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# Unveiling anaerobic soccer training: comparing its effects with small-sided games on youth performance enhancement

Trio Hisbi Muttahid Ahmad<sup>ABDE</sup>, I Dewa Made Aryananda Wijaya Kusuma<sup>ABD</sup>,  
Bayu Agung Pramono<sup>ABCD</sup>, Mochammad Ilham Ramadani<sup>ABD</sup>, Waristra Tyo Nirwansyah<sup>ACD</sup>

*Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya, Indonesia*

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

## Abstract

**Background and Study Aim** Soccer is a high-intensity sport that requires players to maintain optimal physical performance over an extended period. This has led to the development of various training methods to enhance both aerobic and anaerobic energy systems. Small-Sided Games (SSG) is a popular training method in soccer, as it improves both technical skills and fitness. However, its effectiveness in developing anaerobic capacity still requires further investigation. Therefore, this study aims to compare the effects of Anaerobic Soccer Training (AnST) and SSG on aerobic and anaerobic performance in young soccer players.

**Material and Methods** A randomized trial was conducted on 25 male soccer players (AnST: n = 16; SSG: n = 9) aged 18 to 21 years. The average (mean ± SD) values were: age 19 ± 0.65 years, body weight 61.88 ± 5.28 kg, height 167 ± 5.50 cm, and body mass index (BMI) 21.84 ± 2.01. The intervention lasted six weeks. Aerobic capacity was assessed using a 2400-meter run test. Anaerobic performance was evaluated through average power, minimum power, peak power, and fatigue index. Statistical analysis included paired t-tests and percentage change calculations.

**Results** The findings indicate that both AnST and SSG significantly improved aerobic performance. The AnST group showed a greater relative increase ( $\Delta\% = 7.23\%$ ) compared to the SSG group ( $\Delta\% = 5.06\%$ ). For anaerobic performance, AnST produced a significant increase in average power ( $\Delta\% = 16.80\%$ ,  $p < 0.001$ ) and minimum power ( $\Delta\% = 28.60\%$ ,  $p < 0.001$ ). Changes in peak power and fatigue index were not statistically significant.

**Conclusions** Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) are both effective in improving aerobic and anaerobic capacities in young soccer players. AnST demonstrated greater gains, likely due to its higher training intensity.

**Keywords:** anaerobic soccer training; small-sided games; aerobic capacity; anaerobic performance; soccer training.

## Introduction

Modern soccer demands high levels of physical performance due to its fast-paced and dynamic nature. Players are required to repeatedly perform high-intensity efforts, including sprints, rapid accelerations, and quick recovery between actions. This places a substantial burden on both aerobic and anaerobic energy systems. In this context, it becomes essential to examine the available training strategies to better understand their practical applications and impact on physical performance. However, questions remain regarding the extent to which different approaches address both aerobic and anaerobic demands, especially in youth athletes.

Anaerobic Soccer Training (AnST) is an innovative training method developed to enhance physical performance, particularly the anaerobic components of soccer players. This method

emphasizes a holistic approach by combining short-distance sprints with Small-Sided Games (SSG). It has the potential to produce more sport-specific physical adaptations compared to conventional methods. The primary advantage of AnST lies in its ability to simulate real-game scenarios. In these situations, players are often required to perform short sprints before engaging in complex game actions. Previous studies have shown that AnST effectively improves players' anaerobic capacity [1].

On the other hand, SSG has become a widely adopted training method for enhancing the physical capacities of soccer players [2]. Several studies have demonstrated its effectiveness in improving aerobic performance by integrating tactical elements and technical skills. It also requires high levels of concentration during ball possession [3]. Although SSG increases player involvement and the frequency of ball touches, some studies suggest that the training intensity is often insufficient to optimally develop the speed and explosive power required in high-intensity matches [4, 5].

From a physical demand perspective, soccer is a high-intensity sport that requires players to maintain optimal performance over an extended duration [6, 7]. Previous research has shown that elite players cover an average distance of 10 to 13 km during a 90-minute match [8, 9]. Furthermore, match activities include 23% high metabolic load distance, 11% high-intensity accelerations and decelerations, and 6% maximal sprints [10]. Therefore, effective training methods are essential for improving both aerobic and anaerobic capacity to support performance at a high level. Additionally, the evolution of modern game strategies demands greater physical capacity from players to cope with the increasingly fast and dynamic tempo of play. Structured and evidence-based training approaches are thus critical for player success.

As the physical demands in soccer continue to increase, the need for more integrative and game-based training approaches is becoming increasingly urgent [11]. Many coaches still rely on traditional methods that separate physical, technical, and tactical components. However, these approaches often fail to reflect actual match conditions. Training that does not align with game demands may hinder player development and limit the transfer of fitness and skills to real-match situations. As a result, more integrative and game-based training methods are gaining attention among coaches and sports scientists as more effective strategies for enhancing player performance.

Analysis of existing research shows that both Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) offer valuable contributions to the physical development of soccer players. The authors propose that combining short sprints with game-based drills, as in the AnST model, may lead to more specific adaptations relevant to match demands. However, unresolved issues remain, particularly concerning the optimal balance between training intensity and technical-tactical integration. These challenges highlight the need for continued investigation and the development of new approaches to maximize training effectiveness in youth soccer. Therefore, this study aims to compare the effects of Anaerobic Soccer Training (AnST) and SSG on aerobic and anaerobic performance in young soccer players.

## Materials and Methods

### *Participants*

This study involved 28 male soccer players who were recruited based on specific eligibility criteria. Participants were healthy individuals aged between 18 and 21 years. Their average characteristics were as follows (mean  $\pm$  SD): age  $19 \pm 0.65$  years, body weight  $61.88 \pm 5.28$  kg, height  $167 \pm 5.50$  cm, and body mass index (BMI)  $21.84 \pm 2.01$ . All players had

at least two years of playing experience and trained a minimum of four times per week. Individuals recovering from injury or illness were excluded. Initially, 16 players were assigned to the Anaerobic Soccer Training (AnST) group and 12 to the Small-Sided Games (SSG) group, based on the study design and training requirements. However, four players were unable to continue due to injury or illness. In accordance with the approved research ethics, these individuals were allowed to withdraw. As a result, the final sample consisted of 16 participants in the AnST group and 9 in the SSG group. Any player who developed a sudden illness and missed two consecutive training sessions was also considered withdrawn.

### *Research Design*

This study employed an experimental two-group pretest-posttest design. Players were randomly assigned to one of two intervention groups: Anaerobic Soccer Training (AnST) or Small-Sided Games (SSG). The intervention period lasted six weeks, with training sessions conducted three times per week. Before and after the intervention, all participants underwent testing to assess anaerobic and aerobic capacity. Anaerobic performance was evaluated using the Running-Based Anaerobic Sprint Test (RAST), while aerobic capacity was measured with a 2400-meter run test. During training sessions, physiological intensity was monitored using Polar H-10 heart rate sensors to ensure that all exercises were performed within the intended intensity zones.

### *Protocol Test*

The Running-Based Anaerobic Sprint Test (RAST) was used to assess the players' anaerobic capacity [13]. At the beginning of the test, players were instructed to perform maximal sprints toward designated points at opposite ends. Each player completed six maximal 35-meter sprints, with a 10-second recovery period between each sprint. Sprint times were recorded for each attempt and used to calculate key performance parameters, including peak power (W), minimum power (W), average power (W), and fatigue index (%).

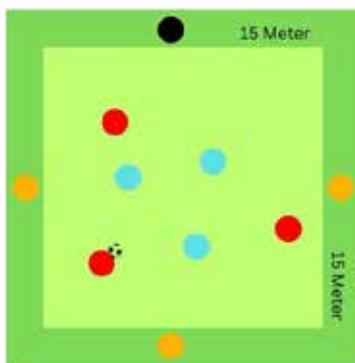
The 2400-meter run test was employed to evaluate aerobic endurance capacity. This test is widely recognized for its practicality and validity in estimating maximal oxygen uptake ( $VO_{2max}$ ) based on submaximal to maximal running performance. It was conducted on a standardized 400-meter athletic track under consistent environmental conditions. Ambient temperature and surface type were recorded prior to testing to ensure external validity and reproducibility. Before the test, all players completed a structured warm-up consisting of five minutes of light jogging. After the warm-up, they were instructed to position themselves behind the designated starting line. At the signal, players

were required to run 2400 meters in the shortest time possible. The structure of the Anaerobic Soccer Training (AnST) protocol, including sprint repetitions and Small-Sided Games integration, is illustrated in Figure 1.



**Figure 1.** AnST Training

AnST combines the Speed Endurance Training (SET) approach with Small-Sided Games (SSG) using a 1:1 work-to-rest ratio. The SSG area is set at 20 × 20 meters, with each player required to complete repeated sprints over distances of 5 meters, 10 meters, and 15 meters before engaging in the SSG. Each sprint repetition covers a total distance of 60 meters, with an estimated time of approximately 2–3 seconds for the 5-meter shuttle, 4–5 seconds for the 10-meter shuttle, and 6–7 seconds for the 15-meter shuttle. The entire 60-meter sprint is completed in about 15 seconds. At the start of each session, players complete a 60-meter sprint, immediately followed by a 1-minute SSG focused on ball control. After the sprint-SSG combination, players undergo a rest period equal to the total previous training duration, approximately 1 minute and 15 seconds (1 minute SSG + 15 seconds sprint), maintaining a 1:1 training-to-recovery ratio. This session is repeated 10 times, making the total training duration approximately 25 minutes. The structure and flow of the AnST session are illustrated in Figure 2.



**Figure 2.** SSG Training

The three vs. three plus four neutral players Small-Sided Game (SSG) training enhances players' technical skills, tactical understanding, and physical capacity. In this drill, players are divided into three groups distinguished by color: red players (Group A), blue players (Group B), and orange players (Group C). The red and blue groups begin the game

in a three vs. three format within a 15 × 15 meter area. Three neutral players from the orange group remain outside the playing area to support attacking plays. Additionally, a coach wearing black acts as a neutral player outside the field but does not take part in the rotation. Each game session lasts 2.5 minutes and is performed at high intensity. After each round, the roles rotate: the red group becomes neutral players, while the blue group plays against the orange group in the same format. This cycle continues until all players have actively participated in 10 sets. The total duration of the training session is approximately 25 minutes.

### Statistical Analysis

Descriptive statistics were used to summarize the characteristics of the participants. The normality of data distribution was assessed using the Shapiro–Wilk test. Paired t-tests were performed to evaluate within-group differences between pre- and post-test results. Independent sample t-tests were used to assess between-group differences in the effects of the AnST and SSG interventions. Levene's test was applied to verify the assumption of homogeneity of variance. All results were reported with 95% confidence intervals (CI) to enhance the precision of the parameter estimates. Statistical analyses were conducted using R software (R Core Team, Vienna, Austria) within the RStudio integrated development environment (Posit Software, PBC, Boston, MA). Data visualization was performed using the ggplot2 package [12]. Additionally, the percentage change ( $\Delta\%$ ) from pre- to post-test was calculated using the formula:  $((\text{post} - \text{pre}) / \text{pre}) \times 100$ .

## Results

The baseline characteristics of the participants in the Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) groups are summarized in Table 1. These data provide an overview of the comparability of the groups prior to the intervention.

**Table 1.** Characteristics of research subjects (n = 25)

Characteristics	AnST (n = 16)	SSG (n = 9)	P-Value
Age (years)	19 ± 0.61	19 ± 0.72	0.517
Body Weight (kg)	61.37 ± 4.44	62.77 ± 6.74	0.536
Body Height (cm)	166 ± 5.30	168 ± 5.80	0.289
Body Mass Index (kg/m <sup>2</sup> )	22 ± 2.03	21.5 ± 2.06	0.607

The comparison of demographic and anthropometric data between the two groups revealed no statistically significant differences. This indicates that both groups were comparable at baseline in terms of age, body composition, and physical dimensions. The absence of significant variation supports the internal validity of the study and ensures that observed training effects can be

attributed to the interventions rather than pre-existing differences.

The normality of the data was assessed using the Shapiro–Wilk test. The detailed results for each variable in both groups, before and after the intervention, are presented in Table 2. The results presented in Table 2 show that in the AnST group, all variables in both the pre-test and post-test conditions had significance values greater than 0.05, confirming that the data were normally distributed. In contrast, in the SSG group, most variables also met the normality assumption. However, the fatigue index in the post-intervention condition had a significance value of  $p = 0.047$ , indicating that the data for this variable were not normally distributed.

To verify the assumption of homogeneity of variances between groups, Levene’s test was conducted for all measured variables. The detailed results are presented in Table 3. The results of the homogeneity test using Levene’s test, as shown in Table 3, indicate that all variables had significance values greater than 0.05: Aerobic test ( $p = 0.311$ ), Mean Power ( $p = 0.319$ ), Peak Power ( $p = 0.477$ ), Minimum Power ( $p = 0.196$ ), and Fatigue Index ( $p = 0.206$ ). These results confirm that the assumption of homogeneity of variances between the AnST and SSG groups was satisfied, supporting the validity of subsequent independent t-test analyses.

The results of the aerobic capacity assessment before and after the intervention are illustrated

in Figure 3. This figure compares the mean values within each group using paired t-tests. In the AnST group, the pre-test result was  $47.52 \pm 5.12$ , while the post-test result increased to  $50.80 \pm 4.32$ . The percentage change was 7.23%, with a confidence interval (CI) of -2.516 to -0.941 and a  $p$ -value  $< 0.001$ , indicating a statistically significant improvement. In the SSG group, the pre-test result was  $49.23 \pm 3.41$ , and the post-test was  $51.63 \pm 2.94$ . The percentage change was 5.06%, with a CI of -1.726 to -0.132 and a  $p$ -value = 0.022, also showing a significant increase.

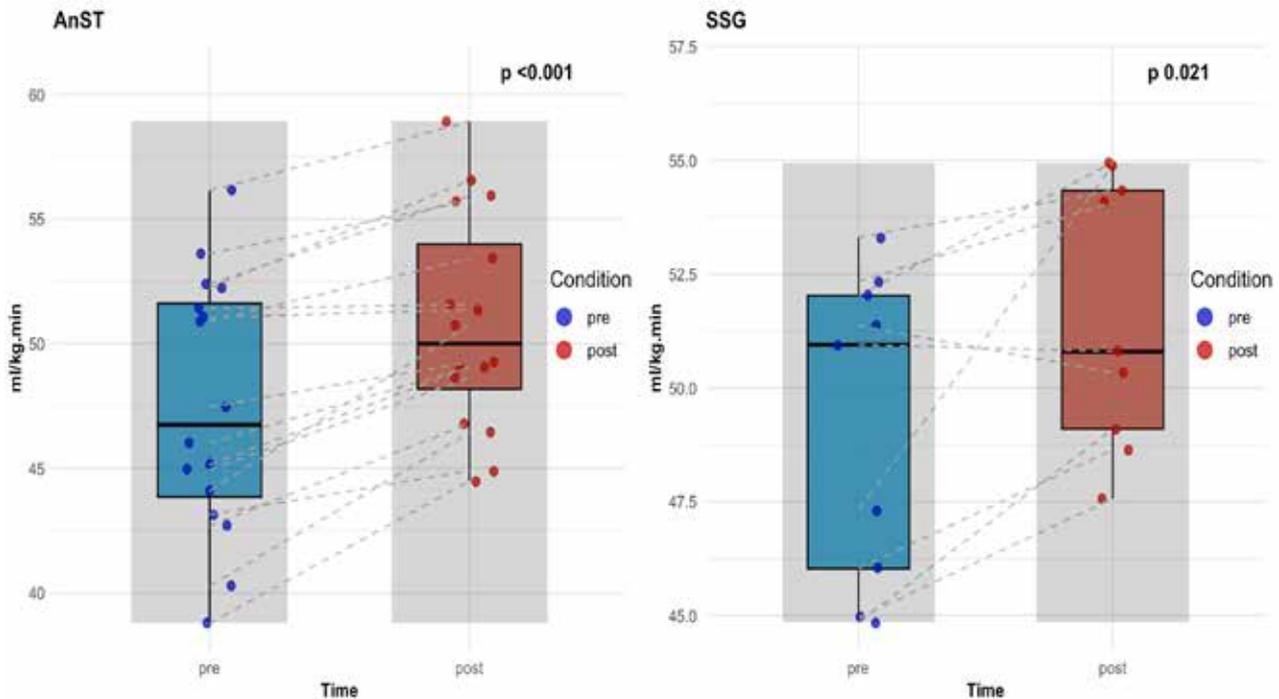
The effects of the intervention on anaerobic performance in the AnST group are presented in Figure 4. This figure displays changes in power output and fatigue index based on pre- and post-test measurements. Mean power increased significantly from  $402.304 \pm 78.819$  W to  $468.001 \pm 95.948$  W, reflecting a relative improvement of  $\Delta\% = 16.80\%$  (CI: -1.876 to -0.564,  $p < 0.001$ ). Minimum power also showed a significant increase, rising from  $299.885 \pm 81.286$  W to  $385.619 \pm 86.664$  W, with a relative improvement of  $\Delta\% = 28.60\%$  (CI: -2.202 to -0.760,  $p < 0.001$ ). In contrast, peak power rose from  $522.676 \pm 101.433$  W to  $567.102 \pm 114.543$  W, but this change ( $\Delta\% = 8.50\%$ ) was not statistically significant (CI: -0.991 to 0.047,  $p = 0.075$ ). The fatigue index slightly decreased from  $6.412 \pm 1.889$  to  $5.536 \pm 1.693$ , showing a reduction of  $\Delta\% = -13.67\%$ , though this change was also not statistically significant (CI: -0.147 to 0.867,  $p = 0.164$ ).

**Table 2.** Normality test of aerobic and anaerobic performance

Group	Variable	df	Shapiro-Wilk			
			Pre		Post	
			Statistic	Sig.	Statistic	Sig.
AnST	Aerobic Test	16	0.957	0.607	0.956	0.586
	Mean power	16	0.935	0.293	0.970	0.839
	Peak power	16	0.921	0.173	0.966	0.769
	Min power	16	0.959	0.649	0.920	0.168
	Fatigue index	16	0.951	0.499	0.954	0.553
SSG	Aerobic Test	9	0.861	0.098	0.872	0.128
	Mean power	9	0.960	0.795	0.949	0.676
	Peak power	9	0.955	0.744	0.949	0.683
	Min power	9	0.964	0.842	0.876	0.142
	Fatigue index	9	0.912	0.328	0.832	0.047

**Table 3.** Homogeneity Test of Aerobic and Anaerobic Performance

Variable	Levene Statistic	df	Sig.
Aerobic test	1.074	23	0.311
Mean power	0.214	23	0.319
Peak Power	0.523	23	0.477
Min Power	1.769	23	0.196
Fatigue Index	0.071	23	0.206



**Figure 3.** Result Paired t-test in aerobic test

The effects of the intervention on anaerobic performance in the SSG group are illustrated in Figure 5. This figure presents pre- and post-test results for key power-related indicators and fatigue index. Mean power significantly increased from  $441.023 \pm 51.295$  W to  $511.672 \pm 87.225$  W, representing a relative improvement of  $\Delta\% = 16.14\%$  (CI: -1.842 to 0.196,  $p = 0.014$ ). Minimum power also improved significantly, rising from  $329.103 \pm 82.822$  W to  $385.873 \pm 58.652$  W, with a relative increase of  $\Delta\% = 17.24\%$  (CI: -1.641 to 0.083,  $p = 0.030$ ).

In contrast, peak power showed a slight, non-significant increase from  $526.934 \pm 75.354$  W to  $561.232 \pm 87.175$  W, with a change of  $\Delta\% = 6.51\%$  (CI: -1.322 to 0.115,  $p = 0.100$ ). The fatigue index, evaluated using the Wilcoxon test, also increased slightly from  $5.757 \pm 1.762$  to  $6.312 \pm 1.411$ , but the difference ( $\Delta\% = 9.64\%$ ) was not statistically significant (CI: -0.812 to 0.326,  $p = 0.211$ ).

The comparison of aerobic performance between the AnST and SSG groups was conducted using an independent t-test. The detailed results are presented in Table 4. Table 4 shows that there was no significant difference in aerobic capacity between the two groups ( $p = 0.612$ ). The effect size was -0.214, and the confidence interval ranged from -1.030 to 0.607, which includes zero. These findings confirm the absence of a statistically meaningful difference in aerobic outcomes between the intervention groups.

