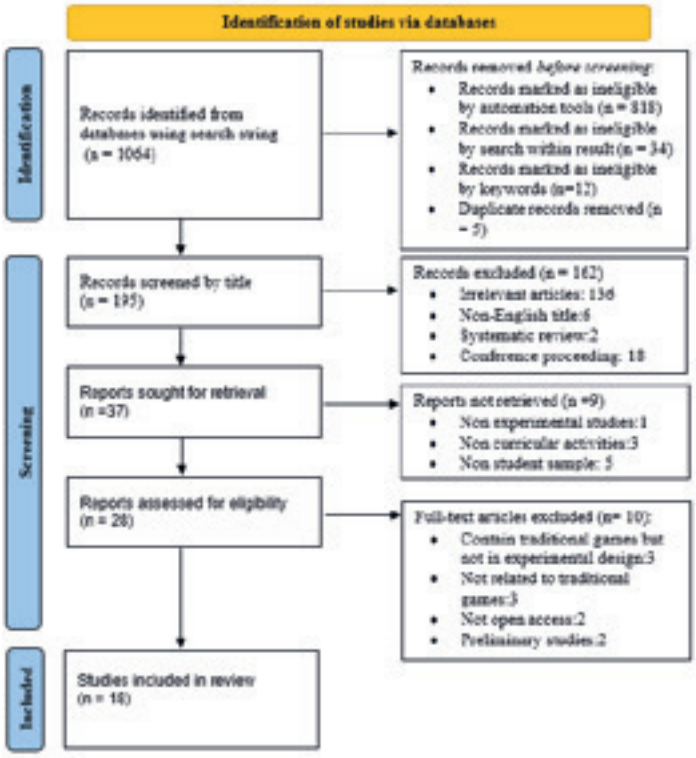

Figure 1. *PRISMA search protocol on this study*

Results

After undergoing a series of search and selection processes adhering to the PRISMA protocol, this research suc-

cessfully selected 18 articles from 7 countries to be analyzed in order to answer the predetermined research questions. The 7 countries involved, along with the number of articles, are Indonesia (8), Spain (4), Macedonia (1), Tunisia (1), Kazakhstan (1), Malaysia (2), and the Philippines (1). The analysis of each article was guided by the research questions to reveal the extent to which traditional sports have been implemented in school curricula.

Scope of implementation

RQ1: To what extent have traditional games been implemented in school learning?

Based on the provided data, traditional games have been primarily implemented in physical education subjects. Analysis of 18 articles reveals that traditional games are predominantly used in physical education (PE) classes, with 13 articles focusing on this application. This emphasis likely reflects the physical nature of these games, which naturally aligns with PE goals like improving fitness, motor skills, and cooperation. Some traditional games used include *Galah Panjang* (Azlan et al., 2021), *Bentengan* (Budiman et al., 2021), *Piko* (Capinding & Remelie Dacumos Salazar, 2023), *Tok Harimau* (Charles et al., 2017), and *Raqassa* (Jebali et al., 2013). Traditional games offer a range of physical benefits, developing speed, agility, power, flexibility, and coordination. Introducing these games into physical education innovatively achieves learning goals while connecting students with local culture. While modern sports like football, volleyball, and basketball are valuable for developing fitness and motor skills, this research highlights the potential of traditional games to achieve these same objectives while simultaneously fostering cultural awareness and values. This approach offers a unique opportunity to enrich physical education beyond its standard curriculum.

This research shows physical education as the primary subject using traditional games. While less common, their use in other subjects like physics, math, and science is a promising trend, suggesting broader recognition of their educational value. This interdisciplinary approach enriches learning by providing culturally relevant contexts for abstract concepts. For example, the growing field of ethnomathematics explores how cultures embed mathematical ideas in their practices, highlighting the connection between mathematics and culture(Nurcahyo et al., 2024; Uula et al., 2024). Ethnomathematics highlights that mathematics is not solely a Western construct but is present in various forms in different cultures. Therefore, it aims to guide students to understand and respect the mathematical knowledge and practices of indigenous and marginalized communities. In this research, there are several articles that highlight the use of traditional games in mathematics learning, including Trajkovik's study (Trajkovik et al., 2018), which uses Macedonian traditional games (Match-box & Hop-scotch) in math classes. Through traditional games, learning can be designed as Game-based learning (GBL) model, which can create a student-centered learning approach that optimize learning engagement. Additionally, another study that adopted traditional games in mathematics learning is Kamid's research(Kamid et al., 2022), which utilizes the educational value of traditional games to improve students' process skills and learning motivation. Regarding RQ1, the diverse nature of traditional games allows teachers to select games appropriate for various subjects and course learning outcomes (CLOs). This versatility explains the wide range of traditional game implementation across school curricula, beyond physical education, including both science and social studies.

Targeted outcomes

RQ2: What learning outcomes are produced from the implementation of traditional games in schools?

This review of experimental studies examined how traditional games (independent variable) affected targeted learning outcomes (dependent variable). Most studies explored how manipulating traditional games impacted these outcomes across the three learning domains: cognitive (intellectual skills like knowledge and critical thinking), affective (emotions, attitudes, and values), and psychomotor (physical skills and coordination). While each subject interprets these domains differently, all aim for holistic education by addressing all three. Although each of the 18 articles had specific target outcomes, all considered cognitive, affective, and psychomotor aspects. Within the cognitive domain, studies used traditional games to improve various cognitive abilities, including learning outcomes, mathematical and scientific thinking, process skills, critical thinking, and creative thinking. The subjects that applied these varied from Physical Education (PE), Mathematics and Science, to Physics(Aliriad et al., 2024; Capinding & Remelie Dacumos Salazar, 2023; Fernández-Oliveras et al., 2021; Khoiri et al., 2023; Trajkovik et al., 2018). Traditional games are not only associated with motor skills but can also be used to achieve cognitive goals. This is due to the wide variety of traditional games that teachers can choose from to suit their desired learning objectives.

For example, a research by Fernández-Oliveras et al., (2021) utilized the Spanish traditional game The Dog and The Goats *"El Perro y las Cabras"*, a traditional board game that involves strategic thinking and planning. Through their research, they identified the various impacts that could result from implementing traditional games in mathematics and science subjects. Their findings concluded that traditional games have successfully promoted the activation of mathematical and scientific content among participants aged 8 to 12 years. The traditional games proved to be effective in mobilizing essential mathematical and scientific concepts, demonstrating their strong didactic potential within the context of primary education. Meanwhile, research by Trajkovik et al., (2018) applied several Macedonian traditional games to different subjects. Specifically, "Matchbox" and "Hop-Scotch" were incorporated into mathematics, "Lady" and "String" into art classes, and "Mosque" and "Hide and Seek" into Nature and Society classes. The results showed that traditional games serve as effective instructional tools that enhance learning outcomes across various subjects, including Mathematics, Art, and Social Science. The study found that these games not only improved test scores but also increased student engagement and interest in the learning process.

Key to effective implementation

RQ3: What is the most effective way to implement traditional games in the learning process?

This review included only experimental studies, as this design is particularly effective for establishing cause-and-effect relationships. By manipulating the independent variable (traditional games) and measuring its impact on the dependent variable (learning outcomes), researchers can confidently determine causality. While the 18 included studies mostly employed a quasi-experimental design, they aim to inform real-world educational applications of traditional games. A key consideration was the duration of the traditional game intervention. Appropriate duration is crucial for accurate results; too short a period may not yield measurable changes, while too long may lead to participant fatigue or boredom, both of which can compromise validity and reliability.

The shortest treatment duration was 12 minutes(Jebali et al., 2013) and the longest duration was 24 sessions with an accumulated time of 1440 minutes (24 hours)(Charles et al., 2017). Studies of both short and long duration confirm the positive impact of traditional games. Jebali's study of the Tunisian game "Raqassa" showed improved cardiovascular response, while Charles found that traditional games enhanced physical fitness. While Jebali's acute study adequately addressed intervention time, Charles, despite having the longest intervention period of the reviewed studies, acknowledged its limitations for chronic response and suggested longer interventions for greater improvement, highlighting the influence of the dependent variable on required intervention length.

Effective program evaluation requires selecting appropriate traditional games. This research identifies diverse games used across subjects, ranging from physically active to mentally stimulating. Research by Capinding & Remelie Dacumos Salazar, (2023) applied the Filipino traditional game *"Tatsing"* or Hit The Cap, which is a game that tests accuracy in hitting a bottle cap target with a stone; players aim to collect bottle caps and answer questions related to science topics. This game does not emphasize physical aspects, similar to the Spanish game *El Perro y las Cabras* (Fernández-Oliveras et al., 2021), this game requires strategic thinking skills so it is suitable to be linked to subjects that involve a lot of thinking skills. This game tends to sharpen cognitive abilities so it will certainly not be suitable if it is linked to the impact on improving physical fitness. If the goal is to improve physical fitness, then the appropriate type of game must be found, such as *Raqassa* (Jebali et al., 2013), *Galah Panjang* (Charles et al., 2017), and *Bentengan* (Fauzi et al., 2023).

The next consideration in ensuring the effectiveness of implementing traditional games is the targeted participants. 17 out of 18 articles (94%) used in this study used children as research subjects. In an educational context, the subjects used were students from elementary to junior high school(Aliriad et al., 2024; Azlan et al., 2021; Capinding & Remelie Dacumos Salazar, 2023; Charles et al., 2017; Ermenova et al., 2020; Fauzi et al., 2023; Fernández-Oliveras et al., 2021; Hartanto et al., 2021; Jebali et al., 2013; Kamid et al., 2022; Khoiri et al., 2023; Luchoro-Parrilla et al., 2021; Muñoz-Arroyave et al., 2021; Saputra et al., 2021; Septianto et al., 2024; Trajkovik et al., 2018). This indicates that one of the positive outcomes of these studies is the suitability of the target participants. Traditional games are objects to fill children's playtime. Traditional games are often played outdoors, use inexpensive and easily obtainable equipment, and have fairly simple rules. For children who are still closely connected to the world of play, traditional games are certainly still able to satisfy their level of enjoyment, while for adults, traditional games may not be as attractive as modern games that have more complex rules that can add challenge and excitement when playing.

Therefore, through this research, it can be concluded that the greatest opportunity for the success of implementing traditional games is when applied to children aged elementary to junior high school.

Discussion

This study highlights the potential of traditional games to enhance learning across disciplines. While their use in physical education is expected, their integration into subjects like math and science is promising. In PE, these games promote fitness, motor skills, and cooperation, enriching curricula and fostering cultural appreciation. In math, games like Match-box and Hop-scotch offer engaging, culturally relevant learning experiences that improve understanding and problem-solving, aligning with ethnomathematics principles. Overall, a game-based learning approach using traditional games can boost student engagement. Research by Kamid et al. (2022) highlight the positive impact of these games on students' process skills and learning motivation.

This review highlights the potential of traditional games to enhance student learning across cognitive, affective, and psychomotor domains. Beyond physical education, these games can be integrated into various subjects to promote holistic development, especially cognitive and affective growth. By engaging in traditional games, students are challenged to think critically, make strategic decisions, and problem-solve, thereby stimulating their cognitive abilities. Studies such as Fernández-Oliveras et al. (2021) and Trajkovik et al. (2018) exemplify how these games can be employed to activate mathematical and scientific concepts, thereby enriching the learning experience. Moreover, these games often involve teamwork, cooperation, and fair play, fostering essential social and emotional skills that contribute to overall well-being. In addition to being beneficial for academic achievement, traditional games also contribute to the preservation of local culture, which is crucial amid modernization and globalization(Narimo et al., 2019; Sulistyanto et al., 2023). Developing culturally aware youth is crucial for producing competent individuals with strong cultural identities, prepared for a globalized world. Traditional games offer a valuable means of fostering such well-rounded development.

This review concludes that the effectiveness of traditional games in education depends on game selection, intervention duration, and target participants. Careful game selection is crucial, given the diverse nature of traditional games. As demonstrated by studies such as Capinding & Remelie Dacumos Salazar (2023) and Fernández-Oliveras et al. (2021), certain games are inherently suited to specific learning objectives. While *"Tatsing"* and *"El Perro y las Cabras"* excel in fostering cognitive skills, games like *"Raqassa," "Galah Panjang,"* and *"Bentengan"* are more aligned with physical development. The alignment of traditional games with desired educational outcomes is crucial for maximizing their effectiveness. Intervention duration significantly influences results; while positive effects were observed across varying lengths, from short sessions to extended programs, the specific outcomes were dependent upon this duration. Acute responses, such as changes in heart rate, were evident even in short-term interventions, as demonstrated by Jebali et al. (2013). Conversely, chronic outcomes like physical fitness, as measured by Charles et al. (2017), required more extended periods. This review highlights the need for careful consideration of intervention duration and participant selection, particularly given the prevalence of child participants. While traditional games' physical and playful nature aligns well with children's development, generalizing these findings to adults may be limited due to potentially different preferences and engagement.

Conclusion

This research concludes that traditional games are widely used in primary and secondary schools across various subjects. This review suggests that all subjects consider incorporating these games, given their potential for both academic achievement and cultural preservation. The reviewed articles demonstrate how to select appropriate games and determine effective intervention durations to achieve specific learning targets. Traditional games offer educators an interactive and culturally enriching alternative learning experience. Future research should explore their application in higher education to understand their impact on older learners.

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Short notice
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Differences in Functional Abilities in Junior Karates in the Pre-Competition and Competition Period

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Abstract: *The sample of respondents on whom this research was conducted consists of 14 male junior athletes (karatists), potential representatives from the Republic of Kosovo. The research was conducted within the framework of the preparatory and pre-competitive period for participation in the Karate World Championship. The potential representatives who entered the sample of respondents were active competitors who participated in the national championship and premier leagues organized by the World Karate Federation WKF (World Karate Federation). The main goal of this research is to monitor and determine the differences that appear in the functional abilities of karate players after ten weeks of programmed training. The obtained results were processed and analyzed with a statistical package of programs appropriate for the research. According to the applied ANOVA and MANOVA tests, out of a total of six analyzed variables, only two (Beep - test and VO2max.) were found to have a statistically significant difference between the three measurements.*
Keywords: *karate, competitors, juniors, potential national team players, preparatory and pre-competition period*

Introduction

Karate, seen from the perspective of sport and martial art, develops great self-discipline, dedication and awareness among practitioners (Kostovski, Ž.et all.2014). Karate, nowadays, is included in the group of the most popular martial arts, practiced all over the world, which attracts an increasing number of participants, practitioners and supporters. During the competitions organized by the WKF (World Karate Federation), two equally important disciplines are present: sports fighting (kumite) and kata (kata). Both disciplines are increasingly relevant among a growing number of researchers, scientists, trainers, practitioners, who research this area on a daily basis.

As a condition for talking about diagnosis in the training process, the existing modalities of fitness training that are used in the training processes of karatekas should first be defined. A relatively large number of studies have been conducted in karate sport, which discuss the dominance of high-intensity structural activities that prevail during a karate fight. During the fight, anaerobic metabolism is used as a source of energy, which according to the physiological classification and dominance of energy processes, karate fight is classified as lactate-glycolytic anaerobic sports (Lehman I Jedliczka 1998; Shmidt I Perry 1976). On the other hand, Beneke R.,et al. (2004), investigating the energy systems and metabolic consumption of aerobic and anaerobic energy in karate fights, came to the conclusion that the dominant source of energy is aerobic metabolism, but there is anaerobic supplementation mainly with high-energy phosphates. Karate as a physical activity belongs to the group of polystructural acyclic sports with a complex and dynamically expressed structure. The dynamism and high frequency of movements during the fight require karatekas to have a high level of functional and motor skills, with a special emphasis on coordination, speed and strength skills (Blaževič i sor, 2006). Karate training and diagnostic procedures aim to develop and analyze the specifics of the sport, such as: the specific structure of movements, the specific situations arising from the structure of karate technique and the levels and needs of specific energy capacities.

For all athletes and sports workers who are professionally involved in this sport, it is of primary importance to have validly confirmed and summarized knowledge about the main functional, motor and psychological factors related to the structuring and modeling of karate training. Oxygen consumption is considered one of the most important estimators for determining the level of intensity of physical activity. The precise measurement of maximal oxygen consumption (VO2max) is carried out by subjecting karatekas to physical exertion, which should be long enough to

achieve complete exhaustion of the aerobic energy system. Both laboratory and field tests are used in testing athletes. In the context of the above, several authors (Najmi, N., et al. (2018); Martínez, Q., Ó.,A. & Izquierdo, M., A., C. (2020); Przybylski. P. et al. (2021); Martinez-de-Quel O et al. 2021), suggest that among the various tests for assessing aerobic capacity, the 20m shuttle run test (Shuttle round or Beep test) is the most commonly used test.

Success in any sport, including karate, depends on the joint action of several factors: technique, tactics, decision-making speed and mental abilities. For this entire system to function normally, it largely depends on the physiological characteristics of karatekas (Zaborski et al, 2015). Training, as well as sports combat, requires karatekas to possess a high level of motor and functional abilities, with special emphasis on the speed, strength, and coordination abilities of the karateka (Blaževič et al, 2006).

Diagnostic procedures during the training process in karatekas aim to monitor and analyze the development of the specific structure of movements, in specific situations, specific energy capacities, etc., which in turn arise from the structure of the karate sport. In this context, it can be concluded that physiological characteristics are of high importance in the process of the efficient preparation of karate athletes to achieve top results.

Methods

The sample of respondents on whom the research was conducted consists of 14 male athletes (junior karate fighters), potential representatives from the Republic of Kosovo. The research was conducted within the framework of the preparatory and pre-competitive period for participation in the Karate World Championship. The research was of a longitudinal nature and was conducted with the respondents on three occasions: initial, control and final measurement. The potential representatives who entered the sample of respondents are active competitors who participated in the state championship and premier leagues organized by the World Karate Federation WKF (World Karate Federation). The subject of the research in this study is the functional abilities of junior karate fighters in the preparatory and pre-competitive period.

The research was conducted in order to determine the differences that appear in functional abilities after ten weeks of programmed training. From the aspect of the athlete's functional abilities, changes that occur in: maximum oxygen consumption (VO2max), maximum heart rate (HRmax) and blood lactate concentration were monitored (1. Lactate concentration at rest KLAM, 2. Lactate concentration after exercise KLNO 3. Lactate concentration after recovery KLNR).

The data obtained from the research according to the size and characteristics of the sample of respondents were processed with a statistical package of programs intended for this type of research. In order to present an objective picture of the research, the following statistical parameters were applied: Multivariate analysis of variance (MANOVA) - which will determine the significance of the differences between the three measurements for each group of respondents. Univariate analysis of variance (ANOVA), which will determine the individual differences for each variable according to the given characteristics.

Results

In table no. 1, the results relating to the maximum oxygen consumption (VO2 max) in Junior karatekas in the different time sequences are shown. From the obtained results it can be seen that, in their programmed training process, the karatekas achieved the best results in the arithmetic means of the variables Beep t (Mean= 9.71± 1.77) and the variable VO2 max (Mean= 45.93 ± 6.28), which they achieved in the third time sequence. This difference in the results between the initial, control and final measurements should be attributed to the well-programmed training in the preparatory period of the karatekas and thus indicates the improvement of their physical fitness. These results, compared to results from the available literature, are within similar limits. Thus, according to data obtained from (Ravier, G., et al. 2009), who conducted a study examining the effects of adding high-intensity sessions twice a week for 7 weeks on markers of aerobic and anaerobic metabolism in elite karate athletes, significant improvements in VO2 max and positive physiological changes were obtained, which improved the time in which they could engage in intense physical activity before fatigue occurred.

From the values shown in table 1, which refer to the statistically significant differences between the time sequences of the measurements, it is evident that based on the results obtained from the three measurements of each variable and the values of Raos's F approximation (743.29), a statistically significant difference was determined

between the three time sequences for the variable maximal oxygen consumption (VO2 max) at a level of p=0.00. According to the analysis of the values from Table 1, which relate to the Beep-test variable and the statistically significant differences between the time sequences of the measurements, it can be concluded that based on the results obtained from the three measurements of each variable separately and the values of Raos's F approximation (385.19), a statistically significant difference was found between the three time sequences (measurements) of the Beep-test at a level of p=0.000.

Table 1. *Multivariate differences in variables from Functional Abilities among Junior respondents*

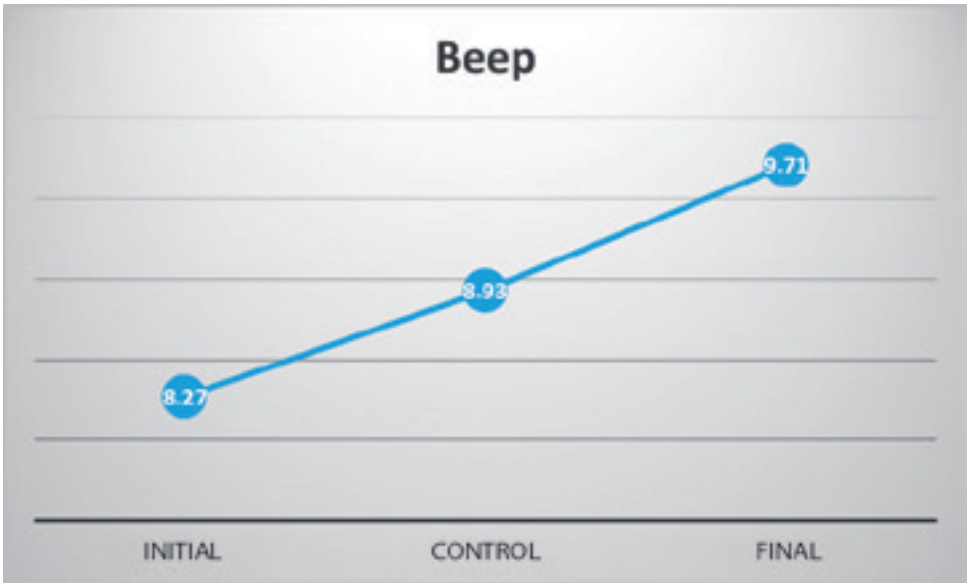
Juniori	Иницијално		Контролно		Финално		F	Sig
	Mean	SD	Mean	SD	Mean	SD		
Beep	8,27	1,82	8,93	1,86	9,71	1,77	385,19	**0,000**
VO2max	40,84	6,23	42,79	6,13	45,93	6,28	743,29	**0,000**
MHRmax	85,29	4,76	83,00	6,19	81,29	6,27	4,41	0,056
HR	98,71	2,20	98,57	2,47	99,07	0,83	0,39	0,542
KLAM			6,57	4,60	6,21	5,01	0,25	0,805
KLNO			15,57	2,24	15,07	1,94	1,34	0,205
KLNR			12,21	5,55	10,86	3,42	1,12	0,285

The differences at the Univariate level are shown in Table 2, i.e. the time sequences that participate in creating the statistically significant difference within the measurements. From the table it can be seen that for the variable Beep test (Beep t), numerical differences between the measurements were determined, which are also statistically significant differences, in all three measurements at the level of p=0.002 to p=0.000. The largest statistically significant difference is determined between the initial measurement and the final measurement at the level of p=0.00.