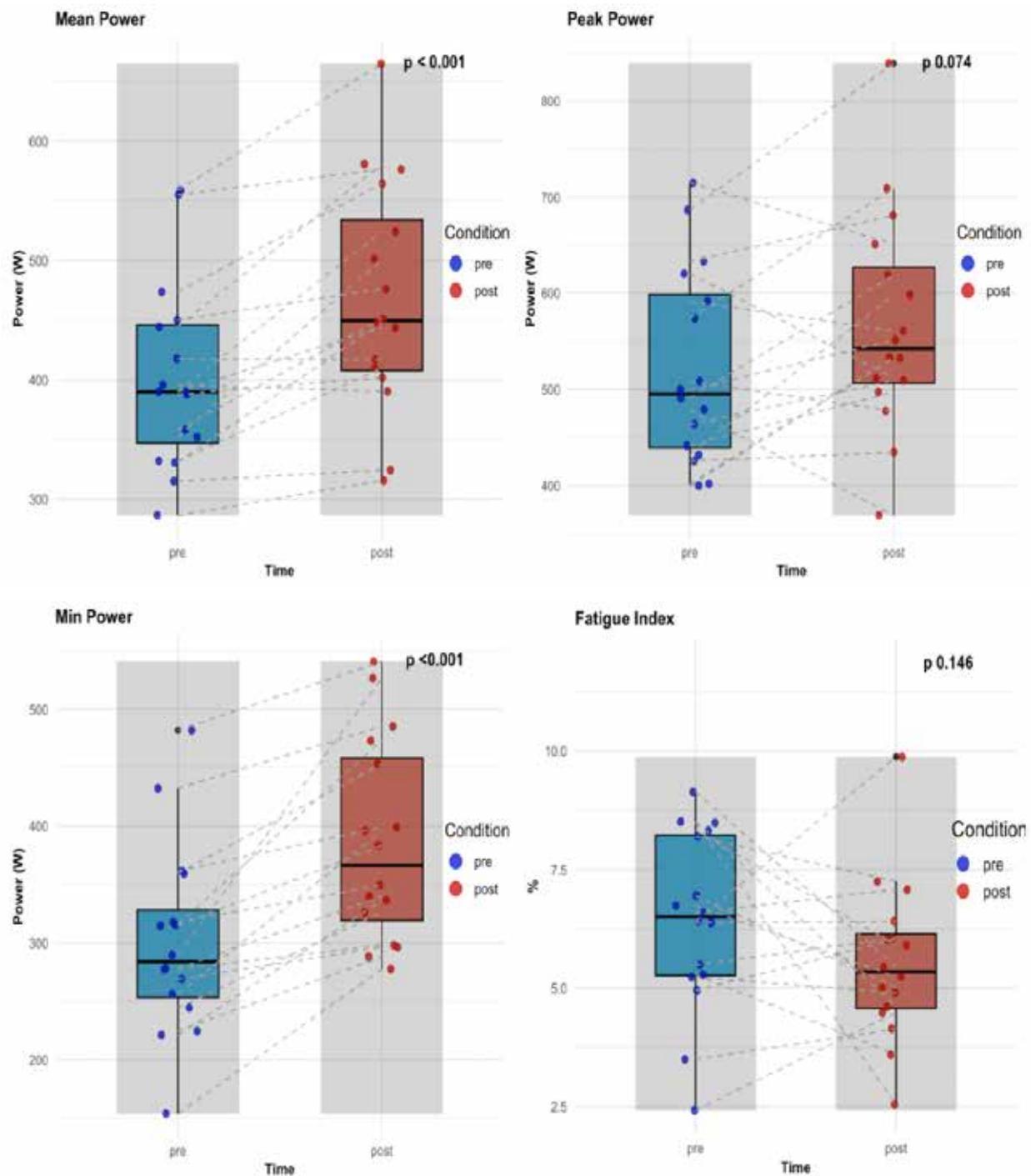
A comparative analysis of anaerobic performance between the AnST and SSG groups was performed using independent t-tests and the Mann-Whitney test. The results are summarized in Table 5. As shown in Table 5, there were no significant

differences in anaerobic power parameters between the groups, with all p-values exceeding 0.05. The Mann-Whitney test applied to the fatigue index also revealed no significant difference, with a p-value of 0.207. These findings indicate that, despite within-group improvements, the between-group differences in anaerobic outcomes were not statistically significant.

## Discussion

This study was designed to compare the effects of Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) on aerobic and anaerobic capacities in young male soccer players over a six-week period. The findings show that both training methods led to significant improvements in aerobic capacity. However, the improvement was more pronounced in the AnST group (7.23%) compared to the SSG group (5.06%). These results are consistent with previous research suggesting that sprint-based training protocols are more effective than game-based methods in enhancing maximal oxygen uptake [14]. The greater aerobic gains observed in the AnST group may be attributed to the repeated high-intensity efforts combined with short recovery intervals [15]. This type of stimulus is known to promote oxidative adaptations and improve the efficiency of the aerobic energy system [16]. Consequently, the AnST protocol appears to better reflect the physical demands of modern soccer, which requires players to recover quickly and maintain high performance across repeated efforts.

The study also found that both AnST and SSG effectively improved repeated sprint ability, as shown by significant increases in mean and

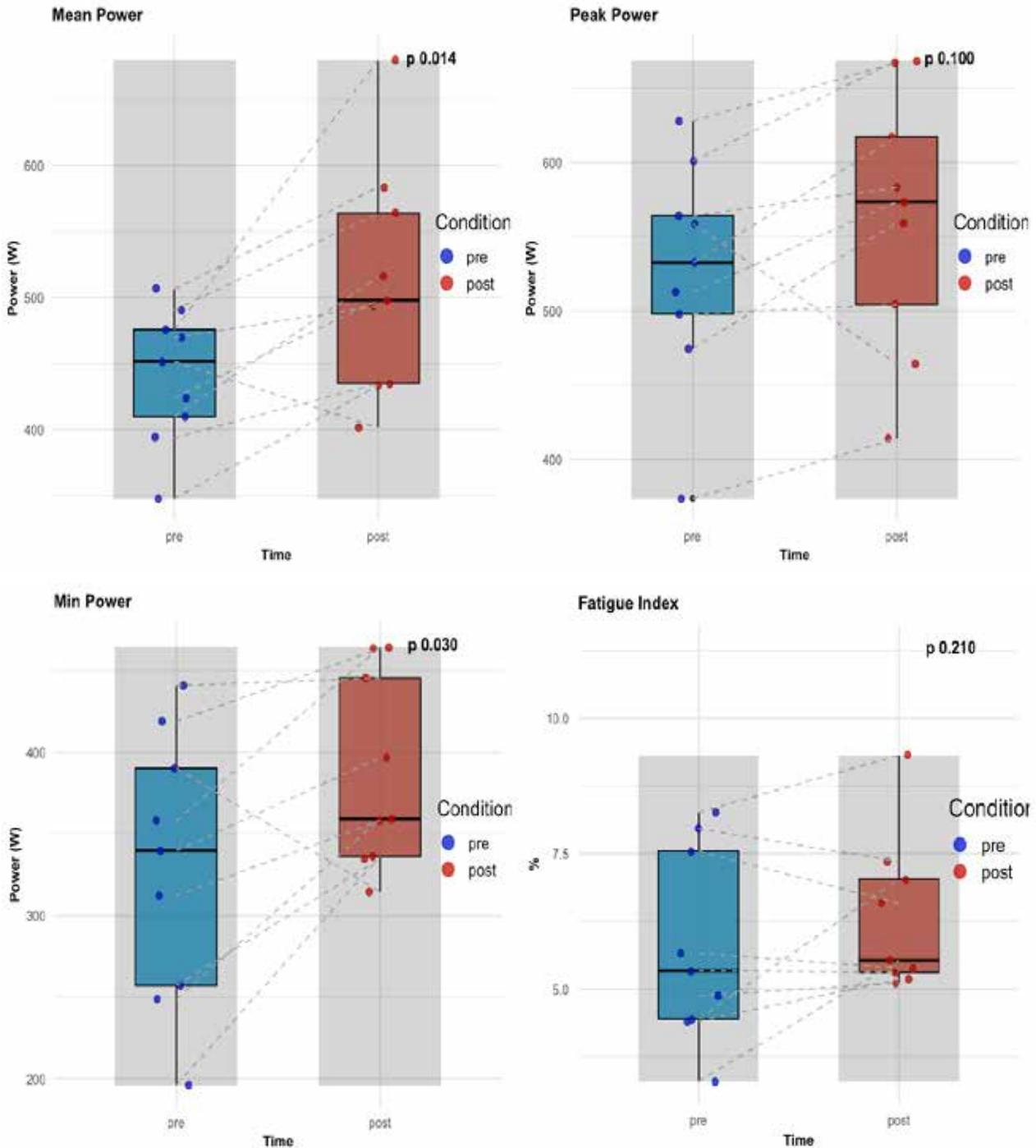


**Figure 4.** Result in anaerobic test AnST Group

minimum power. These improvements suggest that both training methods enhance the body's ability to sustain power output during repeated high-intensity efforts. However, the comparative analysis indicated that the AnST protocol led to more favorable adaptations than the SSG protocol. This outcome is likely due to the high-intensity interval nature of AnST, which includes short work periods and limited recovery time [17, 18]. Such conditions generate substantial metabolic stress, which in turn promotes improvements in anaerobic efficiency [19]. This interpretation is supported by findings

from Arslan et al. [20], who demonstrated that high-intensity training enhances neuromuscular and metabolic efficiency more rapidly and significantly than training at moderate or low intensities.

Conversely, the SSG group also demonstrated improvements in mean and minimum power, although these gains were slightly lower than those observed in the AnST group. This indicates that game-based training can still contribute to meaningful performance adaptations. SSG drills focus on technical and tactical execution within small, constrained spaces, which indirectly activate



**Figure 5.** Result in Anaerobic test SSG group

the aerobic and, to a lesser extent, anaerobic energy systems. This activation primarily occurs through explosive actions such as short sprints and rapid directional changes [21, 22]. These findings align with previous research suggesting that SSG delivers a balanced combination of physiological and technical stimuli within a single training framework [23]. However, due to its greater emphasis on aerobic demands and relatively longer recovery periods between high-intensity actions [24], the resulting adaptations in anaerobic capacity may be suboptimal [25]. This explains why the

improvements observed in the SSG group, while present, were not as pronounced as those resulting from the AnST protocol. Moreover, the absence of significant changes in peak power in both groups indicates that, although mean and minimum power improved, the ability to generate maximal explosive force did not. Peak power reflects the capacity of muscles to produce force over a very short time frame, and the lack of targeted stimulus in either training model may account for this outcome [26].

Interestingly, the study revealed contrasting responses in the fatigue index between the two

**Table 4.** Independent t-test in Aerobic

Variable	df	P-Value	Effect Size	95% CI effect size	
				Lower	Upper
Aerobic	23	0.612	-0.214	-1.030	0.607

**Table 5.** Comparative Analysis of Physical Parameter Means Using Independent t-Test and Mann-Whitney Test

Variable	df	P-Value	Effect Size	95% CI effect size	
				Lower	Upper
Mean power	23	0.271	-0.470	-1.292	0.363
Peak Power	23	0.895	0.055	-0.762	0.872
Min Power	23	0.994	-0.003	-0.820	0.813
Fatigue Index	23	0.207†	-0.319	-0.671	0.149

Note: †: Mann-Whitney test

groups. The AnST group exhibited a slight, although non-significant, decrease in fatigue index. This suggests that high-intensity training may be more effective in enhancing the body's ability to adapt to physical stress under repeated high-intensity conditions. Such adaptation is often linked to physiological improvements in fatigue resistance following intense efforts [28]. Supporting this, Jiménez et al. [29] found that sprint training with limited recovery improves the body's capacity to manage fatigue caused by lactate accumulation, allowing athletes to sustain performance across repeated bouts. In contrast, the SSG group showed an increase in the fatigue index. This may be the result of suboptimal load distribution that fails to sufficiently stimulate the anaerobic system [30]. Without a strong anaerobic stimulus, neuromuscular adaptations may remain limited. As a result, players in the SSG group might have experienced greater fatigue, possibly due to inadequate exposure to prolonged or repeated high-intensity efforts.

#### Limitations

This study has several limitations that should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of the findings. Second, unequal group sizes due to participant dropout may have introduced imbalance, despite random allocation. Third, the intervention period was limited to six weeks; longer training durations may result in different adaptation patterns. Finally, the study did not incorporate biochemical or neuromuscular measurements. Future research should include such parameters to provide a more comprehensive understanding of the physiological mechanisms underlying performance improvements.

In summary, both Anaerobic Soccer Training

(AnST) and Small-Sided Games (SSG) proved effective in enhancing aerobic and anaerobic performance in young soccer players. However, AnST produced more substantial improvements, particularly in repeated sprint ability and aerobic capacity, likely due to its higher training intensity and structured intervals. While SSG remains a valuable and practical method for integrated skill and fitness development, it may be less effective in targeting peak anaerobic performance. These findings support the strategic application of training modalities based on desired performance outcomes and highlight the potential of high-intensity models such as AnST in modern soccer conditioning.

#### Conclusions

This study concludes that both Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) are effective in improving aerobic and anaerobic capacities in young soccer players over a six-week training period. However, AnST led to greater percentage improvements, particularly in VO<sub>2</sub>max, mean power, and minimum power. These results are likely attributable to the higher intensity and structured intervals of the AnST protocol, which provide a stronger physiological training stimulus. The findings offer practical implications for coaches and practitioners, suggesting that AnST may be a more effective approach when the primary goal is to enhance high-intensity performance capacities in youth soccer training.

#### Conflict of interest

The authors declare no conflict of interest. They did not receive any financial support, sponsorship, or endorsement from any organization related to the submitted work.

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#### Information about the authors:

**Trio Hisbi Muttahid Ahmad**; <https://orcid.org/0009-0007-2208-2130>; [triohisbi1612@gmail.com](mailto:triohisbi1612@gmail.com); Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

**I Dewa Made Aryananda Wijaya Kusuma**; (Corresponding author); <https://orcid.org/0000-0002-4939-7294>; [dewawijaya@unesa.ac.id](mailto:dewawijaya@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Bayu Agung Pramono**; <https://orcid.org/0000-0002-9308-1289>; [bayupramono@unesa.ac.id](mailto:bayupramono@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Mochammad Ilham Ramadhani**; <https://orcid.org/0009-0006-5427-8720>; [romadhanilham11@gmail.com](mailto:romadhanilham11@gmail.com); Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Waristra Tyo Nirwansyah**; <https://orcid.org/0009-0005-2314-9064>; [waristra.21043@mhs.unesa.ac.id](mailto:waristra.21043@mhs.unesa.ac.id); Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

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## Comparative effects of Zumba and Yoga on stress, body satisfaction, and self-esteem in working women: a randomized control trial

Noortje Anita Kumaat<sup>1ABD</sup>, Afif Rusdiawan<sup>1,2ABCD</sup>, Procopio B. Dafun JR.<sup>3CD</sup>, Heri Wahyudi<sup>1BC</sup>, Popy Elisano Arfanda<sup>4AC</sup>, Fransisca Januarumi Marhaendra Wijaya<sup>1AD</sup>, Himawan Wismanadi<sup>1BE</sup>, Ary Artanty<sup>5BE</sup>

<sup>1</sup>Faculty of Sport and Health Sciences, Universitas Negeri Surabaya, Indonesia

<sup>2</sup>Sport & Exercise Research Center, Universitas Negeri Surabaya, Indonesia

<sup>3</sup>Department of Physical Education, Mariano Marcos State University, Philippines

<sup>4</sup>Faculty of Sport and Health Sciences, Universitas Negeri Makassar, Indonesia

<sup>5</sup>Faculty of Exact Studies and Sports, Universitas Insan Budi Utomo, Indonesia

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

### Abstract

**Background and Study Aim** Working women experience increased stress due to their dual roles as employees, homemakers, and family carers. This study aimed to compare the effects of Zumba and yoga on stress, body satisfaction, and self-esteem in working women.

**Material and Methods** A total of 159 moderately stressed working women (ages 20 to 50) were randomly assigned to one of three groups: yoga (n = 53), Zumba (n = 53), or control (wellness education, n = 53). Biweekly sessions of yoga (low-to-moderate intensity poses and breathing techniques) and Zumba (moderate-to-vigorous aerobic dance) were provided over a 12-week period. Assessments of stress (Perceived Stress Scale-10), body satisfaction (Body Satisfaction Scale), and self-esteem (Rosenberg Self-Esteem Scale) were conducted before and after the intervention. Effect size analyses and non-parametric tests (Kruskal-Wallis, Wilcoxon, and Mann-Whitney) were performed.

**Results** Compared to the control group (stress:  $\Delta = -3.25$ ; body satisfaction:  $\Delta = -0.78$ , not significant), both the Zumba and yoga groups showed significant reductions in stress (Zumba:  $\Delta = -7.54$ ,  $p < 0.001$ ; Yoga:  $\Delta = -8.86$ ,  $p < 0.001$ ) and improvements in body satisfaction (Zumba:  $\Delta = -12.36$ ; Yoga:  $\Delta = -9.69$ ,  $p < 0.05$ ). Self-esteem increased significantly in both the Zumba ( $\Delta = +5.59$ ) and yoga ( $\Delta = +5.31$ ,  $p < 0.001$ ) groups, but showed little change in the control group ( $\Delta = +0.92$ ). Medium effect sizes were observed for body satisfaction and self-esteem, and large effect sizes for stress reduction (Zumba:  $r = 0.419$ ; Yoga:  $r = 0.504$ ). No significant differences were found between the yoga and Zumba interventions.

**Conclusions** Yoga and Zumba are equally effective, culturally adaptable interventions for improving psychological well-being and reducing stress among working women. Their integration into workplace wellness programs offers a scalable and cost-effective approach to managing occupational stress, particularly in high-pressure, non-Western settings. Such initiatives should be prioritized by organizations and policymakers to support female employees' productivity and resilience.

**Keywords:** working women, stress, Zumba, Yoga, body satisfaction

### Introduction

Occupational stress is increasingly recognized as a serious public health issue, particularly among women who combine professional duties with domestic and caregiving responsibilities. In this context, the ongoing struggle to balance these dual roles often leads to chronic psychological strain and a diminished quality of life.

Many studies confirm this. Working women are particularly susceptible to psychological stress in the pressure-filled modern world due to their dual responsibilities as employees, homemakers, and family carers [1]. The accumulation of these roles

can lead to decreased self-esteem, reduced body satisfaction, and elevated stress levels [2]. Working women who experience chronic stress may develop mental health conditions such as anxiety and depression, along with an increased risk of metabolic and cardiovascular diseases if left untreated [3, 4]. Prolonged stress also lowers productivity and further increases the risk of psychological disorders [5]. Therefore, it is essential to identify effective, affordable, and widely applicable interventions to improve the psychological well-being of this population.

Non-pharmacological strategies, such as exercise, have gained popularity due to their broad benefits, even when pharmaceutical interventions are available. Among these, aerobic activities like Zumba and mind-body practices like yoga are

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increasingly recognized for their ability to reduce stress and improve psychological well-being [6, 7]. However, few comparative studies have assessed the effectiveness of these modalities, particularly among underrepresented populations such as working women in developing countries. Workplace wellness programs remain uncommon in Indonesia, where cultural and occupational pressures further elevate stress levels. Existing literature predominantly focuses on Western populations and often overlooks important outcomes such as body satisfaction and self-esteem [8, 9].

Through enjoyable rhythmic movement, Zumba has been shown to elevate mood, lower cortisol levels, and promote body acceptance [10, 11]. In contrast, yoga has been demonstrated to reduce stress by modulating the hypothalamic-pituitary-adrenal (HPA) axis through breathing awareness and relaxation techniques [12]. Recent meta-analyses indicate that physical activity lowers cortisol via HPA axis regulation, enhances emotional regulation through mindfulness, and fosters social connectedness through the group-based nature of Zumba and yoga [13, 14, 15]. However, methodological concerns remain, including a lack of randomized controlled trials (RCTs) and a narrow focus on outcome variables [16].

Although previous studies have confirmed the psychological benefits of both Zumba and yoga, several methodological and contextual issues remain unresolved. First, there is a lack of comparative research between Zumba and yoga, particularly in the context of developing nations. Most existing studies have focused on populations in high-income countries, which limits our understanding of how these findings apply to working women in developing regions who face specific social and cultural challenges, such as balancing work and domestic responsibilities. Second, while stress is commonly measured in isolation, important dimensions of women's mental health, including body satisfaction and self-esteem, are often overlooked [17, 18]. For example, a meta-analysis by Fong Yan et al. [19] found that only 12 percent of dance intervention studies addressed body image concerns despite the clear importance of this factor.

Moreover, the study designs employed in this field are sometimes methodologically weak. A comprehensive analysis by Remskar et al. [20] revealed that only 23 percent of studies on mindfulness and physical activity used a randomized controlled trial (RCT) design, which raises concerns about the internal validity of earlier findings. In addition, existing programs rarely incorporate cultural adaptations, such as the use of Latin music in Zumba or traditional breathing techniques in yoga, which may enhance participant engagement in developing countries [12, 21]. For example, research by Siregar et al. [22] conducted

in Indonesia examined only short-term effects without directly comparing the two modalities. Furthermore, most studies fail to explore the psychological mechanisms that account for differences in the effects of Zumba and yoga. While yoga is often associated with mindfulness-based emotional regulation, Zumba may enhance social connectedness through group interaction [15, 23]. In the absence of thorough comparative research, policy recommendations for workplace health interventions remain unclear.

A review of the existing literature reveals divergent perspectives among researchers regarding the relative benefits of Zumba and yoga. While most studies emphasize the positive effects of both practices on psychological health, including stress reduction and improved emotional well-being, there is no clear consensus on which modality is more effective or under what conditions. Moreover, current evidence highlights important gaps, particularly in terms of long-term outcomes, cultural adaptation, and the inclusion of diverse populations. These limitations underscore the ongoing need for more rigorous, context-sensitive research to better understand how and for whom these interventions are most effective.