Table 2. *Univariate differences of the variable Beep-test for the group of respondents Juniors*

Pairwise Comparisons (Beep)						
(I) Time		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	(.657)*	.26	.02	-1.21	-.10
	3	(1.443)*	.35	.00	-2.19	-.69
2	1	.657*	.26	.02	.10	1.21
	3	(.786)*	.24	.01	-1.30	-.27
3	1	1.443*	.35	.00	.69	2.19
	2	.786*	.24	.01	.27	1.30

The increase in the values of the beep - test variable is also graphically shown in graph no. 1, where a slight continuous increase in the values achieved by the respondents can be observed between the initial (8.27), through the control (8.93) to the final measurement (9.71), which indicates a significant improvement in physical endurance.

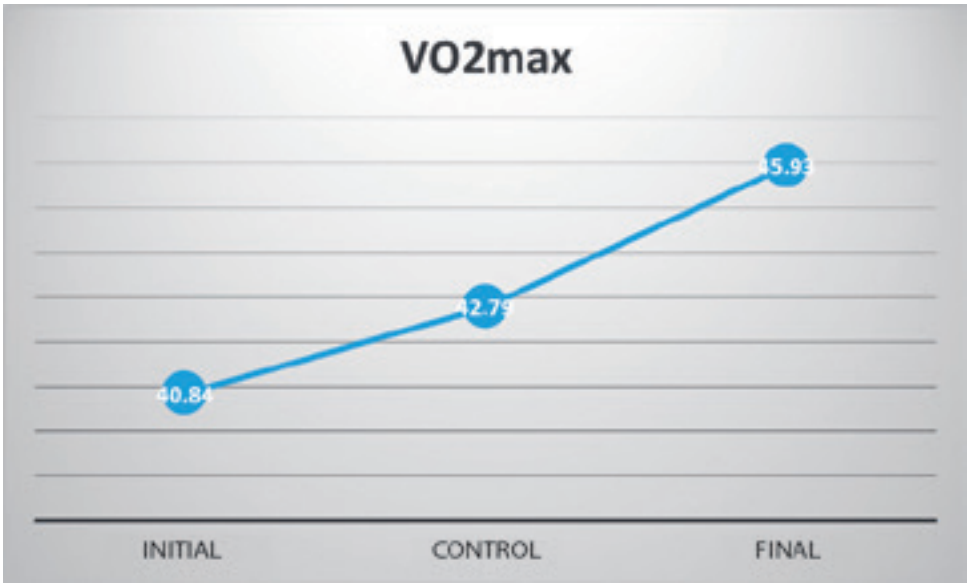


Graph 1. *Beep test*

Table 3 shows the differences at the Univariate level, i.e. the time sequences that contribute to the creation of the statistically significant difference within the measurements. At the same time, it can be seen that for the variable VO2 max, the determined numerical differences are also statistically significant differences, in all three measurements at the level p=0.004 to p=0.000. The largest statistically significant difference is determined between the final measurement and the other two (control and initial) measurements at the level p=0.00. For elite karate athletes to train and compete at a high level, both aerobic and anaerobic metabolic efficiency are important, but aerobic capacity can be a decisive factor. However, it should be taken into account that the level can be variable, depending on age categories and gender-related factors (Gaweł, E., et al.2025)

Table 3. *Univariate differences of the variable VO2max for the Juniors group of respondents*

Pairwise Comparisons (VO2max)						
(I) Time		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	(1.943)*	.83	.04	-3.74	-.14
	3	(5.086)*	1.06	.00	-7.38	-2.79
2	1	1.943*	.83	.04	.14	3.74
	3	(3.143)*	.65	.00	-4.56	-1.73
3	1	5.086*	1.06	.00	2.79	7.38
	2	3.143*	.65	.00	1.73	4.56



Graph 2. *VO2max*

Graph 2. presents the increase in VO2 max. from the initial to the final measurement, where according to the obtained values, from the initial (40.84) to the control (42.79) measurement there is a smaller increase which then records larger values from the control to the final (45.93) measurement, which indicates a great progress in the values of aerobic capacity among the respondents.

Discussion

In the research of Beneka et al. (2004), the structural profile of the acyclic activity of karate fighting indicates that aerobic metabolism is the dominant source of energy with anaerobic compensation, mainly energy rich in phosphates. The functional basis of karate fighting (according to Beneka et al. 2004) consists of 77.8% aerobic capacity and 22.2% anaerobic capacity, (16% ATP adenosine triphosphate, PC creatine – phosphate, and 6.2% anaerobic glycolytic capacities).

The importance of aerobic and anaerobic endurance is also emphasized by Iide, K., et al. (2008), in their research on the physiological response of the body during simulated karate competitions where karate athletes reached approximately 85-93% of HR max. This can be correlated with the significant results obtained from the Beep test from this research, which suggests that karate athletes can effectively work in zones with high heart rate and high VO2 max., and delay fatigue. Güler et al. (2018), emphasize that a high level of aerobic capacity is essential to avoid fatigue and to enable faster recovery during breaks between fights and between intense periods during a fight.

It is also worth mentioning the results obtained from the research of Arazi, H., and Izadi, M. (2017), in which the authors link body weight to maximum oxygen consumption because karatekas in heavier categories showed lower VO2 max. compared to other weight categories.

Several authors (including Nema, K. et al. 2024), suggest that with such precise data on the impact of aerobic and anaerobic capacity, heart rate, fatigue, lactate levels, etc., it will be possible to qualitatively approach the development of work plans and programs and individualization of training in order to improve sports performance, monitor progress and prevent injuries.

Conclusion

In terms of its structural complexity, karate belongs to polystructural acyclic sports, dominated by acyclic unpredictable movements, and only has symbolic destruction of the opponent. This positive destruction, the karateka tries to achieve by delivering controlled blows to the head and body of the opponent, although the movements represent a combination of maximal and submaximal intensity (Kostovski et al, 2015), and the energy is drawn from both aerobic and anaerobic metabolism. In sports performed indoors (gyms), the physical performance of athletes is generally determined by the duration and pace of the competition. In response to this, training programs aim to slow

down the time for fatigue formation and improve endurance (Ismail Kaya at. all 2013). According to Chaabene, H., et al. (2012), between two consecutive fights or between two periods within a fight, aerobic capacity plays a major role because it ensures the recovery processes between those periods, thus preventing fatigue. All of these above-mentioned findings indicate the need for continuous and comprehensive scientific research to understand the exact physiological and conditioning requirements of elite karate, which will also include other parameters and indicators, such as: research and comparisons by gender, age and weight categories, differences between kata and kumite, etc. The inability to find a statistically significant difference in blood lactate levels between the initial, control and final measurements can be attributed to various other influencing factors (a difference exists, but it is not large enough to be significant). Lactate is not a consistently reliable marker of aerobic adaptation and further studies involving very high-intensity training are definitely needed, as blood lactate indicates anaerobic glycolysis, while VO_2max and the beep test measure aerobic endurance capabilities. Most karate studies focus on post-exercise lactate rather than resting lactate, as resting values are usually low and indistinguishable (e.g., Güler, M., et al. 2018). In this context, according to Chaabène, H., et al. (2014), lactate levels are significantly higher in competitive conditions because official fights cause greater physiological stress (and more lactate is secreted in response) than in training conditions. Therefore, the need to replicate competitive intensity during training is emphasized.

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Exploring the Relationship Between Handgrip Strength, Body Fat Mass, and Fat-Free Mass in Male and Female Handball Athletes

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Abstract: *This research endeavors to examine the correlation among handgrip strength (HGS), body fat mass (BFM), and fat-free mass (FFM) within the population of handball athletes.*
This was a cross-sectional study involving 81 handball athletes consisting of 44 males (Age 17.4±1.5 years, height 1.73±0.06 m, body weight 64.7±10.5 kg, BMI 21.6±2.9 kg/m2) and 37 females (Age 17.0±1.4 years, height 1.61±0.06 m, body mass 55.9±10.2 kg, BMI 21.7±3.7 kg/m2).
There was a correlation in male handball athletes where the right HGS was correlated with the right BFM (r=0.231; p=0.022), the right HGS with the right FFM (r=0.302; p=0.003), the left HGS with the left FFM (r=0.297; p=0.003). Meanwhile, in female handball athletes, the right HGS was correlated with the right FFM (r=0.466; p=0.004), and the left HGS with the left FFM (r=0.448; p=0.005). This research elucidates that substantial correlations exist between Fat-Free Mass (FFM) and both right and left handgrip strength (HGS) in male and female handball athletes. In contrast, BFM only correlates with the right HGS, but not with the left HGS. This is likely influenced by the dominant side of the muscle. Thus, strength training programs should be focused on improving FFM as a whole, while also considering the potential for muscle imbalances due to the dominance of one side of the body to enhance the overall efficiency of physical capabilities.
Keywords: *Handball, handgrip strength, body fat mass, fat free mass*

Introduction

Handball is an example of a competitive sport that requires high physical strength, especially in the hands (HGS) when passing (Wagner et al., 2014), shooting, and defending (Karcher & Buchheit, 2014). HGS measurement is one of the most simple yetuseful parameters for measuring hand grip strength (S. H. Lee & Gong, 2020). The force exerted by the hand grip serves not only as an indicator of the strength of a specific muscle group, but it also demonstrates a significant correlation with the overall muscular strength of the entire body. (Szaflik et al., 2025). In contrast, BFM and FFM are thought to affect muscle performance (Ardha et al., 2024). Higher FFM is usually associated with greater muscle strength, while high BFM tends to inhibit performance because it is a non-functional load (Nonaka et al., 2018). However, this is not always true; some athletes with higher FFM have a disproportionate HGS, and vice versa, some athletes with higher BFM but yet have good HGS (Patnaik et al., 2021). This indicates that the relationship between HGS and BFM and FFM is not always linear and consistent because it can be swayed by various additional variables including gender differences, muscle mass distribution, team playing position, and neuromuscular adaptation of each individual (Feuerbacher et al., 2025). In addition, injuries are also an important variable that can interfere with the function of the hand. Differences in hamstring eccentric in handball athletes with a documented history of physical injuries can also affect muscle stability and the risk of re-injury, especially in areas of the hands and wrists that are vulnerable in play (Isna et al., 2024). In a six-year survey, 13% of injuries in young handball players in Japan occurred on the wrist and hand, with sprains being the the predominant category of physical injury (37.9%), followed by contusion (30%) and injuries (20.7%) (Asai et al., 2020). There remains a deficiency in

empirical data that elucidates the precise correlation between handgrip strength (HGS) and both body fat mass (BFM) and fat-free mass (FFM) (Tavares Junior et al., 2023a).

Competitive sports demand optimal muscle strength and body composition because both play a direct role in determining the performance of athletes, especially in the game of handball (Lasković, 2022). Adequate muscle mass also contributes directly to the performance of jumps, which are used when making shots or blocks (Solikah et al., 2025). HGS not only indicates the strength of the upper arm muscles, but can also be used as a general way to assess the fitness level of the entire muscle (Vaishya et al., 2024). Body compositions such as BFM and FFM exhibit fat proportions and fat-free mass which are both essential for speeding up movement, speed, and physical endurance (Hernandez-Martinez et al., 2024). Numerous studies have been conducted on the relationship between muscle strength and body composition in the general population and athletes from various sports (Cataldi et al., 2023). However, there are not many studies that specifically investigate the relationship between HGS and BFM and FFM in male and female handball athletes.

The preservation of an optimal body composition is critically significant for athletes engaged in handball, as the attainment of ideal body fat percentages and sufficient muscle mass substantially enhances physical performance attributes such as strength, velocity, and stamina (Martínez-Rodríguez et al., 2023). Therefore, regular monitoring of body composition, including body fat, muscle mass, and weight, is highly recommended so that trainers can adjust their training program in a timely manner (Giovanelli et al., 2024). One solution that can be implemented is to develop a personalized exercise program based on the results of these measurements (Lukaski & Raymond-Pope, 2021). For example, players with low muscle mass can be given more intensive strength training to improve their performance (Fyfe et al., 2022). In addition, by knowing the correlation between HGS versus BFM and FFM, coaches and medical teams can develop more efficient evaluation methods without having to constantly rely on expensive or invasive measuring devices (Di Vincenzo et al., 2020). Understanding this relationship can also be used to design more specific training programs, such as handgrip enhancement exercises to optimize FFM or reduce BFM to support athlete performance (Nara et al., 2022). Gender differences also need to be considered because men and women may have different correlation patterns, so the approach to physical exercise and evaluation cannot be equalized (Pérez et al., 2024). In the context of periodic monitoring, a handgrip dynamometer can be a practical measuring tool because it is cheap, fast, and non-invasive (Sartorio et al., 2025). If proven to have a strong correlation with BFM or FFM, this tool can be used as an initial screening method or a routine monitoring tool in handball teams (Szaflik et al., 2025).

This research endeavor seeks to systematically examine the correlation between hand grip strength (HGS) and body composition, with a particular emphasis on body fat mass (BFM) and fat-free mass (FFM) among handball athletes. This relationship is important to understand because hand grip strength is an easily measured an indicator of muscular strength and is related to overall physical performance (S. Y. Lee, 2021). While BFM and FFM play a role in supporting or inhibiting muscle performance and physical performance (Merchant et al., 2021). By knowing the correlation between these variables, this study is expected to provide more in-depth information about the factors that affect the physical strength of handball athletes, especially in the aspect of handgrip.

Materials and Methods

Study Participants

Across-sectional study method was used, with subjects classified based on demographic characteristics (age and sex) and anthropometric/physical characteristics (body mass, height, and BMI) as shown in Table 1 (Mayorga-Vega et al., 2014). Prior to testing, all participants were screened for injuries by a physiotherapist. . The are inclusion criteria were: 1) handball athletes registered as participants in provincial championships 2) in good health and have good physical endurance to conduct tests (Riebe et al., 2015)? Specifically no upper-limb injury within the past 6 month 3) Not experiencing any health problems or muscle injuries that may affect physical abilities during data collection. This research have obtained ethical clearance 008/UN38.10/EC.KEPK/HK.01.02/2025 from Universitas Negeri Surabaya, Indonesia.

Study Organization

Data acquisition in the present investigation commenced with an evaluation of stature and an assessment of body composition to ascertain body mass, body fat mass (BFM), and fat-free mass (FFM). Subsequently, a handgrip

strength test was administered on both the dominant and non-dominant arms to evaluate the maximum grip strength. The raw data, encompassing variables such as age, height, weight, body mass index (BMI), BFM, and FFM, along with the peak handgrip strength values, were systematically gathered and organized in accordance with the criteria established in Microsoft Excel. Limitations of the study: This research constituted a cross-sectional analysis involving of 81 handball athletes, comprising 44 males and 37 females which means one time collecting data.

Body composition test

Proper assessment was valid assessment through multifrequency analytical impedance bioelectric and bioelectric devices using InBody 270. The InBody 270 device can be used as a DXA alternative (Dual-energy X-ray Absorptiometry) because the results are quite accurate, especially in active individuals (Czartoryski et al., 2020). The InBody 270 uses multifrequency bioimpedance technology to accurately measure body composition based on the ability of the body's tissues to conduct electrical currents, so that it can assess muscle mass, fat, and body fluids in detail (Bukowska et al., 2021). In weight measurement, BMI, BFM, and FFM were carried out using InBody 270 (Seoul, South Korea). During the measurement, the subject was instructed to remove the footwear and also metal or iron accessories. Then the subject adjusts the position of the foot with an electrode or sensor and takes a weight measurement. Once the weight data has been inputted, the participant is required to authenticate their identity by utilizing their user ID, which facilitates the generation of body composition results. Subsequently, at the commencement of the body composition assessment, the participant is instructed to grasp the handle and position their thumb upon the electrode or sensor. It is imperative that the participant maintains straight elbows, refrains from bringing them close to the body, and keeps their gaze directed forward, remaining immobile until the conclusion of the testing procedure. Each participant engages in a singular experimental trial until the body composition results are displayed on the designated screen; the output from the InBody device will be automatically printed thereafter.

Handgrip strength test

The assessment of hand grip strength was conducted utilizing the Omron Handgrip apparatus (Tokyo, Japan). Prior to the execution of the evaluation, the participants engaged in a series of gymnastic stretches to adequately prepare their muscles. During the assessment, the participant is instructed to adopt a standing position facing forward with their elbows fully extended. Subsequently, the participant exerts maximal force on the handgrip for a duration of three seconds. Each subject performs on both the right and left hands. With a rest time of 30-60 seconds between reps, thus avoiding a large drop in average HGS (Fernandes et al., 2014). Each subject took three measurements and calculated the average strength in (kg). However, hand dominance was not assessed in this study because handedness data was not used to categorize or analyze the handgrip strength results.

Statistical analysis

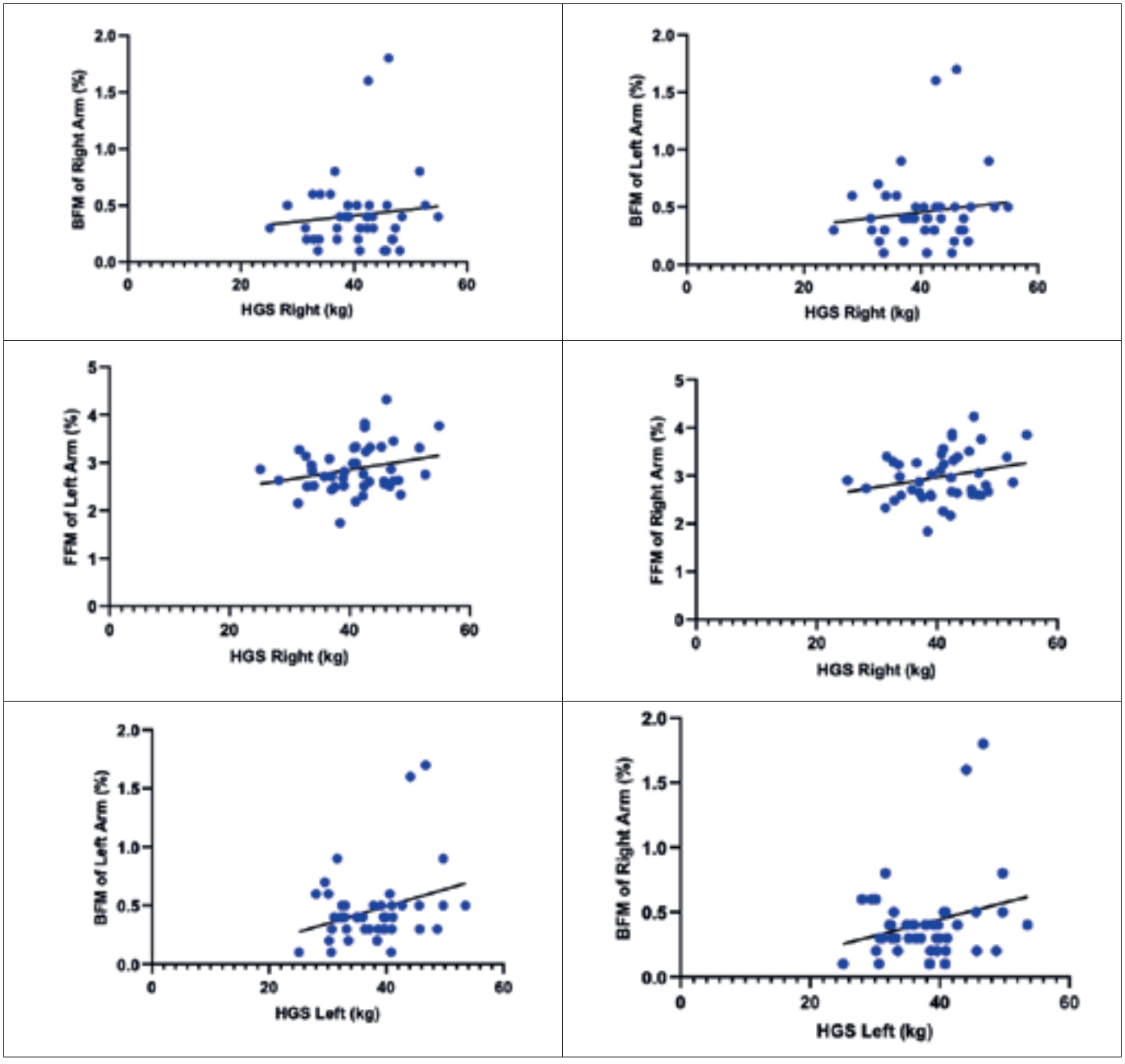
The test outcomes and subject measurement data were meticulously examined utilizing Minitab Version 26 software. Following the selection of data that aligns with the research objectives, a normality assessment was conducted employing the Kolmogorov–Smirnov one-sample method with a significance threshold (p-value < 0.05 indicating normally distributed data). The Pearson Correlation test was employed to evaluate the interrelationships among variables within each cohort (p-value < 0.05 indicating a significant relationship), and the r-value served as the correlation coefficient to ascertain the magnitude of the relationship between variables.

Results

This study involving 81 handball athletes consisting of 44 males (Age 17.4±1.5 years, height 1.73±0.06 m, body weight 64.7±10.5 kg, BMI 21.6±2.9 kg/m^2) and 37 females (Age 17.0±1.4 years, height 1.61±0.06 m, body weight 55.9±10.2 kg, BMI 21.7±3.7 kg/m^2) (Table 1).