This study aimed to compare the effects of Zumba and yoga on stress, body satisfaction, and self-esteem in working women.

## Materials and Methods

### *Participants*

A total of 159 participants were recruited for this study through social media platforms and fitness centers in Surabaya City. From July to September 2024, purposive sampling was conducted via the Instagram, Facebook, and WhatsApp channels of the Sport & Exercise Research Center, Universitas Negeri Surabaya, in collaboration with five local fitness centers and the Department of Labor in Surabaya, Indonesia. Recruitment was facilitated by distributing flyers on social media. The announcement outlined benefits for participants, including free Zumba and yoga sessions aimed at enhancing well-being, participation certificates, and stress management education.

Eligibility criteria included being female, aged between 20 and 50 years, working full-time (more than 35 hours per week), experiencing moderate stress (Perceived Stress Scale-10 score of 14 or higher), and having no prior experience with Zumba or yoga. Exclusion criteria involved pregnancy, cardiovascular or musculoskeletal disorders, or an inability to attend biweekly sessions. Of the 216 individuals screened, 159 met the inclusion criteria and were randomized by age into one of three groups: Zumba, yoga, or control.

Participants were randomly assigned to the

three groups (Zumba, Yoga, and Control), with an equal number of 53 individuals per group. Sample size was determined using G\*Power software, based on a medium effect size ( $f = 0.25$ ), 80% power, and  $\alpha = 0.05$ . Informed consent and ethical approval were obtained prior to participation. Attendance was systematically recorded throughout the intervention period. Participants who missed more than three sessions were excluded from the per-protocol analysis.

*Research Design*

This study employed an experimental design structured as a randomized controlled trial (RCT)

[24]. It compared the effects of two interventions (Zumba and yoga) and a control condition on stress, body satisfaction, and self-esteem. The intervention groups included a Zumba group, which received a 12-week Zumba program, and a yoga group, which participated in a 12-week yoga program. Both interventions were conducted twice per week. The control group received non-physical wellness education. Details of the intervention programs are presented in Table 1.

Table 1 presents the structure of the intervention programs. The Zumba group received moderate-to-vigorous intensity training (50–90% of maximum heart rate), delivered progressively over 12 weeks.

**Table 1.** 12-week intervention program of zumba, yoga and control groups

Week	Group	Intensity (% Max HR)	Focus	Core Movements	Duration	Annotation
1–4	Zumba	50–70% (Moderate to vigorous)	Basic rhythms and enjoyment	<i>Merengue</i> : Marching in place with hip swings; side step with hamstring curl <i>Salsa</i> : Forward–back step with torso rotation; guapea (Cuban basic step) <i>Cumbia</i> : Knee lifts with arm synchronization; side step with clap	45 min	Music: “ <i>La Vida Es Un Carnaval</i> ”(Celia Cruz), “ <i>Danza Kuduro</i> ”(Don Omar)
	Yoga	50–60% (Low)	Basic techniques and breathing	<i>Breathing</i> : Ujjayi Pranayama, Nadi Shodhana <i>Asanas</i> : Tadasana, Balasana, Adho Mukha Svanasana, Virabhadrasana I, Bhujangasana	50 min	Poses held for 15–20 seconds (3 breaths) with simple vinyasa transitions
	Control	—	Basic stress management	Education on stress, its sources, and effects; introduction to visualization and affirmations	45–50 min	Aims to build basic stress awareness and introduce coping tools
5–8	Zumba	60–80% (Moderate to vigorous)	Cardio and rhythm	<i>Reggaeton</i> : Basic perreo; jumping jacks with arm punches <i>Belly dance</i> : Hip drops and snake arms; shimmy with body roll <i>Afrobeat</i> : Bounce step with arm swings; high knees with shoulder rolls	45 min	Music: “ <i>Gasolina</i> ”(Daddy Yankee), “ <i>Jerusalem</i> ”(Master KG)
	Yoga	60–70% (Moderate)	Extended pose duration	<i>Breathing</i> : Kapalabhati, Bhramari <i>Asanas</i> : Virabhadrasana II, Trikonasana, Utkatasana, Setu Bandhasana <i>Flow</i> : Plank → Chaturanga → Cobra → Downward-Facing Dog (3 times)	50 min	Poses held for 30–45 seconds (5–7 breaths); new flows added (e.g., Warrior I → III)
	Control	—	Healthy lifestyle education	Topics include sleep hygiene, nutrition, time management, work-life balance; peer discussion	45–50 min	Encourages sustainable lifestyle changes for stress reduction

**Table 1.** Continued

Week	Group	Intensity (% Max HR)	Focus	Core Movements	Duration	Annotation
	Zumba	70–90% (Moderate to vigorous)	Advanced choreography and endurance	<i>Zumba toning:</i> Squats with overhead press; lunges with lateral arm raises <i>Bollywood fusion:</i> Namaste step with spin jump; arm swirls <i>Latin hip-hop:</i> Body isolations (chest and hips); quick footwork	45 min	Music: “ <i>Waka Waka</i> ” (Shakira), “ <i>Jai Ho</i> ” (A.R. Rahman)
9–12	Yoga	65–75% (Moderate to high)	Advanced poses and balance	<i>Breathing:</i> Sama Vritti (4-4-4 equal breathing) <i>Asanas:</i> Vrksasana, Ardha Chandrasana, Ustrasana, Headstand Prep (wall-supported), Side plank flow (Plank → Side plank → Vasisthasana, 3 times both sides)	50 min	Emphasis on balance transitions (e.g., Tree → Eagle); peak poses in Weeks 11–12
	Control	—	Mindfulness and self-reflection	Activities include mindful eating, music listening, journaling; structured reflection and growth planning	45–50 min	Aims to cultivate self-awareness, emotional regulation, and resilience

During weeks 1 to 4, sessions focused on basic movements such as merengue, salsa, and kumbia. Weeks 5 to 8 incorporated cardio and rhythmic elements, including reggaeton, belly dance, and afrobeat. In weeks 9 to 12, advanced choreography was introduced, including Zumba toning, Bollywood fusion, and Latin hip-hop.

The yoga group received low-to-moderate intensity training (50–75% of maximum heart rate), emphasizing fundamental breathing techniques, endurance in holding poses, and the gradual inclusion of advanced postures such as Tree Pose and Headstand Preparation. The program began with basic breathing exercises and foundational poses in weeks 1 to 4, progressed to extended pose-holding and transitional movements in weeks 5 to 8, and culminated in the integration of advanced poses and complex flow sequences in weeks 9 to 12.

Instead of physical activity, the control group received wellness-based education covering basic stress management, healthy lifestyle practices, mindfulness, and self-reflection. This educational component was delivered online and included facilitated discussions, guided self-reflection, and peer-sharing activities designed to address social interaction factors without involving physical exercise. The sessions were led by health practitioners and academic staff with expertise in wellness education.

Data collection was conducted at two time points: week 0 (pretest) and week 12 (posttest). Stress levels

were assessed using the Perceived Stress Scale (PSS-10), which has demonstrated good internal consistency with a Cronbach’s alpha of 0.865 [25]. The PSS-10 is a 10-item self-report instrument designed to measure the extent to which individuals perceive their lives as unpredictable, uncontrollable, and overloaded. Responses are provided on a 4-point Likert scale ranging from “never” to “very often,” with each item scored from 0 to 4. The total score is obtained by summing all item responses, including four reverse-coded items. Higher total scores reflect greater perceived stress, with a maximum possible score of 40. No universally established cut-off score exists to differentiate between high and mild levels of stress [25].

Body satisfaction was measured using the Body Satisfaction Scale (BSS). The test-retest reliability of the BSS was reported to be 0.86 [17]. Participants rated their satisfaction with 24 specific body features using a six-point Likert scale ranging from “extremely satisfied” to “extremely dissatisfied” [26]. Higher scores indicate greater levels of body dissatisfaction.

Self-esteem was assessed using the Rosenberg Self-Esteem Scale (RSES). Test-retest reliability over a two-week period yielded correlation coefficients of 0.85 and 0.88, indicating excellent temporal stability [27]. The RSES consists of 10 items, each rated on a four-point Likert scale with response options ranging from “strongly agree” (scored as 4) to “strongly disagree” (scored as 1) [28].

### Statistical Analysis

Statistical analysis began with data preparation, which involved addressing missing values and detecting outliers. Datasets for stress (PSS-10), body satisfaction (BSS), and self-esteem (RSES), collected at both pretest and posttest, were screened for missing data. When the proportion of missing values was less than 5% per variable, multiple imputation using fully conditional specification (FCS) was applied. The imputation model incorporated baseline scores, group allocation, and demographic covariates (age and occupational sector). Participants with more than 20% missing responses across the main outcome variables were excluded from the final per-protocol analysis to maintain consistency and analytical rigor.

Outliers were assessed using both univariate and multivariate methods. Univariate outliers were identified based on standardized Z-scores exceeding  $\pm 3.29$ . Additionally, boxplot analysis using Tukey's method was performed to detect mild outliers ( $1.5 \times$  IQR beyond the quartiles) and extreme outliers ( $3.0 \times$  IQR beyond the quartiles). Multivariate outliers were assessed by calculating Mahalanobis distances using the chi-square distribution with three degrees of freedom, with a significance threshold set at  $p < 0.001$ .

Descriptive statistics, including means and standard deviations (SD), were computed for each outcome variable at pretest and posttest. The Shapiro–Wilk test was used to assess normality. The Kruskal–Wallis test was used to examine differences across groups (Zumba, Yoga, Control), while intra-group differences were analyzed using the Wilcoxon signed-rank test for non-normally distributed data. Between-group comparisons were conducted using Bonferroni-adjusted pairwise tests.

Effect sizes were calculated using effect size  $r$ , interpreted as small ( $r = 0.1$ ), medium ( $r = 0.3$ ), or large ( $r = 0.5$ ). All statistical analyses were conducted using SPSS version 25. Sample size adequacy was confirmed using G\*Power software, based on an alpha level of 0.05, statistical power of 80%, and a medium effect size ( $f = 0.25$ ), supporting the sufficiency of the final sample size ( $n = 159$ ). Statistical significance was set at  $p < 0.05$ . Conclusions regarding the effectiveness of interventions were based on comparisons of pre-to-post score changes between groups. The randomized controlled trial design and use of standardized measures were intended to reduce bias and enhance external validity [24].

### Results

This randomized controlled trial included a total of 159 adult working women aged 21 to 50 years. Participants were classified into three age groups: 46.54% were in the 31–40 age group, followed by 35.22% in the 41–50 age group, and 18.24% in the 21–30 age group. The employment sector

distribution was relatively balanced, with 28.93% employed in state-owned enterprises, 24.53% in the private sector, and 23.90% in the public service. The remaining 22.64% were engaged in alternative professions, including entrepreneurship, freelance work, and academia.

This demographic profile reflects the study's emphasis on recruiting a diverse and representative sample of working women in metropolitan Surabaya, Indonesia, thereby strengthening the external validity of the findings. Controlling for potential confounding variables related to age and occupational background was essential to ensure valid comparisons across the intervention groups (Zumba, Yoga, and Control).

Table 2 presents the effects of the Zumba and yoga interventions on perceived stress, body satisfaction, and self-esteem among working women. Both intervention groups demonstrated statistically significant reductions in perceived stress compared to the control group, with large effect sizes (Zumba:  $\Delta = -7.54$ ,  $p < 0.001$ ,  $r = 0.419$ ; Yoga:  $\Delta = -8.86$ ,  $p < 0.001$ ,  $r = 0.504$ ; Control:  $\Delta = -3.25$ ,  $p < 0.001$ ,  $r = 0.334$ ). According to Cohen's classification, these results indicate clinically meaningful effects ( $r \geq 0.5 =$  large;  $r \geq 0.3 =$  medium). Reductions in body dissatisfaction were also observed in both intervention groups, with medium effect sizes (Zumba:  $\Delta = -12.36$ ,  $p = 0.013$ ,  $r = 0.375$ ; Yoga:  $\Delta = -9.69$ ,  $p < 0.001$ ,  $r = 0.295$ ), while the control group showed no statistically significant change ( $\Delta = -0.78$ ,  $p = 0.186$ ). Improvements in self-esteem were statistically significant in both intervention groups, with medium to large effect sizes (Zumba:  $\Delta = +5.59$ ,  $p < 0.001$ ,  $r = 0.386$ ; Yoga:  $\Delta = +5.31$ ,  $p < 0.001$ ,  $r = 0.348$ ). In contrast, the control group showed only a minor, non-significant change ( $\Delta = +0.92$ ,  $p = 0.249$ ). Although slightly greater improvements were observed in the Zumba group across all outcomes, between-group differences were not statistically significant ( $p = 0.526$ ), suggesting that both interventions were similarly effective. Overall, both Zumba and yoga proved to be beneficial for reducing stress and improving body satisfaction and self-esteem among working women.

Furthermore, the Kruskal–Wallis test was conducted to examine whether there were significant differences in pre–post change scores ( $\Delta$ ) across the three independent groups (Zumba, Yoga, and Control). The results showed statistically significant differences for all three outcome variables: stress ( $p < 0.001$ ), body satisfaction ( $p = 0.022$ ), and self-esteem ( $p < 0.001$ ), indicating that the interventions had differential effects across groups. Given these results, pairwise comparisons were performed using the Mann–Whitney U test to determine which specific group differences were statistically significant. The detailed outcomes of these comparisons are presented in Table 3.

**Table 2.** The effect of Zumba and Yoga intervention on variables

Group	Variable		Mean±SD	Min	Max	Shapiro wilk test	Wilcoxon test	Effect-size r
Zumba	Stress	Pre	23.36±4.78	15	32	0.110 <sup>#</sup>	0.00*	0.713
		Post	15.81±2.16	12	20	0.022		
		Δpre-post	-7.54±4.60	-15	3			
	Body Satisfaction	Pre	81.32±16.60	50	109	0.034	0.013*	0.375
		Post	68.97±13.84	49	92	0.002		
		Δpre-post	-12.36±22.76	53	27			
	Self-esteem	Pre	24.00±4.54	17	32	0.011	0.000*	-0.566
		Post	29.59±3.53	24	36	0.014		
		Δpre-post	5.59±5.30	-7	16			
Yoga	Stress	Pre	23.54±4.85	14	32	0.043	0.000*	0.770
		Post	14.68±1.85	12	18	0.003		
		Δpre-post	-8.86±4.93	-20	-1			
	Body Satisfaction	Pre	83.03±18.28	45	111	0.014	0.000*	0.295
		Post	73.34±12.57	52	96	0.009		
		Δpre-post	-9.69±19.34	-47	31			
	Self-esteem	Pre	24.98±4.44	18	32	0.003	0.573	-0.538
		Post	30.29±3.86	24	38	0.047		
		Δpre-post	5.31±5.98	-6	17			
Control	Stress	Pre	24.03±5.09	15	32	0.006	0.000*	0.334
		Post	20.78±4.02	14	29	0.137 <sup>#</sup>		
		Δpre-post	-3.25±4.68	-16	7			
	Body Satisfaction	Pre	84.54±20.82	47	113	0.000	0.186	0.021
		Post	83.76±16.21	53	114	0.166 <sup>#</sup>		
		Δpre-post	-0.78±13.63	-24	29			
	Self-esteem	Pre	26.56±4.60	19	34	0.007	0.249	-0.110
		Post	27.47±3.51	23	34	0.001		
		Δpre-post	0.92±5.84	-10	13			

Δ is the difference; #normally distributed with p>0.05; \*significantly different with p<0.05

**Table 3.** Pairwise Comparisons of Intervention Effects on Perceived Stress, Body Satisfaction, and Self-Esteem (Mann–Whitney U Test)

Variable	Group Comparison		p-value	Effect Size (r)
Stress	Zumba	Yoga	p = 0.394	0.137
		Control	p < 0.001*	0.419
	Yoga	Control	p < 0.001*	0.504
Body Satisfaction	Zumba	Yoga	p = 0.718	0.063
		Control	p = 0.020*	0.294
	Yoga	Control	p = 0.015*	0.257
Self-Esteem	Zumba	Yoga	p = 0.526	0.025
		Control	p < 0.001*	0.386
	Yoga	Control	p = 0.001*	0.348

\* Statistically significant at p < 0.05.

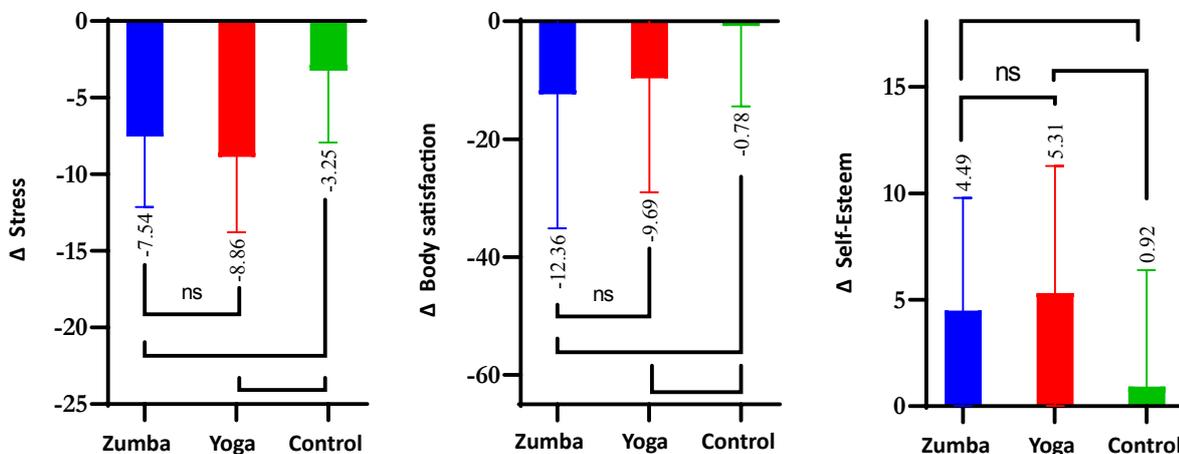
As illustrated in Figure 1, both the Zumba and yoga interventions led to greater improvements across all measured outcomes compared to the control group. The largest reduction in perceived stress was observed in the yoga group, followed closely by the Zumba group, whereas the control group exhibited only a modest decrease. In terms of body satisfaction, participants in the Zumba group experienced the most notable improvement, while the yoga group also showed a meaningful, albeit smaller, reduction in dissatisfaction. The control group, by contrast, demonstrated minimal change. Regarding self-esteem, both Zumba and yoga produced substantial and comparable increases, whereas the control group showed only a slight, non-significant improvement. These patterns suggest that while both interventions were effective, yoga may be more impactful in reducing stress, whereas Zumba appears to offer slightly greater benefits for body satisfaction.

Table 3 presents the results of Mann–Whitney U tests conducted to examine differences in pre–post change scores ( $\Delta$ ) among the three groups (Zumba, Yoga, and Control) for perceived stress, body satisfaction, and self-esteem. Statistically significant differences were observed between both intervention groups and the control group across all psychological outcomes. For perceived stress, the effect sizes were large (Zumba vs. Control:  $r = 0.419$ ; Yoga vs. Control:  $r = 0.504$ ), indicating strong practical significance. For body satisfaction, the effect sizes were in the medium range (Zumba vs. Control:  $r = 0.294$ ; Yoga vs. Control:  $r = 0.257$ ). In terms of self-esteem, both interventions also demonstrated medium to large effects (Zumba vs. Control:  $r = 0.386$ ; Yoga vs. Control:  $r = 0.348$ ). No statistically significant differences were found between the Zumba and Yoga groups on any of the measured outcomes.

This equivalency highlights the complexity of

the psychophysiological mechanisms underlying the two modalities. Although Zumba and yoga produced comparable outcomes in stress reduction ( $\Delta = -7.54$  vs.  $-8.86$ ) and improvements in body satisfaction ( $\Delta = -12.36$  vs.  $-9.69$ ), they likely operate through distinct strategies that influence shared neuroendocrine pathways. One such pathway involves the regulation of cortisol and the hypothalamic–pituitary–adrenal (HPA) axis. Yoga incorporates controlled breathing and mindfulness practices that enhance self-awareness and support emotion regulation. In contrast, Zumba utilizes rhythmic aerobic movement, which may increase endorphin release and foster social connectedness through group interaction [15, 29].

Individual differences in preferences for activity intensity may partially account for the variation in stress-related effect sizes ( $r = 0.419$  vs.  $0.504$ ). For example, individuals with more introverted dispositions may respond more positively to yoga’s inward-focused structure, whereas those with extroverted tendencies may find Zumba’s energetic and socially engaging format more beneficial [23]. Although Zumba produced a greater reduction in body dissatisfaction ( $\Delta = -12.36$  vs.  $-9.69$ ), the difference between the two interventions was not statistically significant ( $p = 0.718$ ). Embodiment theory may offer an explanation for this pattern. It posits that Zumba’s expressive movements, such as those found in Latin dance and body isolations, promote body acceptance through enjoyment rather than through performance-based self-evaluation [21]. In comparison, yoga fosters nonjudgmental body awareness, which can gradually reduce internalized criticism related to physical appearance [18]. Despite these differing mechanisms, both interventions address core sources of body dissatisfaction. Yoga does so through mindfulness and self-compassion, while Zumba achieves similar outcomes through pleasurable and expressive physical activity.



**Figure 1.** Pre-to-post intervention changes in perceived stress, body satisfaction, and self-esteem across the Zumba, Yoga, and Control groups.

## Discussion

This randomized controlled trial examined the comparative effectiveness of Zumba and yoga interventions on perceived stress, body satisfaction, and self-esteem among working women. The results showed that both interventions significantly reduced stress levels and improved body satisfaction and self-esteem, with large effect sizes particularly evident for stress reduction. These findings are consistent with earlier studies that highlight the positive influence of physical activity on psychological well-being.

In the present study, the Zumba intervention, functioning as a form of aerobic exercise, likely contributed to stress reduction and mood enhancement through the release of endorphins [30]. Similarly, prior research by Pascoe et al. [29] demonstrated that aerobic and mind-body activities can reduce the activity of the hypothalamic pituitary adrenal (HPA) axis and lower cortisol levels, thereby decreasing psychological stress. Yoga, which incorporates mindfulness and controlled breathing, also appears to influence these neuroendocrine pathways. Its focus on pranayama, meditative awareness, and relaxation may provide cumulative physiological benefits that are not limited to physical movement alone [31, 32].

Zumba, in contrast, may exert its psychological benefits through rhythmic aerobic movement, musical engagement, and group interaction. These elements are thought to enhance emotional states through mechanisms related to social connection and collective participation, as described in sport psychology literature [22]. The lack of significant differences between the interventions suggests that Zumba and yoga offer similar benefits in psychological outcomes, possibly because both approaches include structured movement, rhythm, and cognitive engagement, even though they activate these components through different mechanisms.

The increase in body satisfaction observed in both the Zumba and yoga groups supports the potential of structured exercise programs to enhance body image. The Zumba group demonstrated the largest improvement ( $\Delta = -12.36$ ), which may be attributed to the expressive and dynamic nature of the activity. This form of movement encourages body acceptance and enjoyment by shifting focus away from performance-based evaluation [33]. Zumba may also incorporate social and artistic elements of dance, which facilitate body appreciation through shared enjoyment and expressive physicality [34]. Among women particularly affected by societal beauty standards, the rhythmic and culturally diverse movements of Zumba may contribute to reduced self-objectification and a stronger sense of embodiment [21].

In comparison, yoga emphasizes mindful awareness and nonjudgmental acceptance of the body. This inward focus may help explain its more moderate impact on body satisfaction [18]. Although less physically intense, yoga fosters a reflective relationship with the body and promotes self-acceptance, which has been linked to greater body appreciation [35]. These findings are consistent with previous meta-analyses reporting small to moderate effects of both modalities on body image outcomes, which align with the effect sizes identified in this study (Zumba:  $r = 0.294$ ; Yoga:  $r = 0.257$ ).

The minimal change observed in the control group underscores the importance of active engagement in structured physical or mental practices. Compared to passive instruction, organized interventions appear to yield greater psychological benefits, particularly in the domain of body image enhancement [20].

Following the intervention, both Zumba and yoga groups demonstrated significant increases in self-esteem, as measured by the Rosenberg Self-Esteem Scale (Zumba:  $\Delta = 5.59$ ; Yoga:  $\Delta = 5.31$ ). Although the difference between the two interventions was not statistically significant ( $p = 0.526$ ), participants in the Zumba group reported slightly greater gains. These findings are consistent with previous research indicating that enjoyable, mastery-oriented physical activities can enhance self-worth, particularly among women who experience the dual demands of occupational stress and societal appearance norms [23].

In addition to the physical component, the group-based delivery of both interventions may have contributed to improved self-perception by promoting social support and a sense of collective efficacy [19]. From a theoretical perspective, self-compassion theory offers further insight into yoga's impact on self-esteem. Through its introspective techniques, yoga may reduce self-criticism and promote emotional regulation, ultimately fostering a more stable and positive self-concept [36].

The therapeutic relevance of the observed effect sizes for stress reduction ( $r = 0.419$  to  $0.504$ ) in both intervention groups, compared to the control, underscores the clinical significance of these findings. These results are consistent with meta-analytic evidence indicating that exercise-based interventions yield moderate to substantial reductions in stress, particularly among populations experiencing high stress levels [37]. At the same time, the absence of a statistically significant difference between Zumba and yoga aligns with previous comparative research suggesting that the specific type of exercise may be less important than the consistency of participation [38].

The limited improvements observed in the control group, which received only wellness-related information without active physical engagement, underscore the importance of

incorporating physical activity into psychological health interventions. The medium to large effect sizes observed between the intervention and control groups, such as the impact of yoga on stress reduction compared to control ( $r = 0.504$ ), highlight the practical relevance of these findings for workplace health promotion. Integrating Zumba or yoga into organizational wellness programs may represent a cost-effective and scalable approach for mental health professionals and educators seeking to improve employees' psychological well-being. This is particularly pertinent for addressing stress, body satisfaction, and self-esteem among working populations.

This randomized controlled trial conducted in Surabaya, Indonesia, demonstrated that both Zumba and yoga were effective in reducing stress, enhancing body satisfaction, and improving self-esteem among working women, with no significant differences between the two interventions. However, several limitations should be acknowledged. The potential influence of group dynamics on mental health outcomes, as well as the possibility of expectancy effects due to participants' awareness of engaging in physical activity, may have contributed to the observed results [33, 34]. The use of a passive control group limits the ability to isolate the specific effects of physical activity itself. Additionally, the reliance on self-reported measures introduces the possibility of response bias.

The cultural specificity of the urban Indonesian context may constrain the generalizability of the findings to other populations. Excluding participants who did not complete the full intervention may have also introduced selection bias. Moreover, the relatively short duration of the intervention and the absence of follow-up assessments limit conclusions regarding the sustainability of the effects over time [25].

Future research should employ more rigorous designs, including active control conditions and objective outcome measures. Longitudinal studies conducted across diverse cultural settings are needed to assess long-term effects. In addition, tailoring interventions to individual psychological and occupational profiles may enhance their effectiveness in high-stress work environments.

Several limitations should be taken into account when interpreting the results of this study. First, the generalizability of the findings is restricted, as the sample included only working women from metropolitan Surabaya, Indonesia. Therefore, the conclusions may not be applicable to men, individuals living in rural areas, or populations from different cultural backgrounds. Second, although the randomized controlled design helps reduce various forms of bias, it does not eliminate the possibility of social desirability bias. Participants may have responded in ways they believed were

expected, particularly when completing self-report questionnaires on body satisfaction and self-esteem.

Third, the study did not include objective physiological or biological measures that could provide independent confirmation of the intervention's effects, such as heart rate variability or cortisol levels. In addition, the 12-week intervention period was relatively short and did not allow for assessment of whether the observed psychological improvements would be sustained over time. Lastly, the study design did not adequately account for non-specific effects of active participation, including increased motivation, social interaction, and engagement related to group-based physical activity. The control condition consisted only of passive wellness education without comparable levels of involvement.

Future studies are encouraged to incorporate biomarker assessments, include actively engaged control groups, and conduct long-term follow-up evaluations in order to better understand the mechanisms and sustainability of intervention outcomes.

## Conclusions

This study, conducted in an urban Indonesian context, found that both Zumba and yoga interventions were equally effective in reducing perceived stress and enhancing body satisfaction and self-esteem among working women. These findings suggest that organizations can implement either modality depending on logistical constraints, cultural context, and participant preferences. The results support the scalability, cost-effectiveness, and cultural adaptability of structured physical activity interventions.

Integrating Zumba or yoga into workplace wellness programs may assist human resources and occupational health departments in addressing employee stress, preventing burnout, and promoting a supportive organizational environment. In addition, such interventions may contribute to improved social support and team cohesion, which are recognized predictors of job satisfaction and workplace productivity. Tailoring intervention content to include culturally relevant music or traditional mindfulness practices may further enhance participant engagement and adherence.

To broaden reach across diverse employee groups, hybrid programs that offer both Zumba and yoga sessions may be beneficial. Incorporating brief, accessible routines such as breathing exercises inspired by yoga or movement breaks based on dance formats can support psychological well-being even among employees with limited time availability. Finally, the study highlights the need for gender- and culture-sensitive models and encourages further research to increase generalizability and strengthen the role of physical activity in public health policy.

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## Conflict of interest

The authors declare no conflict of interest.

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### Information about the authors:

**Noortje Anita Kumaat**; (Corresponding author); <https://orcid.org/0000-0001-6045-7553>; noortjeanita@unesa.ac.id; Faculty of Sport and Health Sciences, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Afif Rusdiawan**; <https://orcid.org/0000-0001-5388-7061>; affrusdiawan@unesa.ac.id; Faculty of Sport and Health Sciences, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Procopio B. Dafun JR.**; <https://orcid.org/0000-0002-4249-6126>; pbdafun@mmsu.edu.ph; Department of Physical Education, Mariano Marcos State University; City of Batac, Ilocos Norte, Philippines.

**Heri Wahyudi**; <https://orcid.org/0009-0000-1355-6954>; heriwahyudi@unesa.ac.id; Faculty of Sport and Health Sciences, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Popy Elisano Arfanda**; <https://orcid.org/0000-0002-8191-6912>; poppy.elisano@unm.ac.id; Faculty of Sport and Health Sciences, Universitas Negeri Makassar; Makassar, Indonesia.

**Fransisca Januarumi Marhaendra Wijaya**; <https://orcid.org/0000-0002-3417-1305>; fransiscajanuarumi@unesa.ac.id; Faculty of Sport and Health Sciences, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Himawan Wismanadi**; <https://orcid.org/0000-0003-2618-172X>; himawanwismanadi@unesa.ac.id; Faculty of Sport and Health Sciences, Universitas Negeri Surabaya; Surabaya, Indonesia.

**Ary Artanty**; <https://orcid.org/0009-0009-1010-937X>; aryartanty@uibu.ac.id; Faculty of Exact Studies And Sports, Universitas Insan Budi Utomo; Malang, Indonesia.

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## Assessing the impact of gender and body mass index on motor competence: a cross-sectional analysis of children

Sandeep Kumar<sup>1BCD</sup>, Yajuvendra Singh Rajpoot<sup>2ACD</sup>, Krishna Kant Sahu<sup>3CD</sup>, Bhanu Pratap<sup>4BD</sup>, Suchishrava Choudhary<sup>5ACD</sup>, Prashant Kumar Choudhary<sup>6ACD</sup>, Nripender Hooda<sup>7ABD</sup>

<sup>1</sup>Department of Physical Education, Swami Vivekanand Subharti University, India

<sup>2</sup>Department of Sports Management and Coaching, Lakshmibai National Institute of Physical Education, India

<sup>3</sup>Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education, India

<sup>4</sup>Department of Physical Education, Lovely Professional University, India

<sup>5</sup>Lakshmibai National Institute of Physical Education, India

<sup>6</sup>Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education, India

<sup>7</sup>Department of Sports Science, International Institute of Sports and Management, University of Mumbai, India

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

### Abstract

**Background and Study Aim** Fundamental motor skills in children serve as the basis for constructing more complex movement patterns. Therefore, the quality of mastering these skills, relative to children's age, largely determines success. These skills are influenced by both gender and weight status. This study aimed to analyze gender differences and the relationship between BMI and motor competence in school-aged children.

**Material and Methods** A cross-sectional study was conducted among 260 children (130 boys and 130 girls) aged 9–13 years from three schools in Mumbai, India. Motor competence was evaluated using the Basic Motor Skills Assessment Scale. The scale assessed locomotor skills, object control, and turning and rolling. Anthropometric data were collected to calculate BMI, categorized as normal, overweight ( $\geq 85$ th percentile), and obese ( $\geq 97$ th percentile). Extracurricular physical activity habits were assessed through a structured questionnaire. Statistical analyses included chi-square tests, t-tests, and one-way ANOVA with Scheffé post hoc comparisons ( $p < 0.05$ ).

**Results** Among the sample, 19.2% were overweight and 11.6% were obese. Boys showed significantly greater engagement in extracurricular physical activity than girls ( $t = 3.214$ ,  $p = 0.002$ ). Boys preferred team-based sports, while girls favored individual activities. Significant intragender differences in locomotor and turning/rolling skills were found among boys. Normal-weight boys outperformed both overweight ( $p = 0.002$ ) and obese peers ( $p = 0.001$ ,  $0.019$ , respectively). Obese boys also showed significantly lower turning and rolling competence than overweight boys ( $p = 0.011$ ). In object control, normal-weight boys and girls both demonstrated superior performance compared to obese counterparts ( $p = 0.018$  for boys;  $p = 0.010$  for girls). Among girls, no significant differences were observed in locomotor or turning/rolling skills across BMI categories.

**Conclusions** Gender and BMI significantly impact motor competence in children. Interventions should consider these factors to support inclusive physical development and target the needs of overweight and obese children.

**Keywords:** fundamental motor skills, body mass index, gender differences, motor competence, school-aged children.

### Introduction

Motor competence is a critical component of children's physical development and overall health, forming the foundation for engagement in physical activity and influencing both current and future participation in active lifestyles. Primary education represents a pivotal stage in this developmental process, providing the first formal setting for systematic instruction and the acquisition of fundamental skills [1]. During this period, children

encounter structured learning environments where they begin to develop core competencies in literacy, numeracy, and social interaction [2]. These early educational experiences contribute to a broader goal: nurturing well-rounded individuals capable of meaningful societal contribution [3]. Central to this holistic development is moral education, which supports children in navigating ethical dilemmas and making responsible choices [4]. Accordingly, primary education addresses a wide spectrum of developmental domains, including intellectual growth, interpersonal abilities, emotional well-being, and motor competence [5, 6]. Within this framework, physical education plays a key role by

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fostering fundamental motor skills essential for an active and healthy lifestyle [7]. Importantly, these motor skills are closely associated with cognitive and socio-emotional development, reinforcing their importance in promoting overall child well-being [8].

The development of motor skills encompasses a broad spectrum of movements, including locomotor skills such as running, jumping, and skipping, and manipulative skills such as throwing, catching, and kicking [9]. Mastery of these foundational skills enables individuals to participate confidently in a variety of physical activities and sports, thereby fostering a sustained commitment to an active lifestyle [10]. These fundamental motor skills serve as the basis upon which more complex and task-specific movements are built, facilitating effective interaction with the physical environment [11, 12]. Universally observed across individuals, they constitute the essential groundwork for acquiring advanced and specialized motor competencies. Motor skill development is a dynamic and progressive process shaped by experiential learning and the maturation of the central nervous system [13]. This process unfolds through distinct developmental stages, commonly referred to as the initial, elementary, and mature phases, each characterized by specific qualitative and quantitative features that reflect evolving motor abilities [14]. Therefore, it is crucial to provide children with diverse and structured movement experiences to support optimal motor development [15]. A lack of such experiences may hinder motor progression and contribute to coordination challenges [13]. Multiple factors influence this developmental trajectory, including genetic predispositions, physical and neurological maturation, and external conditions such as environmental enrichment, quality of life, nutrition, and hygiene [12, 13, 16]. These determinants include intrinsic biological attributes as well as sociocultural and psychological influences that interact to shape motor development [17, 18].

The quality and diversity of experiences during childhood play a critical role in shaping motor development. Opportunities for exploration, experimentation, and repeated practice act as key drivers of motor skill refinement and progression [19]. A decline in basic motor skill proficiency has been consistently associated with an increasingly sedentary lifestyle, as highlighted in multiple studies [20, 21]. Broader societal trends, including technological advancement, social change, and shifts in dietary patterns, have collectively altered human behavior and contributed to adverse health outcomes, most notably the increasing prevalence of overweight and obesity [22]. The widespread adoption of household technologies has unintentionally encouraged sedentary habits by reducing the need for physical effort in routine tasks [23]. These behavioral transformations have

been further amplified by social developments that continue to replace physical activity with convenience-based alternatives in daily life. Industrialized food production, characterized by high levels of fats and carbohydrates, along with a decline in physical activity, has also been implicated in the rising incidence of overweight and obesity [24, 25, 26, 27, 28]. In contrast, cultural factors such as gender identity have been shown to exert a significant influence on motor development, underscoring the importance of sociocultural context in shaping motor behavior [29].

The relationship between childhood obesity and the acquisition of fundamental motor skills constitutes a critical area of research in pediatric health and motor development [8]. Fundamental motor skills, including locomotor, manipulative, and stability components, serve as foundational elements for more advanced movement patterns and are essential for active participation in diverse physical activities [30]. Social cognitive theory provides a framework for understanding how individuals develop gender identity through the continuous interaction of personal experiences and sociostructural influences. These factors shape gender-related behaviors via motivational and self-regulatory mechanisms [31]. Gender identity is constructed through culturally and historically embedded ideas, beliefs, and societal norms that define expected roles for men and women [32]. These roles influence behaviors deemed acceptable and typical within a given society. The development of motor skills in specific sports often occurs within cultural contexts that reflect and perpetuate gender stereotypes. These narratives shape patterns of participation, performance expectations, and social perceptions [33]. Such outcomes are not solely attributable to biological differences but emerge from the complex interplay of societal norms, historical inequalities, and the influential role of media representation [34].

Research indicates that males typically show a preference for contact sports, while females are more likely to engage in activities with an aesthetic emphasis, such as dance or gymnastics [35]. Although these preferences may appear benign, they can create challenges for girls who wish to participate in traditionally male-dominated sports. Such choices may be perceived as inconsistent with societal expectations of femininity, potentially leading to social stigmatization and the attribution of a “masculine” identity [36]. In response, girls often opt for activities that align more closely with culturally accepted feminine norms [37]. Recent developments in the field of physical activity have led to a gradual dissociation of certain forms of exercise from rigid gender classifications. This has contributed to the emergence of shared spaces that integrate both masculine and feminine elements [37]. However,

despite this progress, data consistently show that females continue to participate less frequently in sports compared to males [37, 38]. Significant differences persist in the types of activities preferred, with males tending toward ball sports and females gravitating toward artistic disciplines such as rhythmic gymnastics and figure skating [39, 40]. These gender-based distinctions in physical activity preferences and motor competence reflect a complex interplay of sociocultural expectations and biological predispositions [41]. Furthermore, research suggests that gender differences exist in motor competence, with males generally exhibiting higher proficiency in object control skills than females [39].

An analysis of current research demonstrates that the development of motor competence is influenced by a combination of biological, psychological, and sociocultural factors. Scholars consistently highlight the significant impact of both gender and body mass index on children’s acquisition of motor skills and their preferences for physical activity. Although these associations have been the subject of numerous studies, there remains

a gap in understanding the specific ways in which these variables interact, particularly within varied cultural and educational contexts.

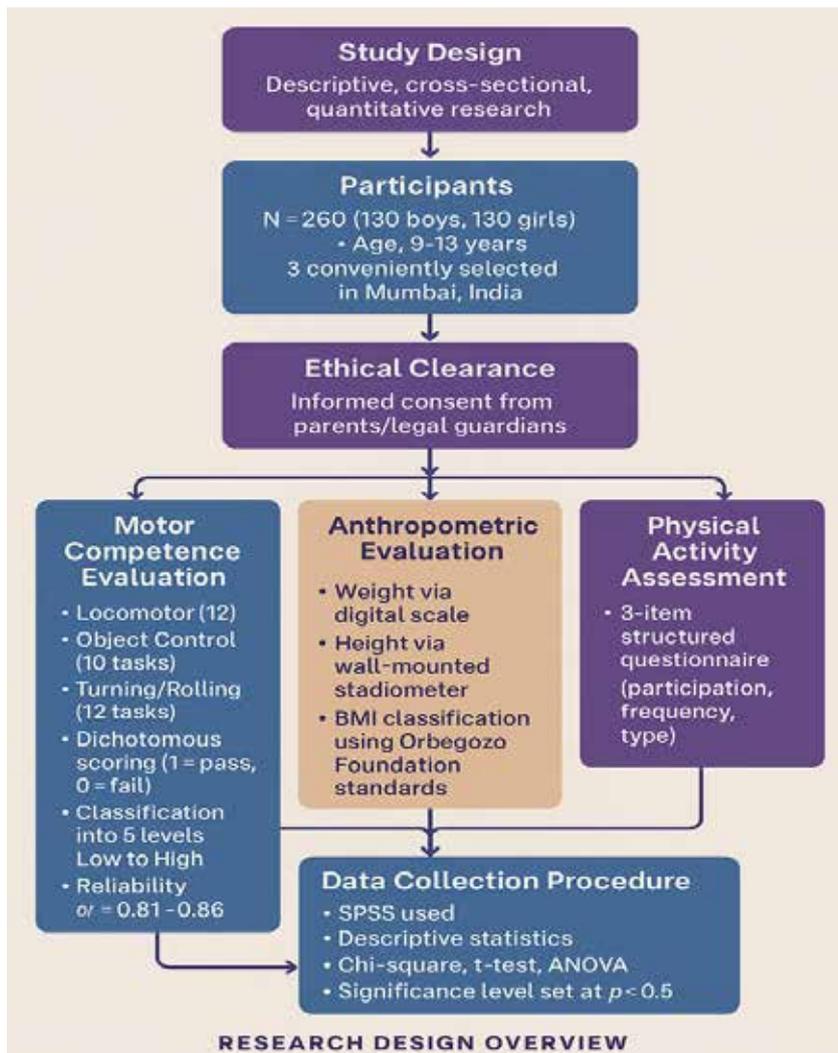
In light of this, the present study aims to investigate the influence of gender and body mass index on motor competence in school-aged children. This research seeks to enhance our understanding of the multidimensional factors that shape physical development during a critical period of growth.