Table 1. *Demographic Characteristics of Subjects*

Characteristics	Male (n=44)	Female (n=37)
Age (yrs)	17.4±1.5	17.0±1.4
Height (m)	1.73±0.06	1.61±0.06
Body weight (kg)	64.7±10.5	55.9±10.2
Body mass index (kg/m^2)	21.6±2.9	21.7±3.7



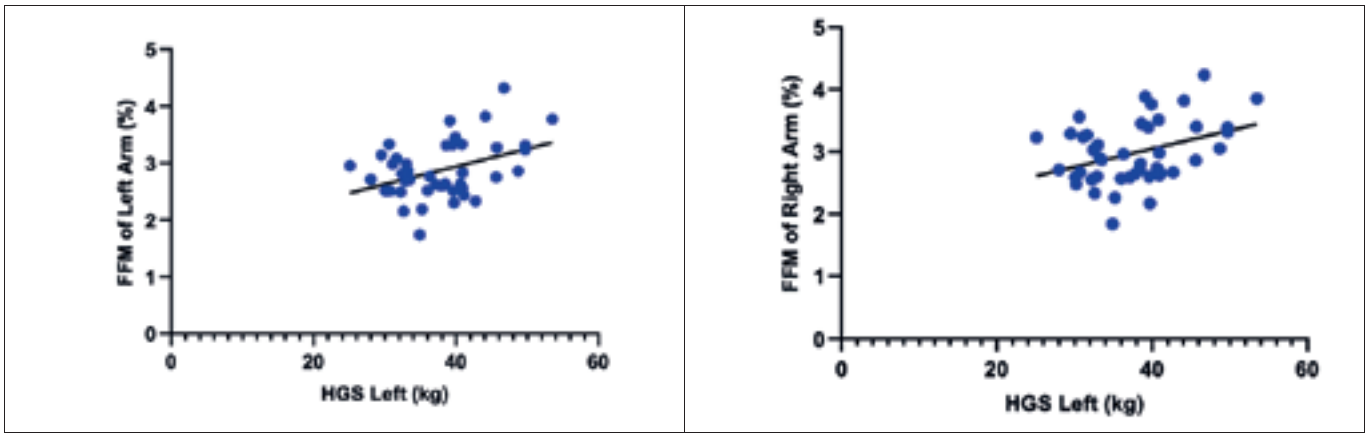
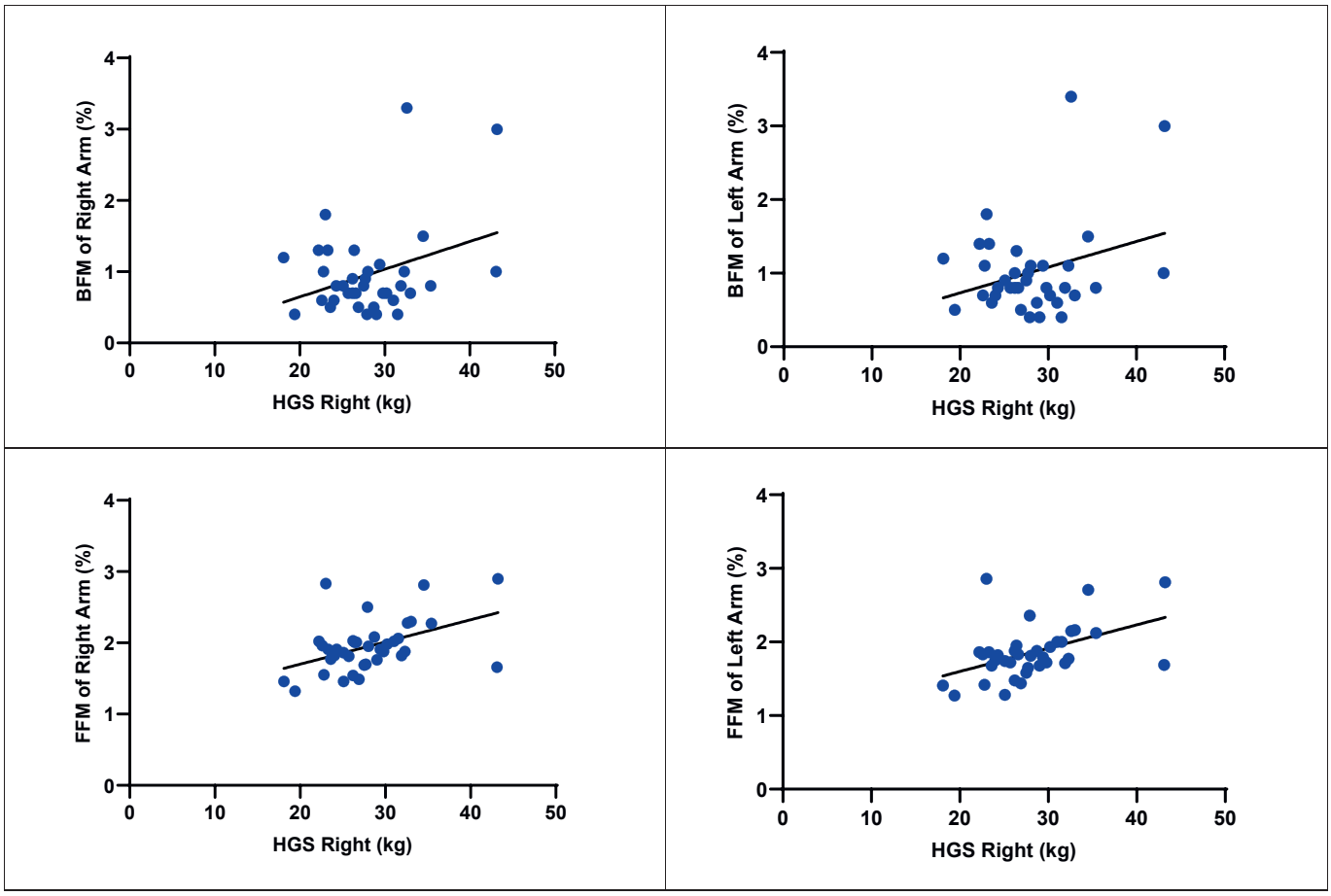


Figure 1. *Correlation between Handgrip and BFM and FFM in Male Handball Athletes*

The correlation between HGS, BFM, and FFM in male handball athletes presented in Figure 1. There were results that showed a correlation in male handball athletes where the right HGS correlated with the right BFM (r=0.231; p=0.022), the right HGS with the right FFM (r=0.302; p=0.003), the left HGS with the left FFM (r=0.297; p=0.003), while the left HGS did not correlate with the left BFM ($p > 0.05$).



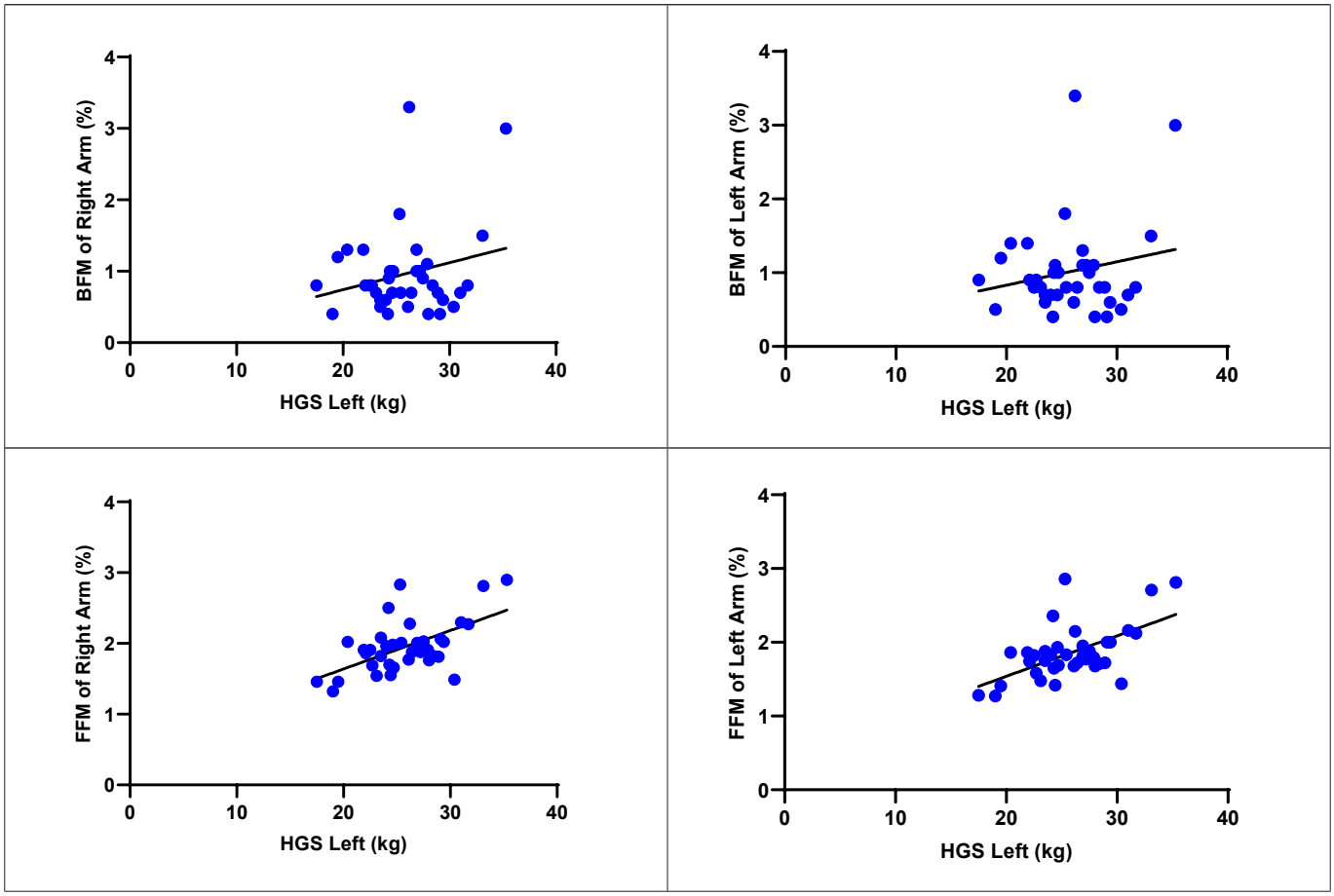


Figure 2. *Correlation between Handgrip and BFM and FFM in Female Handball Athletes*

Figure 2 shows the correlation between handgrip and BFM and FFM in female handball athletes. There were results that showed a correlation in female handball athletes where the right HGS correlated with the right FFM (r=0.466; p=0.004), the left handgrip with the left FFM (r=0.448; p=0.005). While the right HGS has no significant relationship with the right BFM, nor does the left handgrip have a significant relationship with the left BFM.

Discussion

The principal outcomes of the investigation indicate that fat-free mass (FFM) exhibits a significant correlation with both right and left handgrip strength (HGS) among handball athletes of both genders. This finding aligns with numerous prior studies which have posited that FFM serves as a critical determinant of muscular strength. (Zaccagni et al., 2020). According to (Tavares Junior et al., 2023a), FFM reflects a mass of lean tissue that is mostly made up of skeletal muscle, so the increase in FFM describes an increase in muscle mass that plays a role in producing muscle strength, which includes grip strength as well. In contrast, BFM did not show a correlation with HGS in female handball athletes and only correlated with HGS in male athletes. This finding is in line with (Patnaik et al., 2021), which found that increased fat mass does not contribute to increased muscle strength, and in some cases, it can even interfere with performance due to additional non-functional loads. Body fat is generally not involved in the production of strength and in the context of athletics, the accumulation of excess fat can actually reduce movement efficiency and overall physical performance.

Results of a previous recent study (Ardha et al., 2024) showed that there was no significant relationship between FFM and HGS in non-athlete students, both male and female. Athletes exhibit enhanced neuromuscular efficiency, facilitating superior force generation during tasks reliant on grip, as evidenced by grapplers who manifest elevated maximal isometric strength in comparison to untrained subjects (Tavares Junior et al., 2023b). This discrepancy likely arises specifically from sport training adaptations in athletes, where functional muscle development (especially in the forearms) is optimized for grip-dependent tasks, unlike in untrained populations where muscle mass may not

translate directly to specific strength outcomes. Conceptually, FFM that reflects muscle mass without fat content is usually considered to be closely related to muscle strength (Mukti et al., 2024). However, the findings in this study suggest that FFM amounts do not necessarily accurately reflect grip strength levels. Some possible causes of the absence of this relationship include uneven distribution of muscles in the body, differences in neuromuscular activation, and differences in the type of exercises performed by each non-athlete student. The strength of the hand grip itself is more influenced by the strength of specific muscles in the forearm, such as the flexors and extensors, whose growth does not always coincide with the overall increase in FFM (Marques et al., 2023).

BFM showed a correlation with right HGS in male handball athletes, but not with left HGS or in female athletes. This can be attributed to a stronger hand dominance in male athletes, especially since the right hand is often used in certain activities in sports such as throwing the ball in a handball game. Considering that hand-grip strength is influenced by a plethora of factors (including but not limited to gender, age, and physical fitness), it is essential that normative values for hand-grip strength be determined within large and comprehensively defined populations. (Giancotti et al., 2018). Interactions between the hand and a projectile can be characterized as any engagement in which the hand exerts force upon an object, thereby instigating projectile motion of that object. This encompasses a diverse array of activities, which includes, but is not confined to, the act of throwing (for instance, baseball, cricket, water polo, handball, American football, rugby, soccer, shot put, discus, javelin, and hammer throw), bowling (encompassing both overarm and underarm techniques), shooting (as exemplified in basketball and netball), and striking (as evidenced in volleyball and Australian Rules football) (MacDonald et al., 2018). This gender-specific findings may be explained by physiological differences in fat distribution (e.g., males typically store less subcutaneous fat in extremities) and sport-specific role requiring dominant-side power throws, which are more prevalent in male players also, the selective correlation only in the right hand further supports the role of neuromuscular adaptation due to chronic preferential use of the dominant limb, leading to enhanced strength-specific coordination and motor unit recruitment on that side. The hand constitutes the ultimate nexus (i.e., terminal point of contact) within the kinetic chain wherein the imparted forces and torques are conveyed to the implement or object, thereby underscoring the significance of handgrip functionality and strength in relation to the aforementioned sports-specific maneuvers (MacDonald et al., 2018). This is in line with the findings (Foley et al., 2025), which in its systematic review and metaanalysis states that dominant hands are generally about 10% stronger compared to non-dominant hands. This difference is influenced by several factors such as the type of joint and movement, handedness (dominant skill) (Bryden, 2016; Vingerhoets et al., 2023), as well as environmental factors that cause left-handed individuals to adapt to a life dominated by the use of hands (Vuoksimaa et al., 2009)Although it does not show a direct relationship with FFM, the strength of HGS's hand grips still plays an important role in supporting the performance of handball athletes. This sport requires a high ball control ability, accuracy in throwing, strength when making passes and shots, and toughness in keeping the ball from the opponent's pressure (ASAN, 2023). All of these aspects depend heavily on the strength and stability of the muscles of the hands and forearms. In addition, HGS can also be used as an indicator of functional strength and upper body ability, which is closely related to technical skills during matches (Omar Lagunes-Carrasco et al., 2025). Therefore, exercises to improve grip strength should be one of the main component in the training program for handball athletes, regardless of the size of the FFM.

In a comprehensive and meticulously conducted study undertaken by esteemed researchers (Acharya et al., 2022), it was determined through empirical investigation that there existed no statistically significant relationship or correlation between body fat mass (BFM) and handgrip strength (HGS) among male medical students, thereby suggesting that variations in body composition do not appear to influence grip strength in this specific demographic group, these findings suggest that individuals with greater muscle mass showed higher muscle strength capacity than individuals with a dominance of adipose tissue in their body composition. Physiologically, fat mass (BFM) has no direct contribution to muscle contraction performance. Body fat tends to be passive and does not help in generating muscle strength. (Cossio-Bolaños et al., 2020) also found no significant correlation between BFM and HGS in children and adolescent boys and women aged ≥ 7.5 years to ≤15.49 years. These findings indicate that the amount of fat tissue in the body is not the main determinant of muscle strength in this age group. In contrast, the development of muscle strength is more influenced by the increase in muscle mass that occurs physiologically during the period of growth and puberty.

This investigation is subject to numerous limitations. Firstly, the sample size was comparatively modest, encom-

passing merely 81 participants within the age range of 16 to 18 years, which may constrain the broader applicability of the results. Subsequent research endeavors should strive to incorporate a larger and more heterogeneous sample, which includes a wider array of age demographics, in order to augment external validity. Furthermore, this study employed a cross-sectional design; future inquiries may benefit from adopting longitudinal methodologies to ensure that the data obtained is more robust for analytical purposes.

Furthermore, this research did not differentiate between player positions; it only examined handball players based on gender. Future studies could explore a sport-specific role analysis, investigating positions such as goalkeepers, wingers, and center backs.

Conclusion

This study indicates that arm handedness affects muscle mass. As a result, coaches should identify each handball player's dominant arm to enhance their dribbling and shooting training. Additionally, the non-dominant arm can be strengthened using neuromuscular activation techniques and unilateral exercises. This approach can help reduce strength imbalances and lower the risk of injuries. While every player has a dominant arm, training both arms optimally can improve essential skills like ball control and shooting accuracy. This comprehensive training equips handball players with the necessary tools to enhance their overall arm strength.These findings underscore the need for targeted training strategies where coaches should prioritize exercises that increase overall FFM (e.g., compound lifts, plyometrics) while incorporating unilateral techniques such as eccentric wrist curls and sport-specific drills using the non-dominant hand to mitigate strength imbalances and reduce injury risks. Although HGS remains critical for ball control and shooting accuracy, its dependence on FFM highlights the importance of holistic strength development.

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Short notice *Kratko saopštenje*

Latent Structure of Anthropometric Characteristics in Male Adolescents Aged 12–14: A Two-Wave Factor Analytical Study

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Abstract: *Understanding the latent structure of morphological characteristics in adolescents is essential for monitoring their growth, biological maturity and physical development. This study included a sample of 388 male students aged 12 to 14 years from three primary schools in Pristina, in order to identify the dominant latent dimensions that structure anthropometric variability at two time points – initial and final measurement. The applied set of anthropometric measures was processed by factor analysis using the principal components method with Varimax rotation, and the selection of components was performed according to the Kaiser–Gutmann criterion. Two stable and clearly interpretable dimensions were distinguished in both time sections: a body mass and subcutaneous fat tissue factor and a longitudinal dimensionality factor. The high percentage of explained variance and the consistency of the model in both measurements indicate a replicable morphological structure, characteristic of this developmental period. The obtained results have significant practical value, as they provide a valid basis for systematic growth monitoring, identification of risky anthropometric profiles and planning of interventions in the context of education and sports training.*

Keywords: *anthropometry, latent structure, adolescents, factor analysis, body mass, longitudinal dimensionality*

Introduction

Monitoring morphological development is a powerful indicator of health status in childhood, adolescence and adulthood (Ortega, et al. 2008). Even in children and adolescents, morphological development is negatively associated with cardiorespiratory diseases, high blood pressure (Sallis, et al. 1998; Ruiz, et al. 2006), abdominal adiposity (Brunet, et al. 2006), total obesity (Ruiz, et al. 2006; Ortega, et al. 2011), impaired skeletal health (Moliner-Urdiales, et al. 2010), hyperinsulinemia (Gutin, et al. 2004), insulin resistance (Gulati, et al. 2003), atherogenic lipid profile (Mesa, et al. 2006), and a number of metabolic risk factors (Brage, et al. 2004; Ruiz, et al. 2007).

Morphological development can be objectively and accurately measured through laboratory methods, but due to high cost, the need for sophisticated equipment, qualified professional staff, and time constraints, laboratory tests cannot yet be used at the population level. In contrast, field measurements and tests are easy to administer, involve minimal equipment, can test a large number of subjects simultaneously, and can be evaluated in a short period of time (Paineau, 2008; Rodriguez G., et al. 2005; Ruiz, et al. 2009). In the school environment, field tests and measurements are an economical and practical option for assessing the level of morphological development of students.

Based on the previously stated, as well as on previous research, the subject of this research is anthropometric measures, and the main goal is to determine the state of morphological development among male students from the upper grades of primary schools, aged 12 to 14 years (from 7th to 9th grade), who regularly attend physical education, sports and health classes.

To facilitate the interpretation of complex sets of anthropometric data, factor analysis is often used in scientific studies. This method condenses the entire set of manifest measures into a few latent dimensions (factors) that explain the variability in the data. For example, in modern anthropometry, four basic morphological dimensions are recognized: longitudinal dimension (bone growth in length), transverse dimension (growth in width), circular/volume dimension (total body volume), and dimension of body mass and subcutaneous fat. These four dimensions

are often grouped in practice into two "large" factors, one that covers longitudinal and transverse dimensions (bone structure), and the second that covers body mass and fat. Research in kinesiological anthropometry shows that these latent dimensions are present across age groups. In adults, Momirović, K. (1969) found a four-dimensional model (longitudinal, transverse, circular and mass/fat), while in adolescents it often turns out to be simpler. In particular, Viskić-Štalec (1974) summarized adolescence with three main dimensions: skeletal dimensionality, volume/mass and subcutaneous fat.

Šćepanović and Protić-Gava (2013) found two key dimensions in 15-year-old boys: a mass and volume factor (weight and circumferences and thicknesses of folds) and a longitudinal dimensionality factor (body height and arm and leg length). These examples show that latent structures can vary: in some samples two factor dimensions appear, in others three, but they always reflect basic morphological profiles (growing skeleton, body with mass/volume and even distribution of fat tissue).

However, there are gaps in the literature. Previous factor studies have mostly focused on older adolescents or on single measurements (which do not test the consistency of the factor structure). The current state of the latent structure in young teenagers (12–14 years) has not yet been sufficiently examined, especially in the context of longer-term (longitudinal) observation. Unlike single-phase approaches, the two-phase design allows us to test whether these factors remain stable and replicable over time. Namely, as Popović et al. (2016) point out, during growth, each morphological measure may have a different share in the latent structure at different stages of development. Therefore, we need a second measurement to assess the repeatability of the extracted dimensions (i.e., the structural invariance of the factors).

Given the above, the main goal of this research is clear and focused: to determine the latent dimensions of anthropometric measures in male students from 7th to 9th grade (12–14 years old), who regularly attend physical education classes. In this context, "determining latent dimensions" means using factor analysis to identify the main factors that explain the morphological variation in the data. In addition, the design is longitudinal, two measurements were conducted (at the beginning and end of the school year) in order to check the stability of the factor structure over time and to confirm that the obtained dimensions are consistent and replicable. Also, based on the nature of scientific research (Bala, 2007), it falls into the category of empirical research and represents applied, i.e. applicative research aimed at acquiring new knowledge and information necessary for pedagogical practice in schools and beyond. These results will enable a better understanding of physical development in adolescents and will serve as a basis for later practical interventions in education and sports training.