## Material and methods

### Participants

This study adopted a descriptive, cross-sectional quantitative design involving a total of 260 school-aged children, comprising 130 boys and 130 girls, aged between 9 and 13 years. Participants were recruited from three educational institutions in Mumbai, India, selected through convenience sampling based on institutional accessibility and willingness to participate. An overview of the participant selection process is presented in Figure 1.

Ethical approval was obtained prior to the commencement of the study, and written informed



**Figure 1.** Flow Diagram

consent was collected from the parents or legal guardians of all participants in accordance with established ethical research guidelines.

#### *Assessment Tools and Variables*

**Motor Competence Measurement.** Motor competence was assessed using the Basic Motor Skills Assessment Scale developed by Fernández et al. [42]. This standardized instrument includes three core domains: locomotor skills (12 tasks), object control skills (10 tasks), and turning and rolling (12 tasks). Each task was scored dichotomously, with 1 indicating successful or appropriate execution and 0 indicating unsuccessful or inappropriate execution. This scoring system enabled the classification of motor competence levels based on performance. The internal consistency of the instrument was validated through Cronbach's alpha coefficients, which were 0.81 for locomotor skills, 0.84 for turning and rolling, and 0.86 for object control. These values demonstrate high reliability across the assessed domains. Participants' total motor competence scores were categorized into five levels, following the normative criteria established in the original framework: Low, Low Average, Medium, Medium High, and High.

**Anthropometric Assessment.** Height and weight were measured using calibrated instruments, including a digital electronic scale for body weight and a wall-mounted stadiometer for height. All assessments were conducted with participants wearing light clothing and no footwear to ensure accuracy. Body Mass Index (BMI) was calculated using the standard formula: weight in kilograms divided by height in meters squared ( $\text{kg}/\text{m}^2$ ). To determine overweight and obesity status, the BMI values were compared with age- and sex-specific percentile thresholds established by the Orbegozo Foundation growth charts [43]. According to these criteria, overweight was defined as a BMI at or above the 85th percentile, and obesity as a BMI at or above the 97th percentile.

**Physical Activity Profile.** Information on participants' extracurricular physical activity habits was collected using a brief structured questionnaire consisting of three items. The questionnaire inquired whether the child engaged in physical activity outside school hours, the frequency of such participation per week, and the type or nature of physical activity performed.

**Data Collection Procedure.** All assessments were conducted on school premises during regular school hours. Prior to testing, participants received standardized instructions and demonstrations for each motor competence task to ensure full comprehension. The tasks were administered in a fixed sequence. In cases where a participant failed an initial attempt, a second attempt was permitted. If a participant failed three consecutive tasks within

a given domain, the assessment for that domain was discontinued.

Anthropometric measurements (height and weight) were recorded first. These were followed by the administration of motor competence tasks and, subsequently, the completion of the physical activity questionnaire. All procedures were carried out by trained personnel to ensure accuracy and standardization in data collection.

#### *Procedural Framework*

Following the acquisition of informed consent from parents or legal guardians, the data collection process was initiated. This process included the assessment of motor competence, the measurement of anthropometric parameters (height and weight), and the evaluation of participants' extracurricular physical activity patterns.

The data collection was conducted in a structured and sequential manner, as outlined below:

- **Pre-assessment Orientation:** Prior to testing, all participants received a clear explanation regarding the purpose and nature of each assessment to promote transparency and encourage active participation.
- **Anthropometric Measurements:** Height and weight were measured under standardized conditions, with participants wearing a T-shirt and shorts and no footwear. Measurements were obtained using a calibrated electronic scale and a fixed wall-mounted stadiometer to ensure precision and consistency.
- **Motor Skills Assessment:** Participants then completed the Basic Motor Skills Assessment Scale. Each motor task was demonstrated beforehand to ensure comprehension and proper execution. Tasks were administered in a fixed sequence consistent with the original structure of the scale.
  - Each attempt was scored using a binary scale (1 = successful execution; 0 = unsuccessful).
  - If a participant failed a task on the first attempt, a second attempt was permitted.
  - If three consecutive tasks were failed, the motor skills assessment for that individual was discontinued in accordance with the testing protocol to ensure consistency and reduce participant discomfort.
- **Assessment of Physical Activity Habits:** After completing the physical and motor assessments, participants answered a short questionnaire designed to gather information about the frequency, type, and nature of their extracurricular physical activity.

All assessments were conducted during school hours under the supervision of trained personnel to ensure ethical standards, child safety, and the reliability of collected data.

*Statistical Analysis*

Data analysis was performed using IBM SPSS Statistics for Windows, Version 26.0. Descriptive statistics, including means, standard deviations, and percentages, were used to summarize participant characteristics and study variables. To examine group differences, chi-square tests ( $\chi^2$ ) were applied to categorical variables, while independent samples t-tests were used to assess differences between two groups. For comparisons involving more than two groups, a one-way analysis of variance (ANOVA) was conducted. When significant effects were identified, Scheffé post hoc analysis was applied to determine specific between-group differences. The threshold for statistical significance was set at  $p < 0.05$ .

**Results**

Table 1 presents the demographic characteristics of the 260 participants, with an equal distribution between boys ( $n = 130$ ) and girls ( $n = 130$ ). The majority of participants (69.2%) had a Body Mass Index (BMI) within the normal range. In contrast, 19.2% were classified as overweight and 11.6% as obese, based on the percentile thresholds

established by the Orbegozo Foundation growth charts. Regarding physical activity habits, 73.1% of the children reported participating in extracurricular physical activities, indicating a generally active study sample.

The analysis of anthropometric data revealed distinct patterns in BMI classification among participants. As shown in Table 2, 19.2% of children were categorized as overweight and 11.6% as obese. Among boys, 20.0% were overweight and 13.1% were classified as obese, while among girls, 18.5% were overweight and 10.0% obese. Although these distributions suggest slightly higher rates among boys, no statistically significant gender-based difference was found in overall BMI classification ( $\chi^2 = 1.785, p = 0.410$ ). However, further analysis by age and gender revealed a statistically significant difference among 9-year-olds, with boys presenting a higher combined prevalence of overweight and obesity compared to girls ( $\chi^2 = 8.499, p = 0.014$ ).

As indicated, although BMI distributions across most age groups did not show statistically significant gender-based differences, the deviation observed at age 9 merits further investigation. This result highlights a potential early-age gender disparity in weight status that may inform targeted interventions.

**Table 1.** Demographic Characteristics of the Participants (N = 260)

Variable	Category	n	Percentage (%)
Gender	Boys	130	50.0
	Girls	130	50.0
Age (years)	9	50	19.2
	10	60	23.1
	11	65	25.0
	12	50	19.2
	13	35	13.5
Weight Status (BMI Percentile)	Normal Weight (<85th percentile)	180	69.2
	Overweight (85th–96th percentile)	50	19.2
	Obese ( $\geq 97$ th percentile)	30	11.6
Participation in Extracurricular Physical Activity	Yes	190	73.1
	No	70	26.9

**Table 2.** Classification of the Sample According to Gender, Age, and BMI (N = 260)

Age	Normopeso Boys n (%)	Normopeso Girls n (%)	Sobrepeso Boys n (%)	Sobrepeso Girls n (%)	Obeso Boys n (%)	Obeso Girls n (%)	$\chi^2$	p
9	20 (62.5)	18 (56.3)	8 (25.0)	10 (31.3)	4 (12.5)	4 (12.5)	1.873	0.392
10	24 (64.9)	20 (58.8)	8 (21.6)	10 (29.4)	5 (13.5)	4 (11.8)	0.991	0.609
11	22 (68.8)	24 (75.0)	6 (18.8)	5 (15.6)	4 (12.5)	3 (9.4)	1.105	0.575
12	18 (60.0)	20 (66.7)	7 (23.3)	6 (20.0)	5 (16.7)	4 (13.3)	0.598	0.742
13	16 (59.3)	17 (65.4)	6 (22.2)	5 (19.2)	5 (18.5)	4 (15.4)	0.547	0.762

As illustrated in Figure 2, the proportion of normal-weight children remained consistently higher across all age groups, with boys showing a slight predominance. Overweight and obesity were more prevalent among girls in the younger age groups, whereas the prevalence of obesity among boys showed a gradual increase with age.

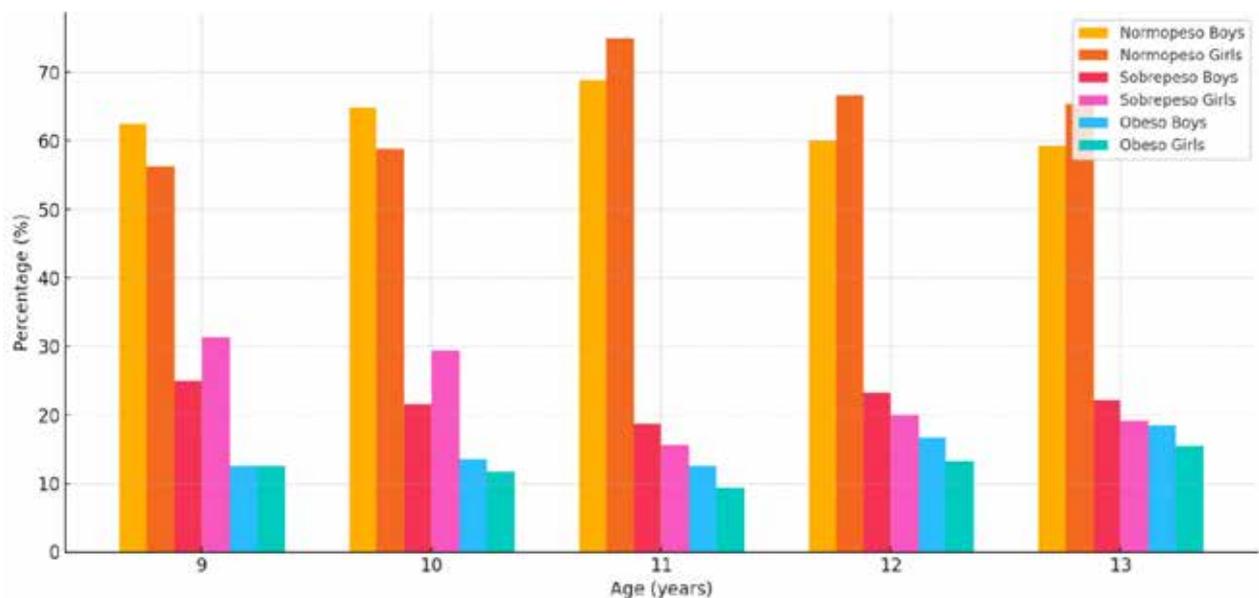
Regarding extracurricular physical activity, 26.9% of girls reported no participation in sports activities, compared to 11.5% of boys. Results from the independent samples t-test indicated that boys participated in physical activity significantly more frequently than girls ( $t = 3.214, p = 0.002$ ). Analysis of sport type preferences revealed that boys predominantly favored team-based sports such as football and cricket, while girls showed a greater inclination toward individual activities such as dance and yoga. A chi-square test confirmed a statistically significant association between gender and type of sport chosen ( $\chi^2(2) = 59.374, p = 0.001$ ). In the assessment of motor competence specific to the running skill domain, no significant differences were observed between genders. Both boys and

girls demonstrated comparable proficiency, with no statistically meaningful variation ( $p > 0.05$ ).

An intragender analysis was conducted to evaluate the effect of BMI category on locomotor skill levels among boys and girls. As shown in Table 3, boys with a normal BMI demonstrated significantly higher levels of locomotor competence compared to their overweight and obese peers. Results from a one-way ANOVA, followed by Scheffé post hoc tests, revealed significant differences between boys with normal BMI and those classified as overweight ( $p = 0.002$ ) or obese ( $p = 0.001$ ). However, no statistically significant difference was found between the overweight and obese groups.

As illustrated in Figure 3, boys with normal BMI demonstrated significantly higher levels of locomotor skill compared to their overweight and obese counterparts. Among girls, although locomotor performance tended to decline with increasing BMI, the observed differences were not statistically significant.

In contrast, no statistically significant differences in locomotor competence were observed across BMI



**Figure 2.** Distribution of BMI Categories by Age and Gender

**Table 3.** Intragender Differences in Locomotor Skill Level According to BMI Category

Dependent Variable	(I) BMI	(J) BMI	Mean Difference (I-J)	Standard Error	p-value
Locomotor Skills Level (Boys)	Normal	Overweight	0.695	0.188	0.002*
	Normal	Obesity	0.953	0.221	0.001*
	Overweight	Obesity	0.258	0.263	0.638
Locomotor Skills Level (Girls)	Normal	Overweight	0.154	0.197	0.721
	Normal	Obesity	0.482	0.303	0.211
	Overweight	Obesity	0.328	0.327	0.318

\*Significant at  $p \leq 0.05$ .

categories among girls, although those with normal BMI exhibited slightly higher average performance. These findings suggest that BMI exerts a more pronounced influence on motor competence in boys than in girls within this sample.

As shown in Table 4, the analysis revealed that among boys, those with a normal BMI demonstrated significantly higher object control skills compared to their obese counterparts ( $p = 0.018$ ). A similar pattern was observed among girls, with those in the normal BMI category outperforming obese girls in object control tasks ( $p = 0.010$ ). These findings indicate that higher BMI is associated with decreased proficiency in object control skills for both genders, highlighting the influence of weight status on motor skill development.

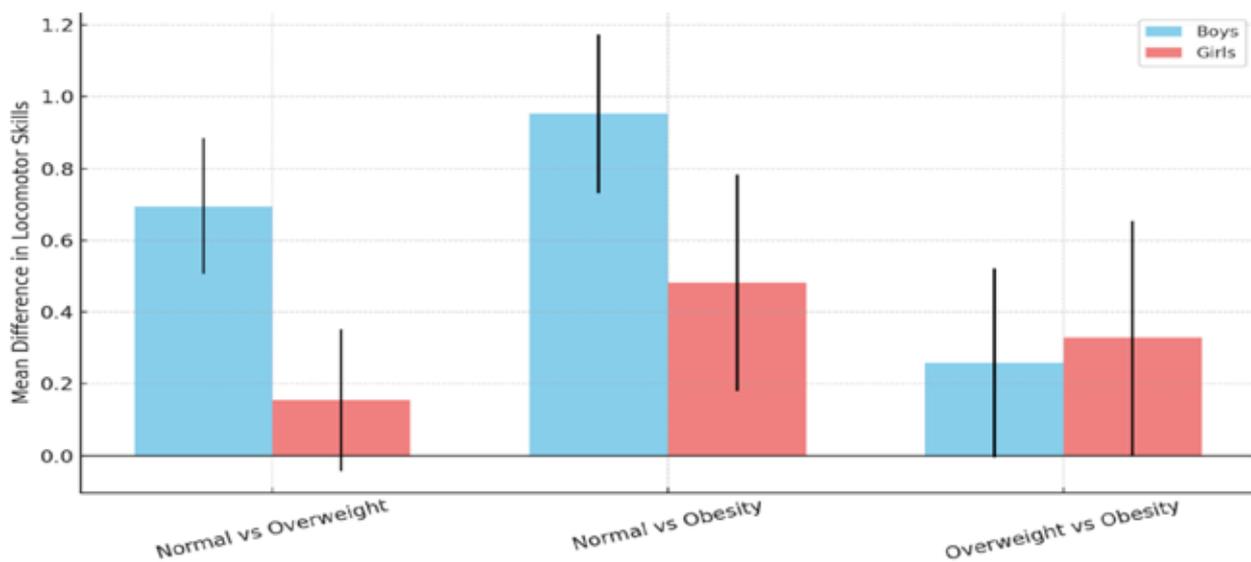
As illustrated in Figure 4, intragender differences in object control skill levels across BMI categories are evident for both boys and girls. Statistically significant differences ( $p \leq 0.05$ ) were observed between the normal-weight and obese groups within each gender, with obese participants demonstrating substantially lower performance. These results underscore the association between higher BMI and reduced motor skill proficiency, particularly when comparing normal-weight to obese children.

Further intragender analysis based on BMI

categories revealed that girls with obesity demonstrated significantly lower object control abilities compared to their peers with normal weight. A one-way ANOVA, followed by post hoc testing, indicated a statistically significant difference between normal-weight and obese girls ( $p = 0.026$ ). However, no significant differences were found between overweight girls and those in either the normal-weight or obese categories. In contrast, the same analysis conducted among boys did not yield statistically significant differences in object control scores across BMI categories. Nonetheless, boys with normal BMI exhibited slightly higher mean performance than their overweight and obese peers.

Lastly, in the assessment of the turning and rolling motor skill domain, both boys and girls showed generally low performance levels. The chi-square test indicated no significant gender differences ( $p > 0.05$ ), suggesting that this motor skill poses a similar level of difficulty for children regardless of gender.

As shown in Table 5, significant intragender differences in turning and rolling skills were identified among boys, particularly between the normal-weight and obese, as well as overweight and obese groups ( $p \leq 0.05$ ). These findings indicate a decline in performance with increasing BMI.

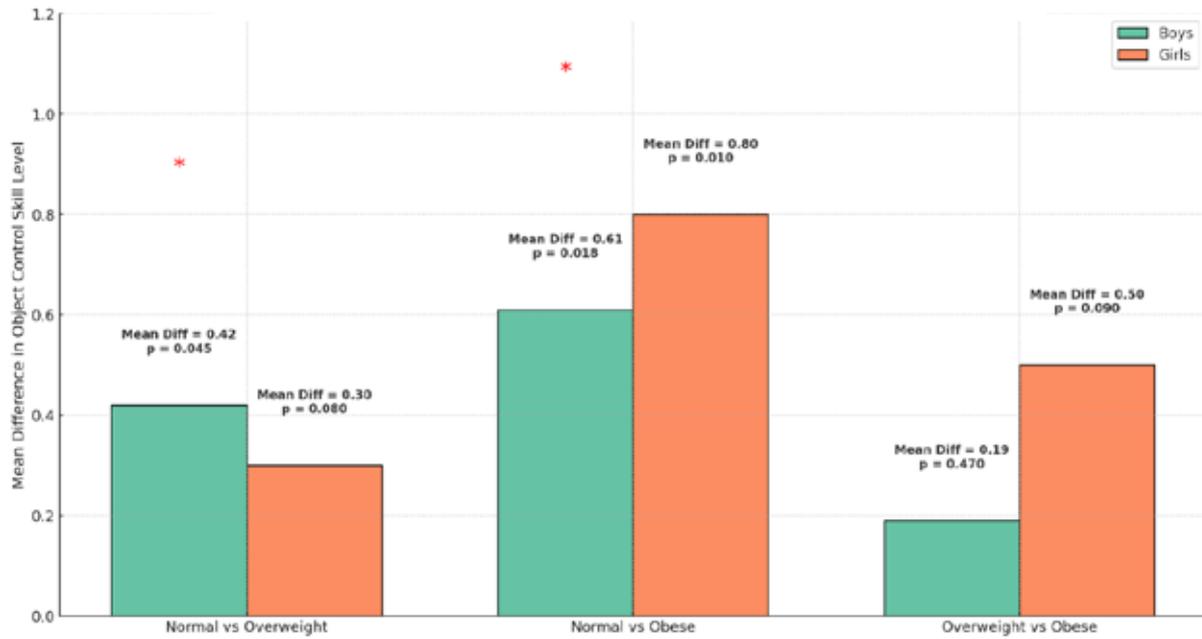


**Figure 3.** Locomotor Skill Performance by BMI Category and Gender

**Table 4.** Intragender Differences in Object Control Skill Level by BMI Category

Dependent Variable	(I) BMI	(J) BMI	Mean Difference (I-J)	Standard Error	p-value
Object Control Level (Boys)	Normal	Overweight	0.420	0.190	0.045*
	Normal	Obese	0.610	0.230	0.018*
	Overweight	Obese	0.190	0.260	0.470
Object Control Level (Girls)	Normal	Overweight	0.300	0.170	0.080
	Normal	Obese	0.800	0.270	0.010*
	Overweight	Obese	0.500	0.290	0.090

Significant at  $p \leq 0.05$

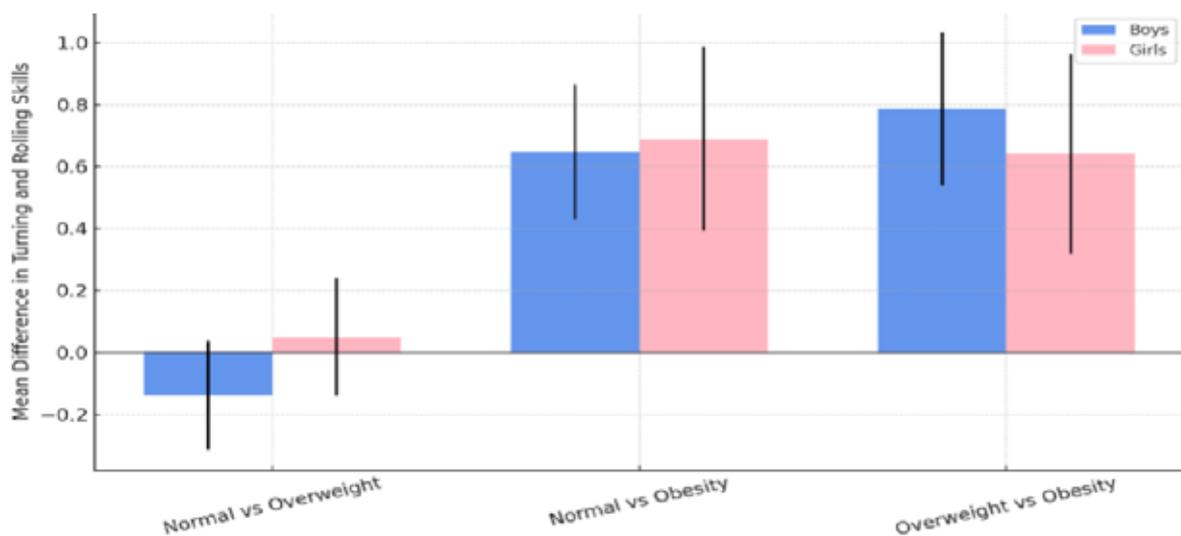


**Figure 4.** Intragender Differences in Object Control Skill Levels Across BMI Categories

**Table 5.** Intragender Differences in Turning and Rolling Skill Level by BMI Category

Dependent Variable	(I) BMI	(J) BMI	Mean Difference (I-J)	Standard Error	p-value
Turning and Rolling (Boys)	Normal	Overweight	-0.125	0.172	0.710
	Normal	Obesity	0.620	0.210	0.019*
	Overweight	Obesity	0.745	0.243	0.011*
Turning and Rolling (Girls)	Normal	Overweight	0.058	0.188	0.942
	Normal	Obesity	0.675	0.289	0.072
	Overweight	Obesity	0.595	0.312	0.148

Significant at  $p \leq 0.05$



**Figure 5.** Intragender Differences in Turning and Rolling Skill Levels Across BMI Categories

Among girls, none of the comparisons reached statistical significance, although a marginal trend was observed between the normal-weight and obese categories. Overall, the data suggest that BMI has a more pronounced impact on motor coordination

in boys than in girls, particularly in tasks requiring postural control and whole-body movement, such as turning and rolling.

As illustrated in Figure 5, obese boys performed significantly worse in turning and rolling skills

compared to their normal-weight peers. Among girls, although a decline in performance was observed with increasing BMI, the differences did not reach statistical significance.

Among girls, although obese participants demonstrated lower average performance in turning and rolling skills, no statistically significant differences were observed between BMI groups ( $p > 0.05$ ). This indicates a non-significant trend, suggesting that excess body weight may negatively affect performance, though not to a statistically detectable extent within this sample.

In contrast, boys exhibited significant differences in performance across BMI categories. Boys with normal weight significantly outperformed their obese peers ( $p = 0.014$ ), and a statistically significant difference was also found between the overweight and obese groups ( $p = 0.008$ ). These findings suggest that increasing levels of excess weight are associated with progressively reduced performance in turning and rolling tasks among boys.

## Discussion

The primary aim of this study was to examine the influence of gender and body mass index (BMI) on motor competence among school-aged children. The results revealed that BMI significantly affected motor performance, particularly among boys, with higher weight status associated with lower proficiency in locomotor, object control, and turning and rolling skills. In contrast, girls showed less pronounced and mostly non-significant differences across BMI categories. Gender differences were also observed in physical activity patterns and sport preferences, reinforcing the multifactorial nature of motor development.

Basic motor skills such as running, jumping, turning, and object control are fundamental actions common to all individuals and are essential for the development of more complex motor abilities [12, 13, 44]. These skills evolve progressively throughout childhood, influenced by environmental factors and advancing from basic patterns to more structured and purposeful movements [5, 13, 16]. The findings of Fernández-García et al. [29] support the present study by confirming that both gender and weight status significantly affect motor competence in primary school children. Consistent with our results, their study reported that boys outperformed girls in object control tasks, while overweight boys demonstrated reduced performance in locomotor and turning skills. These similarities reinforce the case for targeted interventions that address specific subgroups.

In line with previous research, boys in our sample exhibited overall higher motor competence compared to girls [12, 45, 46]. This trend may be partly explained by differing levels of engagement in physical activity. A greater proportion of girls in our

study reported no participation in extracurricular sports, which is consistent with earlier studies highlighting lower physical activity levels among girls [46, 47]. Additionally, object control skills appeared to be a domain with marked gender differences, where boys significantly outperformed girls. This observation supports findings reported in prior studies [45, 48].

Our results are further corroborated by international research from the United States, Spain, Japan, and Australia, all of which identified superior performance among boys in object manipulation tasks such as throwing and catching [40, 48, 49].

A clear pattern also emerged in sport preferences, with boys favoring team-based sports such as football and basketball, while girls showed a preference for individual activities such as yoga and dance. This discrepancy may reflect gender-based differences in motivation and socialization within the context of sport. As noted by previous research [50], understanding the underlying factors that influence children's sport participation preferences is essential for promoting inclusive and engaging physical education environments.

The relationship between weight status and motor competence was clearly evident in our results. Children with obesity performed significantly worse than their normal-weight peers in several motor tasks, particularly those involving locomotor actions. These findings support previous studies that associate excess body weight with mechanical limitations and reduced movement efficiency [20, 51, 52]. Our observations, especially the reduced performance of obese children in tasks requiring stride-based movement, suggest that biomechanical constraints in the lower limbs may hinder motor execution [53, 54].

Tasks that involved obstacle negotiation and motor planning appeared especially challenging for overweight and obese participants, possibly due to diminished joint mobility and reduced motor control. These difficulties are consistent with findings indicating impaired knee flexion and altered postural adaptation in overweight children during movement tasks [55]. This may reflect a compensatory strategy aimed at increasing stability by limiting the range of joint articulation [55, 56].

Locomotor skills such as running, jumping, and hopping show mixed findings in the literature. Some studies report that boys tend to perform better in these tasks, particularly with respect to speed and power, while girls may perform better in activities requiring precision and control [57]. However, other studies have found no significant gender differences in locomotor performance, suggesting that these skills may be less sensitive to gender-specific influences [58, 59].

Regarding object control, the results revealed particularly low competence levels among obese

girls. This deficit may be attributed to limited exposure to developmentally appropriate physical experiences during early childhood, which are critical for the refinement of coordination-based skills such as throwing and catching [60, 61]. Object control relies not only on physical attributes such as strength and direction but also on precise eye-hand coordination, a component likely diminished in children with low physical literacy and sedentary behavioral patterns.

Lastly, the analysis of turning and rolling skills revealed generally low proficiency among both boys and girls, with the lowest performance observed in children classified as overweight or obese. Although the literature on the specific association between turning and rolling abilities and BMI is limited, our findings suggest that these motor actions, which require dynamic balance, core strength, and body orientation control, are negatively influenced by excess body weight. Body Mass Index (BMI) has been shown to significantly affect motor competence in school-aged children. Higher BMI levels are frequently associated with reduced motor competence, particularly in tasks that demand coordination, balance, and object control [62, 63]. Previous studies have demonstrated that balance-focused interventions can improve dynamic stability, thereby supporting the need for targeted programs aimed at enhancing motor competence in children. The relationship between BMI and motor competence may also be influenced by gender [64]. Some studies have reported that the negative impact of elevated BMI on motor performance is more pronounced in girls than in boys. For instance, research using the TGMD-2 test found that girls with higher BMI levels performed significantly worse in both locomotor and manipulative skills compared to boys with similar BMI levels [65, 66]. Furthermore, the findings of [67] reinforce the present results by confirming consistent strength-assessment accuracy among girls aged 10 to 12, which aligns with our observation of relatively stable motor competence across BMI categories in girls.

These findings indicate that gender-specific interventions may be necessary to address the motor competence challenges experienced by children with higher BMI levels. Biomechanical adaptations, such as reduced knee flexion aimed at lowering the center of gravity, may inadvertently limit the fluidity and accuracy required for effective execution of motor tasks.

#### *Study Limitations and Future Directions*

Several limitations should be acknowledged when interpreting the findings of this study. First, the cross-sectional design does not allow for causal inferences between BMI, gender, and motor competence. Longitudinal studies are needed to

determine the direction and stability of these relationships over time.

Second, the study sample was geographically limited to urban schools in Mumbai, which may reduce the generalizability of the results to rural populations or different cultural contexts. Future research should aim to include more diverse populations across regions and socioeconomic backgrounds.

Third, motor competence was assessed using an observational scale based on binary scoring, which, while practical and reliable, may lack the sensitivity to detect subtle qualitative differences in movement execution. Incorporating biomechanical analysis tools or motion capture systems in future studies could provide a more detailed understanding of movement patterns and compensatory strategies, particularly in children with obesity.

Finally, self-reported physical activity data may be subject to bias or inaccuracy. Future studies should consider using objective activity monitors to improve the validity of physical activity measurements.

Despite these limitations, the findings highlight important gender- and BMI-related disparities in motor competence and support the need for tailored interventions. Future research should explore the effectiveness of school-based motor skills programs that are adapted to children's weight status and gender-specific needs.

## **Conclusions**

This study highlights the influence of gender and weight status on fundamental motor skills among school-aged children in Mumbai. While boys and girls demonstrated comparable abilities in locomotor and turning/rolling tasks, boys showed significantly higher competence in object control skills. Girls, particularly those classified as obese, exhibited the lowest performance in this domain.

Intragender analysis revealed that boys with normal BMI outperformed their overweight and obese peers in both locomotor and turning skills. Among girls, weight status primarily affected object control performance. These findings emphasize the need for early identification of motor skill deficits and targeted interventions, especially for children with excess weight.

The results also highlight gender-specific patterns in sport participation and preferences, reinforcing the importance of inclusive physical activity programs that address diverse developmental needs. Enhancing access to quality movement experiences during the primary school years may contribute to the development of core motor competencies and foster healthier, more active lifestyles.

Furthermore, gender differences in motor competence were evident, with boys generally excelling in object control tasks, and girls more

often demonstrating strengths in fine motor activities. BMI emerged as a significant factor, with higher levels associated with reduced motor competence, particularly in skills requiring balance and coordination. Collectively, these findings underscore the importance of promoting physical activity and healthy lifestyle behaviors to support motor development in school-aged children.

### Suggestions

Based on the findings of this study, several key recommendations are proposed. First, it is essential to implement targeted motor skill programs by developing and integrating specialized interventions that enhance object control and locomotor skills, particularly for overweight and obese children. Second, promoting gender-inclusive physical activities is recommended through the design of physical education curricula that offer a diverse range of options, including both team-based sports and individual exercises, to reflect and support gender-specific preferences. Finally, early screening and continuous monitoring of motor competence should be adopted in school settings to

identify at-risk children. Timely and individualized interventions should be provided to ensure sustained motor development and the promotion of healthy movement patterns.

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### Conflict of Interest

The authors declare that there are no conflicts of interest related to this study.

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#### Information about the authors:

**Sandeep Kumar**; Professor; <https://orcid.org/0000-0002-0925-159X>; sandeepchaudhary317@gmail.com; Department of Physical Education, Swami Vivekanand Subharti University; Subhartipuram, India.

**Yajuvendra Singh Rajpoot**; Associate Professor; <https://orcid.org/0000-0002-0331-705X>; yajupitu25@gmail.com; Department of Sports Management and Coaching, Lakshmibai National Institute of Physical Education; Gwalior, India.

**Krishna Kant Sahu**; Associate Professor; <https://orcid.org/0000-0001-5694-0382>; krishnalnipe@gmail.com; Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education; Gwalior, India.

**Bhanu Pratap**; Assistant Professor; <https://orcid.org/0009-0006-9318-3783>; bhanu.dohila27@gmail.com; Department of Physical Education, Lovely Professional University; Punjab, India.

**Suchishrava Choudhary**; (Corresponding author); PhD; <https://orcid.org/0000-0001-7491-5404>; suchishrava05@gmail.com; Department of Sports Psychology, Lakshmibai National Institute of Physical Education; Gwalior, India.

**Prashant Kumar Choudhary**; Assistant Professor; <https://orcid.org/0000-0001-6163-8065>; prashantlnipe2014@gmail.com; Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education; Gwalior, India.

**Nripender Hooda**; Master Degree; <https://orcid.org/0009-0009-7200-5947>; nripenderhoodalt@gmail.com; Department of Sports Science, International Institute of Sports and Management, University of Mumbai; Mumbai, India.

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## Declarative and procedural tactical knowledge in youth soccer players: an exploratory study in Chile

Ricardo Souza de Carvalho<sup>1ABDE</sup>, Eugenio Merellano-Navarro<sup>1CDE</sup>, Manuel González-Farías<sup>2,3BCE</sup>, Jorge Mendez-Cornejo<sup>1BCE</sup>, Alejandro Almonacid-Fierro<sup>1ABDE</sup>

<sup>1</sup> Department of Physical Activity Sciences, Faculty of Education Sciences, Universidad Católica del Maule, Chile

<sup>2</sup> Instituto Nacional del Fútbol (INAF), Chile

<sup>3</sup> Club de Deportes Cobresal, Chile

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### Abstract

**Background and Study Aim** Tactical knowledge, both declarative and procedural, is an essential component of cognitive development in youth soccer. The aim of this study is to describe and analyze the declarative and procedural tactical knowledge of youth football players from a professional club in southern Chile.

**Material and Methods** The Soccer Offensive Tactical Knowledge Test and Procedural Tactical Knowledge Test were the instruments used in the study to assess declarative tactical knowledge (game principles and decision making) and procedural knowledge (execution based on the tactical strategy in a 3x3 reduced-field). Assessments of functional differences could be evaluated due to the representation of players from various positions in the sample.

**Results** The results indicated superior performance in off-ball procedural skills (JSB:  $4.19 \pm 1.64$ ) but poor performance in off-ball marking (MJSB:  $3.56 \pm 2.09$ ), illustrating limitations in defensive anticipation and positional reading. Defenders performed better than midfielders and forwards in all procedural dimensions ( $p < 0.05$ ), indicating an internalization of tactics in a functional way according to their positional roles. At the declarative level, operational principles-based knowledge among the participants was found to be relatively higher ( $8.57 \pm 2.63$ ), while decision making was found to be lower in this study ( $5.94 \pm 2.28$ ), indicating a deviation from theory to practical execution. No significant differences were found by position in this type of knowledge.

**Conclusions** The finding of a partial dissociation between declarative and procedural learning, as confirmed earlier in related work, has implications for the methodological design of coaching at the U13 and U14 levels. It indicates why emergent-based methodologies that support the interweaving of tactical thought and action to enable adjusted and effective learning in grassroots football are urgently needed.

**Keywords:** grassroots football, declarative tactical knowledge, procedural tactical knowledge, teaching, learning, coaching.

### Introduction

Tactical knowledge is a crucial component of player development in modern football. At the core of such knowledge are cognitive aspects of performance, including players' ability to interpret, anticipate, and respond to dynamic game situations. In this context, each stage of player development presents specific training characteristics aligned with age-related developmental indicators.

Grassroots football serves as the foundation of the sport, nurturing talent development, promoting social inclusion, and fostering community engagement [1, 2]. Research highlights that teaching and learning methodologies focused on tactical skill development enable players to effectively apply their technical abilities under match conditions. This underscores the necessity of a game-situation-

based teaching approach, often referred to as the active method, which places tactical reasoning and decision making at the core of the learning process [3, 4].

Within this framework, tactical decision making in sports requires athletes to assess what action to take, why it is necessary, how to execute it, when to apply it, and where to position themselves. Ultimately, they must determine the most suitable technical skill to resolve a given task or challenge within the dynamic context of the game [5].

In team sports pedagogy, the development of tactical knowledge is a priority for coaching staff, serving as a cornerstone in youth football training, especially during the early stages of competitive development [3]. Mastery of tactical principles not only enhances players' ability to interpret game demands but also equips them to respond effectively in complex scenarios. In grassroots football, tactical knowledge is considered a fundamental component for fostering adaptive decision making, integrating

both theoretical understanding and practical execution [6].

The literature distinguishes between two types of knowledge: declarative knowledge and procedural knowledge [7, 8]. Declarative tactical knowledge is verbalized through an understanding of player positions and basic defensive and offensive strategies. In sport, this knowledge reflects an athlete's ability to recognize what to do in a specific game situation [9, 10]. On the other hand, procedural tactical knowledge is demonstrated through actions requiring advanced motor skills and is defined by an understanding of how to perform specific movements. As procedural knowledge involves the execution of motor actions, it necessitates complex cognitive processing for effective implementation, making it inherently more intricate than declarative knowledge [11, 12, 13].

In team sports, players who exhibit strong technical ability (such as ball control and refined skills) often struggle with tactical decision making during interactions with opponents. This difficulty may stem from an incomplete transfer of declarative knowledge to the procedural level or the inability to apply knowledge in the correct context, leading to tactical inefficiencies and a lack of game awareness [14, 15]. Sports science research has consistently shown that experienced players possess more structured strategic, declarative, and procedural knowledge, reinforcing the importance of integrating cognitive and motor components in player development [16, 17, 18].

Research suggests that procedural knowledge is a more complex process, encompassing not only the selection of an action but also its execution through a specific technique or technical skill [13, 19, 20]. In team sports, procedural knowledge is directly linked to problem-solving responses in training and match scenarios. Given the unpredictable and adaptive nature of these games, a high level of procedural proficiency is essential for developing effective motor responses to game situations in sports like football [21].

In the instruction and training of grassroots football, many players face difficulties in translating declarative knowledge into effective tactical execution [3]. This gap between knowing and doing presents a critical challenge for coaching staff, highlighting the need for integrated learning approaches.

The analysis of research findings indicates that the development and application of tactical knowledge play a pivotal role in the cognitive and motor performance of youth football players. The authors emphasize the importance of distinguishing between declarative and procedural knowledge and highlight how these forms of knowledge interact within real-game contexts. Furthermore, attention is drawn to the role of

integrated training methodologies that foster both theoretical understanding and practical execution. Nevertheless, despite numerous existing studies, there remains a pressing need for more in-depth research that explores the mechanisms underpinning the transfer of knowledge to effective in-game decision making and tactical execution.

The aim of this study is to describe and analyze the declarative and procedural tactical knowledge of youth football players from a professional club in southern Chile.

## Materials and Methods

### *Participants*

The study examined a sample of 41 athletes aged 13 to 14 years. A single cross-sectional design was conducted in Talca, in the Maule Region of Chile. A non-probabilistic sample was selected from a population of U13 and U14 soccer players. The exclusion criteria for the study included: a) lack of affiliation with the club in the U13 and U14 categories; b) presence of an injury preventing completion of the physical tests; c) absence on the day the instruments were administered; and d) refusal of consent by the player's parents or guardians. The final sample consisted of 41 players who completed both assessments.

Participation was voluntary. Parents or guardians were informed about the study's objectives, procedures, and potential risks and benefits during a meeting at the club. Written informed consent was required for participation, in accordance with the 1964 Declaration of Helsinki and its subsequent updates. The research was approved by the Scientific Ethics Committee of the Universidad Católica del Maule, under document Act 139-2024.

### *Research Design*

#### *Instruments*

To assess Procedural Tactical Knowledge (PTK), the 3x3 Procedural Tactical Knowledge Test proposed by Castro et al. [22] was utilized. The test involves a 3x3 situation performed with the feet to measure the frequency or absence of tactical behaviors during gameplay in game-like or competition-like scenarios. It includes three attackers and three defenders (numbered from 1 to 3, with different colors for each team) playing for four consecutive minutes on a 9x9 square meter field, aiming to maintain possession of the ball. A video camera is positioned in one corner of the field at a height of 1.5 meters, capturing the entire field in focus. A GoPro Hero 11 camera was used for this study. The tests were conducted in the afternoon under clear, well-lit conditions. All recordings took place at the same time on different days, using the same natural grass pitch to ensure consistent environmental conditions.

Defenders can anticipate, intercept, or take the ball from the attacking player. If the defender successfully regains possession, their team transitions to the offensive role. To incentivize defensive efforts, the number of successful interceptions is counted in the same way as the number of passes exchanged. Upon the restart of play (first pass), defenders must refrain from touching the ball and maintain a “statue” position, with arms outstretched beside the body and hands fixed to their sides.

Consistent with previous studies [7, 10, 13], this research presents the overall results for the team under study. However, individual player performance is also documented, allowing for analysis focused on either team dynamics or individual contributions. To evaluate Declarative Tactical Knowledge (DTK), the Soccer Offensive Tactical Knowledge Test proposed by Rechenchosky et al. [23] was administered. This assessment consists of a 15-question multiple-choice questionnaire divided into two sections. The first part contains direct questions assessing general knowledge of offensive actions in the game and its rules.