Methods

The research was conducted in order to determine the latent dimensions of morphological characteristics in male students from the upper grades of primary education. The sample consists of a total of 388 students from three primary schools: OU "Nazim Gafuri", OU "Elena Gjika" and OU "Zelena Shkola" in the city of Pristina R. Kosovo, aged 12 to 14 years ± 6 months, who regularly attend classes in physical education, sports and health. The respondents are students from the 7th, 8th and 9th grades.

The research has a longitudinal design, with two measurements: the first (initial) was carried out at the beginning of the school year, while the second (final) was carried out at the end of the same school year.

To measure morphological characteristics, a standardized set of six anthropometric variables was used, selected based on the International Biological Program – IBP (Weiner & Lourie, 1981), which is a reference methodology in the field of biological anthropology and physical education (Bala, 2007). The variables are grouped into the following subdimensions:

- Longitudinal dimensionality of the skeleton
  - Body height (ATLVIS)
- Body mass and volume
  - Body weight (ATLMAS)
  - Abdominal circumference (AOBTRB)
- Subcutaneous fat
  - Upper arm skinfold (ANABNA)
  - Back skinfold (ANABLE)
  - Subcutaneous fat index (BMI)

To determine the latent structure of the applied manifest variables, the Hotaling method of principal components was used. The selection of significant factors was made according to the Kaiser-Gutmann criterion, i.e. factors with an eigenvalue greater than 1. Varimax orthogonal rotation was applied to increase the interpretability of the obtained components. All statistical processing was carried out in the SPSS 26.0 statistical package. The level of statistical significance in the analysis was set at $p \leq 0.05$.

Results

Based on the intercorrelation matrix of the applied manifest variables of morphological characteristics, the characteristic roots (lambda) were obtained, which explain the common variance of each isolated principal component in the first-order space (table no. 1). The applied Guttman-Kaiser criterion extracted 2 significant latent dimensions. The first of them with an eigenvalue (total=3.822) explains 63.706% of the total variance of the variables, the second with a value (total=1.691) explains 28.184% of the total variance. The total explained variance by the extracted latent dimensions amounts to 91.890% of the common variance of the entire system and seems to be sufficient for the explication of the variability and covariability of the manifest variables applied to the student sample.

Table 1. *Factor Analysis Results -Total variance explained in the initial measurement*

Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.344	72.403	72.403	4.344	72.403	72.403	3.822	63.706	63.706
2	1.169	19.487	91.890	1.169	19.487	91.890	1.691	28.184	91.890
3	0.225	3.756	95.646						
4	0.172	2.867	98.513						
5	0.085	1.419	99.932						
6	0.004	0.068	100.000						

On the first latent dimension, tests for assessing body weight and body circumference, and tests for assessing subcutaneous fat tissue, show high saturation: body weight (.926) body mass index (.956), abdominal circumference (.962), upper arm skinfold (.851) and back skinfold (.864). All applied tests for assessing morphological characteristics except the body height test (ATLVIS), have high projections and thus diagnostic validity on this latent dimension.

In the second latent dimension, the body height assessment test (.885) has a high projection, and thus diagnostic validity on this latent dimension.

Table 2. *Factor Loadings of Variables on Extracted Components (Component Matrix 1 and 2)*

Component Matrix[a]	Component	
	1	2
I_ATLVIS	0.421	0.885
I_ATLMAS	0.926	0.343
I_BMI	0.956	-.086)
I_AOBTRB	0.962	0.011
I_ANABNA	0.851	-.382)
I_ANABLE	0.864	-.339)

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

Table 3. *Factor analysis – Varimax rotated component matrix for the initial measurement*

Rotated Component Matrix[a]	Component	
	1	2
I_ATLVIS	0.026	0.979
I_ATLMAS	0.707	0.689
I_BMI	0.909	0.309
I_AOBTRB	0.875	0.400
I_ANABNA	0.933	-.004)
I_ANABLE	0.927	0.040

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

Factor analysis, applied to anthropometric measures with varimax rotation, identifies two independent factors that explain different aspects of body composition. This factor structure shows that anthropometric characteristics can be grouped into two main latent factors: one that reflects body mass and adipose tissue and another that represents basic body dimensions.

The first factor shows high projection with body mass index (BMI) (.909), waist circumference (.875), upper arm skinfold (.933) and back skinfold (.927). These strong correlations indicate that this factor mainly reflects variations in body mass and adipose tissue. The high projection of these variables indicates that the factor is mainly related to body composition, especially adiposity. Therefore, this factor can be interpreted as a factor of body mass and adipose tissue.

The second factor has an exceptionally high correlation with body height (.979), while body weight also has a significant projection (.689). This suggests that the factor mainly reflects basic body dimensions, i.e. body height as a dominant characteristic. Since body weight has a relatively high projection with both the first and second factors, it can be concluded that it is a complex variable, which is influenced by both adipose tissue and body structure. In view of this, the second factor can be defined as a factor of longitudinal dimensionality.

Table 4. *Factor Analysis Results -Total variance explained in the final measurement*

Component	Total	% of Variance	Cumulative %	Total	% of Varianc	Cumulative %	Total	% of Variance	Cumulative %
1	4.348	72.470	72.470	4.348	72.470	72.470	3.979	66.315	66.315
2	1.164	19.406	91.876	1.164	19.406	91.876	1.534	25.561	91.876
3	0.233	3.880	95.755						
4	0.154	2.570	98.325						
5	0.097	1.609	99.935						
6	0.004	0.065	100.000						

Based on the intercorrelation matrix of the applied manifest variables of morphological characteristics, characteristic roots (lambda) were obtained, which explain the common variance of each isolated principal component in the first-order space (table no. 4). The applied Guttman-Kaiser criterion extracted 2 significant latent dimensions. The first of them with an eigenvalue (total=3.979) explains 66.315% of the total variance of the variables, the second with a value (total=1.534) explains 25.561% of the total variance. The total explained variance by the extracted latent dimensions amounts to 91.876% of the common variance of the entire system and seems to be sufficient for the explanation of the variability and covariability of the manifest variables applied to the sample of students.

Table 5. *Factor loadings of variables on extracted components (Component Matrix 1 and 2)*

Component Matrix[a]	Component	
	1	2
second_ATLVIS	0.362	0.914
second _ATLMAS	0.926	0.339
second _BMI	0.956	-.092)
second _AOBTRB	0.958	0.003
second _ANABNA	0.856	-.343)
second _ANABLE	0.892	-.298)

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

From the heights of the projections of the manifest variables on the first principal component of the Varimax factor matrix, it can be concluded that most variables have significant, moderately high and high projections, which could mean that the obtained factors are in a relatively significant correlation. The value of the communalities is high, which means that the system of factors defines the variability and covariability of the manifest variables relatively well.

Table 6. *Factor analysis – Varimax rotated component matrix for the initial measurement*

Rotated Component Matrix[a]	Component	
	1	2
II_ATLVIS	0.029	0.983
II_ATLMAS	0.755	0.634
II_BMI	0.930	0.239
II_AOBTRB	0.900	0.329
II_ANABNA	0.922	-.031)
II_ANABLE	0.940	0.024

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

In the final measurement, factor analysis with varimax rotation again isolated two latent factors, reflecting the structure of the anthropometric measures. The first factor shows high correlations with body mass index (BMI) (.930), waist circumference (.900), upper arm skinfold (.922) and back skinfold (.940), indicating a clear latent dimension reflecting body mass and subcutaneous fat. This consistency with the results of the first measurement confirms that this factor can be interpreted as a body mass and adiposity factor, which includes the basic parameters of body composition related to adiposity. The high correlation of body weight (.755) with this factor further confirms that this factor mainly reflects the fat and muscle component of body structure, i.e. it can be defined as a body mass and adipose tissue factor.

The second factor is dominantly defined by body height (.983), while body weight has a moderate correlation (.634), indicating that this factor predominantly reflects constitutive body dimensions. Such a factor model suggests that the factor can be interpreted as a factor of longitudinal dimensionality, which is consistent with the results of the first measurement.

Discussion

The comparative analysis between the two measurements shows a high stability of the factor structure, with the factors maintaining a similar composition. This indicates a high replicability of the identified factors and confirms that anthropometric characteristics can be reduced to two main latent dimensions: ***body mass and adiposity and longitudinal dimensionality***. This factor stability may have important implications for monitoring body composition in sports and health contexts. Scepanović, T., & Protić-Gava, B. (2013), in their study on determining the factor structure

of morphological status in male adolescents (15 years ± 6 months), isolated the same factors, which fully coincides with the analyses of this research. Also, according to Rađo, I., et al. (2011), in a study conducted on a sample of 1332 boys aged 11-14, isolate dimensions (volume factors, subcutaneous fat, growth and development, and longitudinal dimensionality) with which they identify and define the latent structures of morphological characteristics. Most of the previous research on determining the latent structure of morphological characteristics has been conducted on young athletes aged 11-15 (basketball players, swimmers), not only on students, but still the same latent dimensions have been extracted (Ostrowska, B., et al.2006 and Begu, B., al. 2018).

The analysis of morphological data from early adolescence (12–14 years) identified two dominant latent dimensions. The first factor, designated as the "transverse morphological dimension", is formed by the variables body weight, abdominal circumference, upper arm skinfold, back skinfold and body mass index (BMI). These indicators indicate that this factor reflects body mass and the amount of subcutaneous fat tissue. In other words, it is a dimension that expresses the volume and mass of the body, i.e. the physical "thickening" of the body, which is characteristic of this age due to hormonal changes associated with puberty.

The second factor represents the "longitudinal morphological dimension" and is mainly defined through body height. It reflects the longitudinal expansion of the body, i.e. growth in height, which is also a central process in pubertal development in adolescents.

Approximately equal shares of the variation were accounted for by these two factors, which were relatively stable within our sample. This means that the factor structure is maintained without significant changes by gender and other subgroups, indicating a gradual, consistent pattern of development in early adolescence (Gudelj et al., 2009). Namely, we can conclude that our results confirm the existence of two key scans in morphological change, one associated with the accumulation of tissue mass and generally proportional body growth, and the second with intensive prolonged bone expansion that overall explains a significant part of the variation in growing children.

From a scientific point of view, this two-dimensional structure reflects the complex nature of biological maturation in adolescents. The factor reflecting the longitudinal growth of the body, i.e. increase in body height, is associated with intensive growth in height and can be interpreted as an indicator of accelerated biological maturation. In some cases, this growth occurs earlier in girls than in boys, which is consistent with the general patterns of pubertal maturation. On the other hand, the transverse factor, which includes body weight, fat tissue and bulkiness, is more characteristic of boys at this age, in whom puberty usually begins later, and the phase of intensive growth in height has not yet fully begun. According to Gudelj et al. (2009), in 12-year-old girls the "full swing" of puberty is already present (intensive prolonged growth), while in boys this period is still expected to occur (delayed onset of puberty). These differences indicate that the morphological age of children can differ drastically from the chronological age, which is of crucial importance in the context of developmental morphology. Our data suggest that genetic and hormonal mechanisms play a dominant role in determining these developmental trajectories, while the influences of physical activity (quality and quantity of exercise) largely serve only as additional factors. This is in agreement with the conclusion of Gudelj et al. (2009) that the intensity of kinesiological activity only partially explains these morphological processes. In other words, this means that for the successful rationalization of physical activity and sports at this age we should be guided primarily by biological, and not only by chronological, maturation.

Our findings are largely consistent with a growing body of international research. For example, Gudelj et al. (2009) used a similar factorial distinction in their analysis of 12-year-olds from Croatia and observed two main morphological dimensions – one related to fat accumulation and muscle development, and the other to lower bone growth – illustrating the same bipolar pattern of development that we found. In line with this, Damsgaard et al. (2001) documented anthropometric differences in child athletes (9–13 years), noting that boys and girls, as well as different sports, select children with specific morphological profiles. They, for example, found no significant effect of training itself on body composition, suggesting that genetic characteristics dictate morphology in selective sport participation. Our data are consistent with this idea: physical activity per se does not obscure the underlying developmental trajectories detected by factor analysis.

Similarly, Katanić et al. (2023) in a representative study of adolescents in Montenegro highlight the interaction between environment and growth. They found that urban children aged 12–14 years had lower body mass index (BMI) values than rural children, while girls in the central areas of the country were taller than those in the northern and coastal regions. These findings are consistent with ours, as they suggest that structural factors, such as urban or

rural environment, influence the body characteristics and health parameters of adolescents, which further confirms our results.

A broad perspective on the global problem is provided by studies on the epidemiology of obesity. Wang & Lobstein (2006) reported that the prevalence of childhood overweight has increased in almost all countries in recent decades, especially in economically developed societies. The World Health Organization (WHO) also warns of an explosion of obesity in adolescents: according to WHO statistics, the percentage of youth who are overweight or obese has increased from about 4% in 1975 to over 18% in 2016, with nearly 340 million children and adolescents aged 5–19 years classified as overweight or obese. Ogden et al. (2016) further reported that in the United States in 2015–2016, nearly 18.5% of the population aged 2–19 years was obese. These global trends confirm the importance of our findings and illustrate the urgency of continuing to monitor physical growth and body composition in the early teens.

Among the strengths of this study is the use of consistent and quite extensive anthropometric measurements. By collecting a wide set of over twenty morphological variables and their multivariate modeling (factor analysis), we ensured qualitative and quantitative-structural processing of the data. The use of factor analysis reduces the complexity of the input measures and highlights their internal structure, which facilitates scientific interpretation. In addition, the sample was large enough to ensure statistical robustness, and all measures were performed according to standardized protocols with high reliability. With these methodological approaches, the study obtains the necessary representativeness and validity, which ensures the precision of the findings.

However, it is necessary to highlight certain limitations of the research. First of all, hormonal or genetic indicators of biological maturity were not included, which is why we cannot directly analyze the internal mechanisms that drive morphological development in the subjects. A limited geographical area was covered, so the results are initially valid for this context, while their application to wider populations needs to be confirmed by further studies. Factor analysis as a research method carries its own limitations and confirmatory analysis of an independent set is needed to supplement the reliability of the factor structure. Also, there may be variables that were not included (e.g. daily eating habits, pharmaceutical influences or mental health) that affect growth, and which our study did not cover. These factors should be taken into account when interpreting the results.

The identification of stable latent dimensions in morphological development in adolescents allows for more informed adjustment of physical activities and sports programs in schools. Instead of being guided solely by chronological age, teachers and trainers should consider biological maturity as reflected in morphological indicators. The presence of different factor profiles – such as height growth or increased body mass – requires an individualized approach to load dosing, exercise selection, and progress monitoring. Such an approach may contribute to better growth support, injury prevention, and early recognition of developmental abnormalities. Future research should focus on monitoring the stability and variability of the identified latent dimensions over a longer period of time. Longitudinal studies with multiple measurement points would allow for the distinction between the effects of age, training, and biological maturation on morphological structure (Malina & Bouchard, 2004). Additionally, the inclusion of biological indicators, such as hormonal parameters or skeletal maturity, would allow for a deeper understanding of the physiological mechanisms behind each factor. To verify the resulting structure, applying confirmatory factor analysis on independent samples is a logical next step.

Conclusion

The conducted factor analysis of morphological characteristics in male students from the upper grades of primary education, allowed the identification of two clearly differentiated and stable latent dimensions. The first covers body mass and subcutaneous fat tissue, while the second refers to the longitudinal structure, i.e. growth in height. The comparison between the initial and final measurements showed high consistency in the composition of the factors, which indicates the stability of the structure over time. This stability confirms the relevance of the obtained factor organization and opens up possibilities for its application in monitoring and assessing morphological development in educational and sports contexts. The research indicates that the appropriate selection of anthropometric indicators allows for the identification of the essential components of body structure in adolescents with a small group of variables.

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PROCEDURA RECENZIJE

Radovi poslati časopisu će najprije biti ocijenjeni od strane Uredništva imajući u vidu nekoliko kriterijuma: prikladnost teme i sadržaja časopisa; uređivanje (priprema rukopisa) i format; i “opšta” valjanost. Ako su ovi kriteriji ispunjeni, rad će biti poslat na dvostruku anonimnu recenziju od strane najmanje dva priznata i nezavisna recenzenta, a proces recenzije može trajati do 8 sedmica.

Samo radovi koji dobiju pozitivne recenzije će biti prihvaćeni. Jedan od presudnih razloga recenzije je navođenje citata i referenci relevantne literature. Urednički odbor ima pravo da komentariše formu rada prije nego što on bude prihvaćen za objavljivanje. Redakcija nije obavezna da objavljuje radove po hronološkom redosledu njihovog prijema ili po redoslijedu po kom su prihvaćeni za objavljivanje. Nijedan značajan dio rada ne treba da bude objavljen negdje drugdje. Prikazivanje rezultata u izvodima, sažecima, kratkim pregledima, disertacijama i magistarskim tezama, recenzijama i radovima sa konferencija (do tri stranice, koje sadrže sažetke, grafičke prezentacije i literaturu) ne smatra se objavljivanjem. Ako rukopis sadrži rezultate koji su već objavljeni, autor(i) moraju dobiti pristanak prvog izdavača i jasno citirati izvor.

ETHICS

Publication ethics, disclosure policy and malpractice statement

Publication and authorship

- All submitted articles are subject to strict peer-review process by at least two reviewers that are experts in the area of the particular paper.
- The factors that are taken into account in review are relevance, soundness, significance, originality, readability and language.
- The paper acceptance is constrained by such legal requirements as shall then be in force regarding libel, copyright infringement and plagiarism.
- For published articles, information on relevant potential conflicts of interest will be made available to the public.

Authors' responsibilities

- Authors must certify that their manuscripts are their original work.
- Authors must certify that the manuscript has not previously been published elsewhere.
- In case a submitted manuscript is a result of a research project, or its previous version has been presented at a conference in the form of an oral presentation (under the same or similar title), detailed information about the project, the conference, etc. shall be provided navesti gde se navode. A paper that has already been published in another journal cannot be reprinted in this journal.
- Authors must certify that the manuscript is not currently being considered for publication elsewhere.
- Authors must identify all sources used in the creation of their manuscript.
- It is the responsibility of each author to ensure that papers submitted in this journal are written with ethical standards in mind.

Reviewers' responsibilities

- Reviews should be conducted objectively, with no personal criticism of the author.
- Reviewers are required to provide written, competent and unbiased feedback in a timely manner on the scholarly merits and the scientific value of the manuscript.
- Reviewers should keep all information regarding articles confidential and treat them as privileged information.
- Reviewers must not have conflict of interest with respect to the research, the authors and/or the funding sources for the research. If such conflicts exist, the reviewers must report them to the Editor without delay.
- Any selected referee who feels unqualified to review the research reported in a manuscript or knows that its prompt review will be impossible should notify the Editor without delay.

Editors' responsibilities

- Editors have complete responsibility and authority to reject/accept an article.
- Editors are responsible for the contents and overall quality of the publication.
- Editors should always consider the needs of the authors and the readers when attempting to improve the publication.
- Editors should preserve the anonymity of reviewers.
- Editors should act if they suspect misconduct, whether a paper is published or unpublished, and make all attempts to persist in obtaining a resolution to the problem.
- Editors should not reject articles based on suspicions.

Etika

Etika objavljivanja, pravila objavljivanja i zloupotreba podataka

Objavljivanje i autorska prava

- Svi pristigli članci podliježu strogoj recenziji od strane barem dva recenzenta koji su stručnjaci iz oblasti naučnog rada.
- Faktori koji se uzimaju u obzir prilikom recenzije su relevantnost, ispravnost, značaj, originalnost, čitljivost i jezik.
- Prihvatanje rukopisa je ograničeno takvim zakonskim uslovima koje će se primijeniti u slučaju klevete, zloupotrebe autorskih prava i plagijata.
- Kod objavljenih članka, informacije o relevantnim potencijalnim sukobima interesa biće dostupne javnosti.

Odgovornosti autora

- Autori moraju da potvrde da je njihov rukopis njihovo autorsko djelo.
- Autori moraju da potvrde da njihov rukopis nije prethodno objavljen na nekom drugom mjestu.
- U slučaju da je poslati rukopis rezultat naučnoistraživačkog projekta ili da je, u prethodnoj verziji, bio izložen na skupu u vidu usmenog saopštenja (pod istim ili sličnim naslovom), detaljniji podaci o projektu, konferenciji i slično, navode se u navesti gdje se navode. Rad koji je već objavljen u nekom časopisu ne može biti preštampan u ovom časopisu.
- Autori moraju da potvrde da se njihov rukopis trenutno ne razmatra za objavljivanje negdje drugdje.
- Autori su dužni da navedu sve izvore koje su koristili u pisanju njihovog rukopisa.
- Autori su dužni da se pridržavaju etičkih standarda koji se odnose na naučnoistraživački rad.

Obaveze recenzenta

- Recenzija mora biti objektivna. Komentari koji se tiču ličnosti autora smatraju se neprimjerenim. Sud recenzenata mora biti jasan i potkrepljen argumentima.
- Recenzenti bi trebalo svoje stavove da iskažu jasno, sa pratećim argumentima.
- Recenzenti bi trebalo da čuvaju u povjerenju sve informacije u vezi članka i smatraju ih privilegovanim informacijama.
- Recenzent ne smije da bude u sukobu interesa sa autorima ili financijerom istraživanja. Ukoliko postoji sukob interesa, recenzent je dužan da o tome momentalno obavijesti urednika.
- Recenzent koji sebe smatra nekompetentnim za temu ili oblast kojom se rukopis bavi dužan je da o tome obavijesti urednika.

Obaveze urednika

- Urednici imaju punu odgovornost i ovlaštenje da odbiju/prihvate članak.
- Urednici su odgovorni za sadržaj i ukupni kvalitet publikacije.
- Urednici bi uvijek trebalo da razmotre potrebe autora i čitaoca pri pokušaju da se poboljša publikacija.
- Urednici bi trebalo da sačuvaju anonimnost pregledanog članka.
- Urednici bi trebali da osiguraju da je sav materijal koji objavljuju u skladu sa međunarodno prihvaljivim etičkim smjernicama.
- Urednici bi trebalo da djeluju ukoliko posumnjaju na zloupotrebu, bez obzira da li je rad objavljen ili ne, i preduzmu mjere kako bi uspjeli da riješe problem.
- Urednici ne bi trebalo da odbace članak na osnovu sumnje.

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