The second section of the test focuses on tactical problem solving, with responses based on images illustrating offensive game scenarios. Tactical knowledge is assessed across four dimensions: operational tactical principles, collective tactical-technical elements, rules, and decision making. In this study, the test was administered individually in a designated room equipped with chairs, clipboards, questionnaires, and pens. Data collection began with an introduction to the research team and study objectives, followed by participant orientation and completion of the instrument. There was no time limit for the athletes to complete the test. Both tests were selected based on their development and application within cultural contexts similar to the Chilean reality, as evidenced by their inclusion in published research within this field.

*Statistical analysis*

Statistical analysis was conducted using IBM SPSS® version 24. Sample characteristics were described using means ± standard deviation for continuous variables and frequency distributions for categorical variables. The Kolmogorov–Smirnov test was applied to assess normality. Differences between playing positions and categories were examined using the Student’s t-test. Additionally, correlations between numerical variables were analyzed using Pearson’s correlation coefficient, with adjustments for the covariate category in which the player competes. The Shapiro–Wilk test was also used to assess the normality of the sample, while Levene’s test verified the homogeneity of variances. No significant differences were observed between the variances of the compared groups ( $p >$

0.05). Differences based on playing positions and categories were analyzed using the Student’s t-test.

**Results**

Table 1 presents the general characteristics of the players in the U13 and U14 categories. Although the players in both categories show similar anthropometric profiles, minor variations in height and BMI suggest differences consistent with age-related development stages. Notably, players in the U14 group tend to have slightly more experience, which may reflect their longer involvement in structured training environments. These descriptive patterns provide context for interpreting the tactical knowledge results presented in subsequent analyses.

**Table 1.** Player characteristics

Variable	U13 (n = 22)	U14 (n = 19)
Age	13.38	14.27
Height (cm)	166.02	164.15
Weight (kg)	58.48	59.23
BMI (kg/m <sup>2</sup> )	20.85	20.49
Years of experience	6	7

Note. BMI: body mass index

Table 2 summarizes the team and individual scores for each dimension of Procedural Tactical Knowledge.

From the results presented in Table 2, it is evident that players performed better in scenarios involving off-ball movement without direct marking pressure. This may reflect a higher level of spatial awareness and anticipation when players are not constrained by immediate defensive engagement. In contrast, performance decreased in situations where players were required to act with the ball or while being marked, suggesting that decision making and execution under pressure remain areas for development. The distribution of scores across the different roles indicates a consistent trend: players appear more tactically effective in unmarked, off-ball contexts compared to marked or ball-involved situations.

Table 3 presents the individual scores for each dimension of Declarative Tactical Knowledge among the 41 participants. The results indicate that players demonstrated a stronger understanding of conceptual and theoretical frameworks related to tactical principles, suggesting effective internalization of key strategic ideas. In contrast, lower performance in the decision-making dimension may reflect a gap between theoretical knowledge and its application in dynamic game scenarios. This discrepancy points to the need for instructional methods that promote contextualized learning and applied cognitive processing during

play. The moderate results in rule-based and practical knowledge areas suggest an opportunity to reinforce foundational concepts in tandem with situational decision training.

Table 4 presents the levels of tactical performance and declarative tactical knowledge of players according to their playing position (forward, midfielder, defender).

The results reveal that defenders consistently outperformed forwards and midfielders in all dimensions of procedural tactical knowledge, with statistically significant differences observed in all categories ( $p < 0.05$ ). This suggests that defenders possess more developed tactical behaviors, particularly in situations involving both on- and off-ball responsibilities, likely due to the demands of their role in game dynamics.

In contrast, no statistically significant differences were found between playing positions in any of the declarative tactical knowledge dimensions. This indicates a relatively uniform level of theoretical

understanding across positions, suggesting that differences in practical execution are not due to disparities in knowledge but possibly to positional demands or situational experience on the field.

## Discussion

The aim of this study was to describe and analyze the levels of declarative and procedural tactical knowledge among youth football players from a professional club in southern Chile. The findings revealed that players demonstrated higher performance in procedural dimensions related to off-ball situations, particularly among defenders, who outperformed their peers across all tactical tasks. In contrast, while declarative tactical knowledge was generally well developed across all players, no significant differences were observed between positions, indicating a shared theoretical understanding regardless of on-field role.

The results of this study provide valuable insights into the procedural and declarative tactical

**Table 2.** Level of Team and Individual Procedural Tactical Knowledge

Performance Dimension	Global Score (Mean $\pm$ SD)	Individual Score (Mean $\pm$ SD)
Performance at JSB	187.25 $\pm$ 2.89	4.19 $\pm$ 1.64
Performance at JCB	163.25 $\pm$ 2.62	3.60 $\pm$ 1.77
Performance at MJSB	162.50 $\pm$ 3.49	3.56 $\pm$ 2.09
Performance at MJCB	184.25 $\pm$ 3.26	4.05 $\pm$ 1.98

Note. JSB - player without the ball; JCB - player with the ball; MJCB - player with the ball marker; MJSB - player without the ball marker.

**Table 3.** Individual Declarative Tactical Knowledge

Dimension	Mean $\pm$ SD
Practical Knowledge	6.36 $\pm$ 2.22
Operational Tactical Principles	8.57 $\pm$ 2.63
Operational Tactical Elements	7.58 $\pm$ 2.52
Rules	6.35 $\pm$ 2.44
Decision Making	5.94 $\pm$ 2.28

**Table 4.** Level of Tactical Performance and Declarative Tactical Knowledge of Players Based on Playing Position

Dimension	Forward (n = 13)	Midfielder (n = 14)	Defender (n = 14)	p-value
Performance at JSB	3.50 $\pm$ 0.89	3.41 $\pm$ 0.90	5.41 $\pm$ 1.84	0.00
Performance at JCB	2.75 $\pm$ 0.89	2.86 $\pm$ 1.08	4.93 $\pm$ 1.94	0.00
Performance at MJSB	2.61 $\pm$ 1.21	2.61 $\pm$ 1.26	5.15 $\pm$ 2.28	0.00
Performance at MJCB	3.48 $\pm$ 1.95	3.04 $\pm$ 0.90	5.46 $\pm$ 1.95	0.01
Practical Knowledge	5.94 $\pm$ 1.79	6.61 $\pm$ 2.21	7.01 $\pm$ 2.22	0.55
Operational Tactical Principles	8.53 $\pm$ 2.87	8.79 $\pm$ 1.87	8.93 $\pm$ 2.47	0.95
Operational Tactical Elements	7.46 $\pm$ 2.03	8.24 $\pm$ 1.87	7.98 $\pm$ 2.51	0.73
Rules	5.87 $\pm$ 2.06	6.34 $\pm$ 2.48	7.19 $\pm$ 2.34	0.39
Decision Making	5.44 $\pm$ 1.84	6.20 $\pm$ 2.42	6.59 $\pm$ 2.28	0.53

Note. JSB - player without the ball; JCB - player with the ball; MJCB - player with the ball marker; MJSB - player without the ball marker.

knowledge of young soccer players in the U13 and U14 categories of a Chilean professional club. This research not only corroborates findings from previous international literature [8, 13] but also highlights the importance of considering both “on-game” and “in-game” knowledge to deepen the understanding of cognitive-tactical development in grassroots football.

In terms of Procedural Tactical Knowledge, the 3x3 format assessment revealed stronger competence in off-ball performance (JSB:  $4.19 \pm 1.64$ ) compared to lower performance in off-ball marking situations (MJSB:  $3.56 \pm 2.09$ ). This trend aligns with Cardoso et al. [19], who suggest that tasks involving game reading and defensive decision making out of possession demand higher cognitive complexity and advanced anticipatory skills. These findings suggest potential gaps in current training methodologies. Defensive tactical intelligence without the ball may not be sufficiently prioritized, possibly due to an overemphasis on technical and tactical aspects related to ball possession.

However, Santos et al. [24] present a different perspective. Their findings suggest that small-sided games enhance consistency in player positioning both with and without the ball. These results highlight how spatial awareness, including player spacing and proximity to goals, is influenced by variations in technical skills that stem from diverse learning experiences.

Looking at specific positions, the data reveal significant differences across all aspects of procedural tactical knowledge ( $p < 0.01$ ), with defenders demonstrating a stronger understanding than midfielders and forwards. These findings suggest a connection between a player’s role within the team structure and the extent to which tactical behaviors are internalized. This perspective is consistent with the views of Sarmiento et al. [4] and Aquino et al. [11], who argue that specialization in a tactical role influences the quality of motor decisions made during play. Trained players, particularly experienced defenders, appear to be more attuned to these tactical demands, which may contribute to their effectiveness. Regarding declarative tactical knowledge, participants performed better in operational tactical principles and lower in the decision-making dimension. This disparity may indicate a gap between theoretical understanding of the game and its application in context-dependent situations.

The observed disconnection between a general understanding of game principles and the ability to apply them effectively in decision-making processes warrants attention. Gaviria Alzate et al. [20] and García-Ceberino et al. [15] highlight the distinction between conceptual knowledge, which involves understanding what actions to take, and the nuanced ability to execute those actions appropriately in

specific contexts. The lack of significant positional differences in declarative knowledge indicators, contrasted with disparities in procedural knowledge, reinforces the idea that declarative knowledge is less dependent on direct situational experience. Instead, it appears to be more closely associated with formal or explicit instructional methods [9].

One of the key contributions of this study is the empirical evidence supporting the partial dissociation between declarative tactical knowledge and procedural tactical knowledge. These findings reinforce the arguments of López et al. [14] and de Castro Júnior et al. [7], who suggest that the development of tactical knowledge is neither linear nor homogeneous. Simply understanding rules and principles does not guarantee effective execution on the field, which underscores important implications for training methodologies. Consequently, integrating both levels of knowledge in a situated, dynamic, and contextually relevant manner is essential [5, 25].

Acknowledging the methodological and pedagogical implications of this study, the findings advocate for training paradigms grounded in authentic game scenarios, exemplified by the situational method. This approach supports the simultaneous development of tactical acumen and technical proficiency within ecologically valid contexts. Consequently, practitioners are encouraged to critically reassess the prevalent reliance on decontextualized analytical drills and instead prioritize learning environments that cultivate advanced tactical reasoning, real-time problem-solving skills, and post-activity reflection as a metacognitive tool [3, 26]. This pedagogical shift aims to nurture players who possess a deep understanding of the game’s inherent logic while demonstrating adaptability to its dynamic demands. Accordingly, the design of training tasks should seek an optimal challenge point—one that fosters exploratory behavior and tactical innovation without inducing cognitive overload, which could hinder creative expression.

Gradually introducing more complex game situations, while carefully maintaining a balance that promotes player autonomy and informed decision making, appears to be a more effective developmental strategy in foundational football programs. In contrast, research by Matos et al. [10] highlights significant variance in tactical performance, based on underlying game principles, which is contingent upon players’ specific field positions. These findings reinforce the need for tactical instruction that is carefully contextualized to the unique demands of each role. A well-founded understanding of tactical training principles, grounded in the logic of the game, can enhance both coaches’ and players’ ability to anticipate individual actions within the broader team dynamic.

Among the primary limitations of this study are the relatively small sample size and its confinement to a single club, which inherently restrict the generalizability of the findings. Furthermore, the cross-sectional nature of the research design precludes an exploration of longitudinal developmental trajectories in tactical knowledge acquisition. Future research should therefore adopt a longitudinal perspective and integrate qualitative methodologies to gain deeper insights into players' cognitive schemata. Additionally, it is recommended that future studies validate the assessment instruments within the Chilean context and explore the interplay between tactical knowledge and technical, physical, and psychological performance across developmental stages.

## Conclusions

This study presents empirical evidence on the relationship between procedural and declarative tactical knowledge in young Chilean footballers (U13 and U14 cohorts). The results reveal a significant disparity: although players demonstrate

a basic understanding of game tactics, they struggle to apply this knowledge effectively in real match situations due to the dynamic pressures involved. This discrepancy is especially evident in off-ball defensive scenarios, where players must anticipate and respond under higher cognitive demands.

Integrating both types of knowledge within authentic and adaptive learning contexts is crucial for enhancing performance. Coaches and educators should create training environments that foster tactical reasoning, decisional autonomy, and the effective transfer of theoretical knowledge into practical execution. Targeted pedagogical strategies that address the gap between declarative ("knowing what") and procedural ("knowing how") knowledge are essential for developing tactically intelligent players capable of responding effectively to the dynamic nature of the game.

## Conflict of interests

The authors declare that there is no conflict of interests.

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### Information about the authors:

**Ricardo Souza de Carvalho**; <https://orcid.org/0000-0003-1715-9213>; [rsouza@ucm.cl](mailto:rsouza@ucm.cl); Department of Physical Activity Sciences, Faculty of Education Sciences, Universidad Católica del Maule; Talca, Chile.

**Eugenio Merellano-Navarro**; <https://orcid.org/0000-0002-1557-2285>; [emerellano@ucm.cl](mailto:emerellano@ucm.cl); Department of Physical Activity Sciences, Faculty of Education Sciences, Universidad Católica del Maule; Talca, Chile.

**Manuel González-Farías**; <https://orcid.org/0009-0005-6359-7814>; [mgonfarias@gmail.com](mailto:mgonfarias@gmail.com); Instituto Nacional del Fútbol (INAF); Santiago, Chile.

**Jorge Mendez-Cornejo**; <https://orcid.org/0000-0002-3925-170X>; [jmendez@ucm.cl](mailto:jmendez@ucm.cl); Club de Deportes Cobresal; Talca, Chile.

**Alejandro Almonacid-Fierro**; (Corresponding author); <https://orcid.org/0000-0002-8328-017X>; [aalmonacid@ucm.cl](mailto:aalmonacid@ucm.cl); Department of Physical Activity Sciences, Faculty of Education Sciences, Universidad Católica del Maule; Talca, Chile.

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## Specific features of cognitive skill development in athletes of situational sports

Vyacheslav Romanenko<sup>1ABCDE</sup>, Yrui Tropin<sup>1ABCD</sup>, Leonid Podrigalo<sup>1ACD</sup>, Natalya Boychenko<sup>1ABD</sup>, Anatoly Abdula<sup>1BCD</sup>, Nataliia Sereda<sup>1BCD</sup>, Yaroslav Yatsiv<sup>2CDE</sup>

<sup>1</sup>Kharkiv State Academy of Physical Culture, Ukraine

<sup>2</sup>Vasyl Stefanyk Precarpathian National University, Ukraine

Authors' Contributions: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript preparation; E – Funds Collection.

### Abstract

**Background and Study Aim** The formation of cognitive skills in athletes engaged in situational sports follows specific patterns determined by the characteristics of gameplay or competitive activity, as well as by the influence of psychophysiological and individual traits. An equally important factor in the development of cognitive skills is the training process, which incorporates specialized exercises and techniques aimed at stimulating cognitive processes, situational analysis, spatial imagination, and adaptive behavior. This study aimed to identify the peculiarities of cognitive skill formation in athletes participating in situational sports.

**Material and Methods** The study involved 97 participants, including 80 qualified male athletes with 5 to 9 years of training experience, representing three sports: football (n = 26, age 15.3 ± 0.49 years), judo (n = 31, age 16.6 ± 2.83 years), and taekwondo (n = 23, age 16.5 ± 1.90 years), and 17 boys (age 8.71 ± 1.16 years) who were not engaged in organized sports but expressed interest in doing so. Psychophysiological testing was conducted using tablet-based applications on iOS devices: the “Spatial Perception” test was used to assess spatial perception, and the “TestSTMemory” was used to evaluate short-term visual memory. Mathematical and statistical analyses were conducted using RStudio. Linear discriminant analysis was applied to differentiate athletes by sport. Wilks' Lambda was used to evaluate the quality of the discriminant model. Analysis of variance (ANOVA) was performed to identify variables with significant intergroup differences. The Kruskal–Wallis test was used to assess the reliability of differences between the studied groups.

**Results** The results of the short-term visual memory test indicate that the differences between the study groups, as assessed by the Kruskal–Wallis test, were not statistically significant (p > 0.05). In the spatial perception test, statistically significant differences were observed only at the fourth stage, in the percentage of errors (p-value = 0.01). The results of the discriminant analysis show that, when constructing a linear discriminant analysis (LDA) model with three classes (football, judo, taekwondo), two discriminant functions were identified, explaining 62% (LD1) and 38% (LD2) of the variance between the groups, respectively. The Wilks' Lambda = 0.455 indicates statistically significant differences between the groups (F = 1.611, p = 0.0295). Model testing confirmed high accuracy in classifying respondents according to their respective sports profiles: judo (0.88 ± 0.11) and football (0.98 ± 0.03).

**Conclusions** Situational sports, including team sports and martial arts, require athletes to demonstrate a high level of executive functions. The development of these functions follows specific patterns influenced by the nature of sports activity. The characteristics of short-term visual memory and spatial perception in football, judo, and taekwondo athletes were identified. Based on discriminant analysis of the psychophysiological testing results, a model with a predictive accuracy of 72.5% was developed, allowing for the classification of respondents into their respective sport groups (football, judo, taekwondo). Analysis of variance revealed that statistically significant differences between the groups are associated with indicators related to spatial perception. The findings confirm that spatial perception exhibits distinct features depending on the type of sport.

**Keywords:** psychophysiological indicators, cognitive skills, qualified athletes, children, judo, taekwondo, football.

### Introduction

The modern sports environment is characterized by rapid development and increasing complexity of competitive activities, which demand of athletes

not only physical, technical, and tactical excellence, but also a high level of psychophysiological skill development [1, 2]. The study of psychophysiological indicators has attracted considerable interest among researchers worldwide [3, 4]. The investigation of cognitive processes in situational sports is of particular relevance, as athletic performance largely depends on the ability to quickly perceive, analyze,

and interpret information in a constantly changing competitive context [5].

Situational sports, including team games and martial arts, are marked by a high degree of unpredictability and the necessity to make decisions under time pressure. In such conditions, cognitive skills such as attention, memory, perception, thinking, anticipation, and decision-making are critical for achieving effective athletic performance [6]. Athletes with well-developed cognitive abilities demonstrate superior decision-making and more adaptive, positive thinking [7, 8].

The scientific community is increasingly focusing on the cognitive component of athletes' preparedness. Several studies have investigated the mechanisms of visual information processing, cognitive flexibility, and stress resistance in athletes across various sports disciplines [9]. Research has also explored the impact of fatigue on athletes' perceptual and cognitive performance [10]. Other studies have assessed cognitive abilities in relation to age, anthropometric parameters, physical fitness, and technical skills in young athletes [11], as well as sports experience [12]. At the same time, the formation of cognitive skills in athletes engaged in situational sports follows specific patterns shaped by the nature of gameplay or competitive activity, as well as by the influence of psychophysiological and individual characteristics [13, 14].

An equally important factor in cognitive skill development is the training process, which incorporates specialized exercises and techniques aimed at stimulating cognitive functions, situational analysis, spatial imagination, and adaptive behavior [15, 16]. Modern technologies enhance this process through cognitively oriented training methods, including virtual and augmented reality, computer programs, and simulation training devices that replicate real-game scenarios [17].

Another critical aspect is the influence of individual psychological characteristics on the effectiveness of cognitive skill development [18, 19]. Researchers highlight the roles of motivation, personality traits, thinking styles, and prior sports experience as key determinants of cognitive development [20].

The study of the peculiarities of cognitive skill formation in situational sports contributes to a deeper understanding of the patterns governing cognitive functioning in athletes. It enables the identification of optimal pathways for cognitive development and the implementation of effective methods within the training process. These insights offer promising opportunities for enhancing the sports training system and improving athletes' competitiveness on the international stage.

*Purpose of the Study:* To identify the specific features of cognitive skill development in athletes engaged in situational sports.

## Material and Methods

### *Participants*

The study involved 97 participants, including 80 qualified male athletes with 5 to 9 years of training experience, representing three sports: football ( $n = 26$ , age  $15.3 \pm 0.49$  years), judo ( $n = 31$ , age  $16.6 \pm 2.83$  years), and taekwondo ( $n = 23$ , age  $16.5 \pm 1.90$  years). To test the developed model, data were also collected from 17 boys (age  $8.71 \pm 1.16$  years) who had not yet chosen a specific sport. All participants provided informed consent to take part in the study and were informed about its objectives, testing procedures, and their right to withdraw at any time without penalty. For underage participants, informed consent for psychophysiological testing was obtained from their parents, who were present during the assessment. At the time of the study, all participants were in good health. All procedures were carried out in accordance with fundamental bioethical principles, including the Council of Europe Convention on Human Rights and Biomedicine (04.04.1997), the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects (1964–2008), and the Order of the Ministry of Health of Ukraine No. 690 dated 23.09.2009.

### *Research Design*

Psychophysiological testing was conducted using specialized applications for mobile devices running iPadOS. Spatial perception was assessed using the "Spatial Perception" test, and short-term visual memory was evaluated using the "TestSTMemory" application. These tests have been validated in previous studies [19, 21]. The spatial perception test consisted of four stages involving the rapid recognition of geometric shapes. In the first stage, participants were required to recognize two-dimensional objects (square, rhombus, hexagon, circle, triangle). The second stage involved the identification of static three-dimensional objects (cube, cylinder, sphere, hexagonal prism, octahedron). The third stage assessed the recognition of dynamic three-dimensional objects, and the fourth stage presented dynamic three-dimensional objects with visual distractors (Fig. 1). During the task, participants selected the appropriate response by tapping the screen. If the shapes were identical, they tapped "Same" (green circle); if the shapes differed, they tapped "Different" (red circle).

The computer program "TestSTMemory," designed to assess short-term visual memory, consisted of five stages, each comprising 10 trials (Fig. 2). In the first stage, participants were required to respond to a single monochromatic visual stimulus in the first five trials by memorizing its location and tapping the corresponding circle. In the subsequent five trials, they responded to



Figure 1. Interface of the computer program “Spatial Perception”

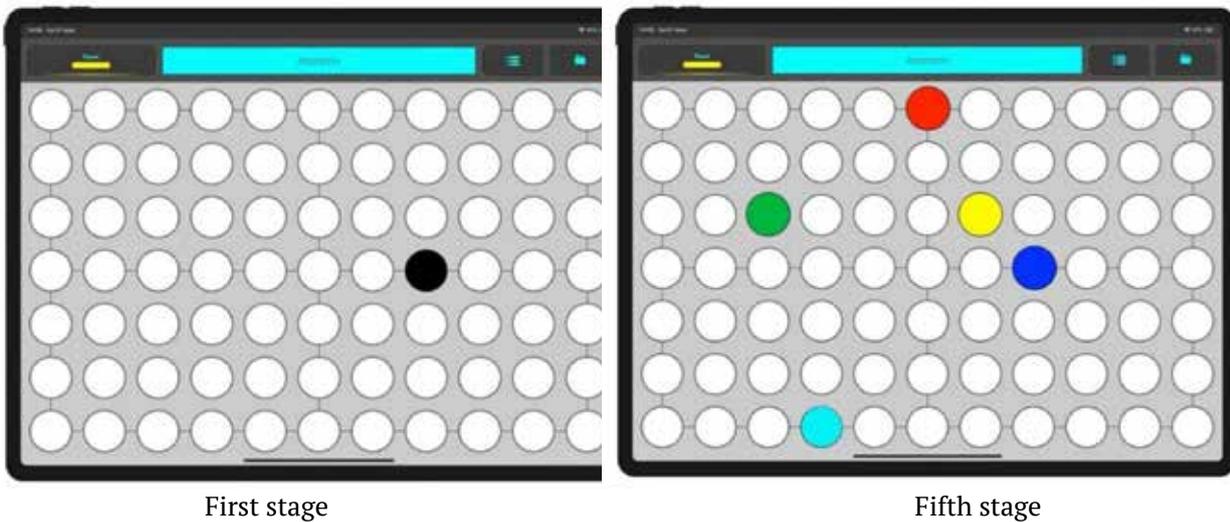


Figure 2. Interface of the computer program “TestSTMemory”

stimuli of different colors. At each following stage, the number of simultaneously presented stimuli increased by one. By the fifth stage, participants had to memorize the positions of five stimuli and tap the corresponding circles. To evaluate short-term visual memory, a memory coefficient was calculated as the ratio of correct responses to the total number of attempts. The duration of each visual stimulus was set at 300 ms.

#### Statistical analysis

Mathematical and statistical analyses were conducted using the RStudio software. To classify athletes into distinct groups based on their psychophysiological characteristics, linear discriminant analysis (LDA) was performed using the “MASS” package for discriminant analysis. To evaluate the model’s quality within a multivariate context, Wilks’ Lambda was calculated. The classification performance was assessed using key metrics: balanced accuracy, precision (positive predictive value), and recall (sensitivity), obtained via the *confusionMatrix()* function from the “caret”

package in R. To identify variables with statistically significant differences between groups, analysis of variance (ANOVA) was applied. The Kruskal–Wallis test was used to assess the reliability of differences across the study groups where assumptions of parametric testing were not met.

#### Results

Eighteen numerical variables characterizing the level of cognitive skill performance at various stages of the test exercises were selected as independent predictors for the discriminant analysis. These included reaction time, number of errors (from the spatial perception test), trial duration, and the short-term visual memory coefficient (from the short-term visual memory test) (Tables 1 and 2).

The nonparametric Kruskal–Wallis test was used to identify differences between the study groups. The results of the short-term visual memory test indicated that differences across all stages were not statistically significant ( $p > 0.05$ ). In contrast, the spatial perception test revealed statistically

significant differences only at the fourth stage, specifically in the percentage of errors ( $p = 0.01$ ). To determine which groups differed significantly, Dunn's test was performed (Table 3).

The results of the discriminant analysis indicate that, when constructing the LDA model with three classes (football, judo, taekwondo), two discriminant functions were identified, accounting for the variance between the groups: LD1 explained 62% and LD2 explained 38% of the total variation (Fig. 3).

Based on the values of the discrimination

coefficients, we identified the numerical variables that had the greatest influence on class separation. These variables primarily included trial duration (i.e., the time required by participants to reproduce the location of visual stimuli) in the short-term visual memory test. The most influential factor for LD1 was the trial duration at stage 4 (coefficient = 3.981). Trial duration at stage 1 significantly contributed to both LD1 (-1.447) and LD2 (-6.686). Trial durations at stages 5, 3, and 2 also played a notable role in the differentiation of classes in the LDA model. According to the trial duration values, athletes in the football

**Table 1.** Values of group means (test: "Spatial Perception")

Group	Err1, %	Err2, %	Err3, %	Err4, %	R1, ms	R2, ms	R3, ms	R4, ms
Football (n=26)	8.846	9.423	5.385	6.923	739.996	788.423	801.577	844.777
Judo (n=31)	7.419	7.419	5.161	3.065	768.187	806.494	805.529	835.874
Taekwondo (n=23)	8.478	8.478	5.000	7.609	690.770	721.530	753.626	771.117

Err1 - errors on the first stage; Err2 - errors on the second stage; Err3 - errors on the third stage; Err4 - errors on the fourth stage; R1 - reaction time on the first stage; R2 - reaction time on the second stage; R3 - reaction time on the third stage; R4 - reaction time on the fourth stage.

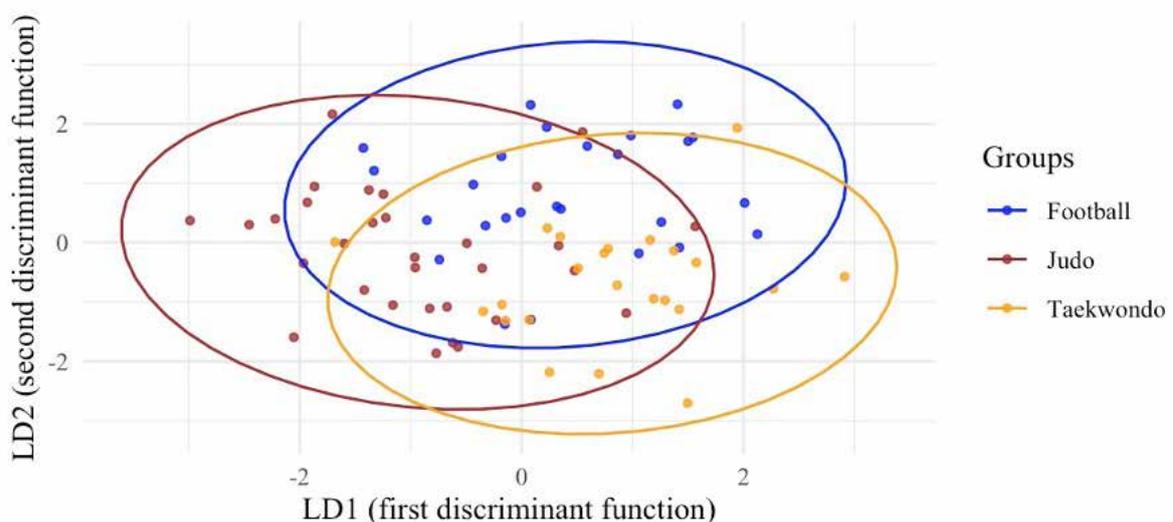
**Table 2.** Values of group means (test: "TestSTMMemory")

Group	D1, s	D2, s	D3, s	D4, s	D5, s	C1, %	C2, %	C3, %	C4, %	C5, %
Football (n=26)	0.648	1.009	1.373	1.753	2.160	99.615	98.654	93.4589	89.711	82.846
Judo (n=31)	0.681	1.027	1.422	1.838	2.346	99.032	98.226	93.768	85.726	81.097
Taekwondo (n=23)	0.701	1.056	1.456	1.909	2.305	100.000	97.608	94.343	88.370	82.087

D1 - duration of trial at the first stage; D2 - duration of trial at the second stage; D3 - duration of trial at the third stage; D4 - duration of trial at the fourth stage; D5 - duration of trial at the fifth stage; C1 - coefficient of short-term visual memory at the first stage; C2 - coefficient of short-term visual memory at the second stage; C3 - coefficient of short-term visual memory at the third stage; C4 - coefficient of short-term visual memory at the fourth stage; C5 - coefficient of short-term visual memory at the fifth stage.

**Table 3.** Differences between the groups (test: "Spatial Perception", stage 4, percentage of errors)

Comparison	Z-statistics	p-value
Judo vs Football	2.578	0.015
Taekwondo vs Judo	-2.626	0.013
Taekwondo vs Football	-0.130	1.000



**Figure 3.** Discriminant analysis: LD1 vs LD2

group demonstrated the shortest average response time (1.39 s) and the highest percentage of correct answers (92.9%). The taekwondo group showed the longest average duration (1.49 s) with a moderate accuracy rate (92.5%). The judo group recorded the lowest accuracy (91.6%) with an intermediate trial duration (1.46 s).

The discriminant analysis yielded a classification accuracy of 72.5%, indicating a satisfactory ability to distinguish among athletes from the three sports (football, judo, taekwondo) (table 4). Specifically, 16 out of 26 observations (61.5%) were correctly classified in the football group, 25 out of 31 (80.6%) in the judo group, and 17 out of 23 (73.9%) in the taekwondo group. The Wilks' Lambda value = 0.455 ( $F = 1.611, p = 0.0295$ ) indicates statistically significant differences among the groups, suggesting that the model reliably distinguishes between the athlete groups based on the selected predictors, especially between judo and taekwondo, where balanced accuracy exceeded 0.8 (Fig. 4).

According to the results of the analysis of variance, statistically significant differences between the studied groups were found in the

indicators reflecting athletes' levels of spatial perception (Table 5).

The model (LDA) was tested using indicators of psychophysiological measurements of children ( $n = 17$ ) who had not yet chosen a sport for regular training (Fig. 4).

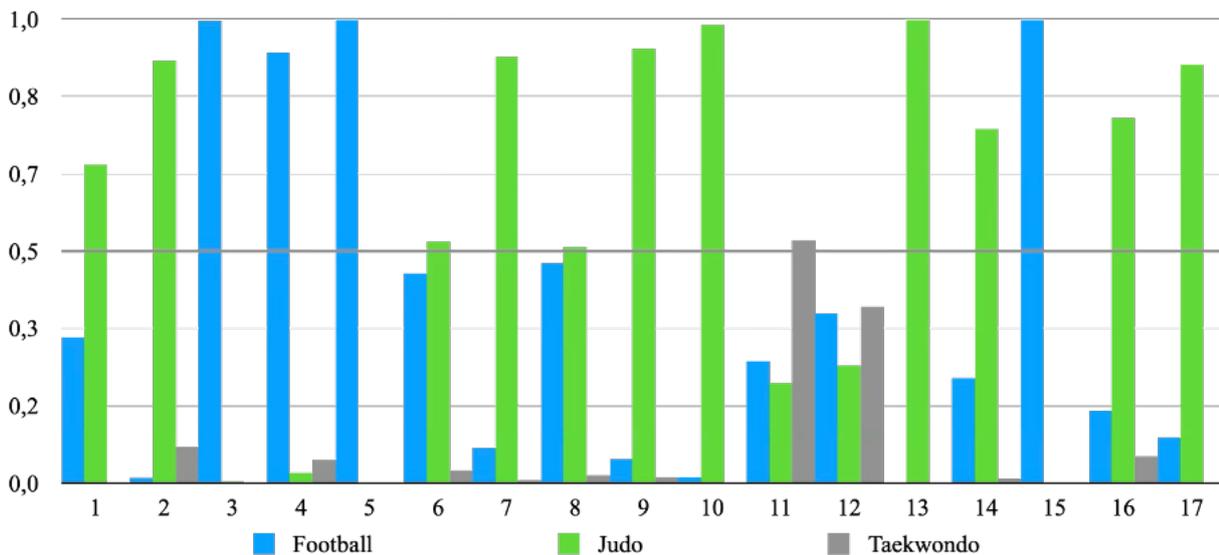
The analysis of predictive classification results indicates that several children (1, 2, 7, 9, 10, 13, 14, 16, 17) exhibit cognitive characteristics closely aligned with the judo profile (mean probability =  $0.88 \pm 0.11$ ). Children 3, 4, 5, and 15 correspond to the football profile (mean probability =  $0.98 \pm 0.03$ ). Children 6 and 8 display mixed characteristics, falling between the football and judo profiles. Meanwhile, children 11 and 12 partially match the taekwondo profile. The classification results suggest that none of the tested children exhibited a clear predisposition toward the taekwondo profile.

### Discussion

Situational sports, encompassing both martial arts and team sports, demand that athletes rapidly analyze evolving competitive contexts, make decisions in real time, and adapt their behavior to

**Table 4.** Model performance (confusion matrix)

Class	Balanced Accuracy	Precision (Pos Pred)	Recall (Sensitivity)
Football	0.743	0.696	0.615
Judo	0.822	0.758	0.807
Taekwondo	0.808	0.708	0.739



**Figure 4.** Prediction of class affiliation (n=17)

**Table 5.** Variations between classes (Analysis of Variance - ANOVA)

Indicators	Sum Sq	Mean Sq	F value	P-value
Reaction time on the first stage «Spatial Perception»	79538	39769	3.300	0.042
Reaction time on the fourth stage«Spatial Perception»	78730	39365	3.332	0.041
Errors on the fourth stage «Spatial Perception»	337.60	168.78	6.244	0.003

unpredictable conditions [1, 10]. Success in these sports depends on a high level of perceptual–intellectual and emotional–volitional capabilities, enabling effective performance amid dynamic environments [5, 22]. Core characteristics of situational sports include dynamic competitive conditions [4, 23, 24], elevated cognitive demands [9, 13], strong moral and volitional qualities [20, 25], and a creative approach to problem-solving [17, 26].

The study of cognitive skills provides insight into the mechanisms and characteristics of visual information processing among athletes from different sports disciplines [5, 10]. Research has established associations between cognitive functions, skill acquisition, and athletic performance [6]. According to [7], highly skilled athletes demonstrate a higher level of cognitive functioning compared to those with lower qualifications. However, their findings also suggest limited evidence supporting the predictive value of general executive functions for future sports performance. Executive functions constitute a broad category encompassing various cognitive abilities [27]. Evidence indicates that different sports may influence these functions in distinct ways [32]. Current research suggests that improvements in executive functioning are largely dependent on the motor demands specific to each sport [29, 30]. Sports such as martial arts and team games engage athletes in complex cognitive activities, including perception, attention, planning, strategy development, adjustment to changing conditions, continuous adaptation, and real-time decision-making [31]. Actions in these sports are performed in dynamic and unpredictable environments, fostering the development of cognitive functions such as attention, perception, and short-term visual memory [32, 33]. Further studies [34] have reported a strong correlation between participation in sports like basketball, martial arts, and football and higher mathematics achievement. This association is likely linked to the enhancement of spatial abilities, which contribute to mathematical problem-solving. However, the authors did not observe a significant effect on literacy outcomes among the participants, suggesting that these sports-related cognitive benefits are less relevant to the executive functions involved in reading and language processing.

This study used specialized computer programs for mobile devices running iPadOS. These programs were designed to assess short-term visual memory and spatial perception in martial artists. The test tasks within these programs create conditions that impose a cognitive load comparable to that of a sports match. For example, in the short-term visual memory test, participants must not only memorize the location of visual signals of the same color (black or monochrome circles of varying intensity) but also process signals of different colors, which requires additional cognitive effort [21]. The

spatial perception test includes a task that involves quickly recognizing rotating 3D geometric shapes and responding accordingly. Another task requires recognizing 3D geometric shapes presented against a background of distracting visual stimuli. Such test tasks demand increased attention and concentration from the respondent and, as visual load increases, require a balance of nervous processes that supports rapid decision-making [19].

As noted in the results of the study, statistically significant differences ( $p$ -value = 0.01) between the study groups were found only in the percentage of errors on the fourth, most difficult stage of the “Spatial Perception” test. The lowest percentage of errors was shown by judokas (3.07%), the highest by representatives of the taekwondo group (7.61%), and an average percentage was shown by football players (6.92%). Moreover, taekwondo athletes demonstrated the best reaction time at this stage (771.1 ms), which is due to the specific demands of their activity, requiring rapid reactions during technical and tactical actions under active opponent pressure. A reduced reaction time affects the ability to cognitively process information, which decreases the accuracy of actions and increases the likelihood of errors [35]. The lower error rate among judokas may be due to the fact that, compared to other combat sports such as boxing or taekwondo, judo emphasizes the principles of “maximum efficiency, minimum effort” and “mutual benefit and prosperity.” It has been noted that these principles can translate into cognitive benefits such as better impulse control, stress resistance, and an improved ability to make complex decisions [36].

For the discriminant analysis, 18 numerical variables were selected to characterize the level of cognitive skills of athletes. According to the results of the study, the numerical variable that most strongly influenced class separation was the duration of trials (i.e., the time spent by the respondent on reproducing the locations of visual stimuli) in the short-term visual memory test. The duration of the trial depends on the pace of the test exercise chosen by the subject. Each athlete selects a comfortable pace that allows them to retain the locations of visual stimuli in memory and respond accordingly. The duration of attempts also depends on the accuracy of clicking on the presented circles. Inaccurate clicking increases trial duration, while clicking on mismatched circles reduces the short-term visual memory coefficient. These indicators reflect the specific characteristics of visual information retention and the corresponding motor actions of the tested athletes. In the “TestSTMemory” test, the shortest trial duration (1.39 s) and the highest percentage of correct answers (92.9%) were shown by football players. Taekwondo athletes showed the longest trial duration (1.49 s) and a slightly lower accuracy rate (92.5%), while judo athletes had an

average trial duration and the lowest percentage of correct answers (91.6%). A sufficiently high pace in completing the test task allowed football players to achieve the best result at the most difficult, fifth stage of the test (82.8%) compared to representatives of other sports. The authors of [13, 37] noted that elite football players demonstrate excellent perceptual and cognitive abilities. They show higher performance in tracking multiple objects compared to less skilled and younger athletes. In soccer, players operate on a large field where events unfold at a considerable distance. This provides slightly more time for decision-making compared to martial arts. However, the challenge lies in processing a large volume of information, such as the positions of teammates and opponents, ball trajectory, tactical schemes, and so on. This demands a high level of cognitive processing and decision-making in constantly changing situations [38].

The results of the analysis of variance indicate that athletes from different sports exhibit distinct characteristics in spatial perception. In the "Spatial Perception" test, football players demonstrated an average recognition time for geometric shapes of 793.7 ms and a relatively high error rate of 7.6%. Taekwondo athletes achieved the shortest recognition time (734.3 ms) and a moderate error rate (7.4%). Judokas exhibited the longest recognition time (804.0 ms) but the lowest error rate (5.8%).

The nature of striking martial arts, such as taekwondo, requires athletes to respond rapidly under conditions of continuous threat from an opponent's attacks (punches, kicks), often at close distances. This constant exposure to dynamic, high-stakes situations necessitates ongoing analysis of visual information. Competitive bouts stimulate targeted behavioral responses, which in turn foster improvements in cognitive functions such as visual selective attention, verbal working memory, and reaction time [39]. As noted in [19], martial artists employ a variety of strategies to recognize opponents' movements, with peripheral vision playing a critical role during matches [40]. Skilled athletes are believed to outperform non-athletes in processing and interpreting visual cues, drawing upon sport-specific perceptual strategies developed over the course of their training and competitive experience [41, 42].

Studies on reaction speed in judo reveal that response time is positively correlated with training experience [43]. Experienced judokas display reduced reaction times due to enhancements in both sensory latency and motor response [44]. This improvement is likely attributable to their adaptation to specialized training tasks, which reduce cognitive load and enhance attentional focus [45]. A unique feature of grappling sports such as judo is the emphasis on physical contact, where tactile feedback plays a prominent role. Tactile

information is processed differently in the brain compared to visual or auditory stimuli. As a result, experienced judokas may possess superior tactile perception abilities relative to athletes in visually or acoustically dominant sports [43].

The results of the study show that the accuracy of the model created based on discriminant analysis was 72.5%. The model reliably distinguishes between groups, especially judokas and taekwondo athletes (Table 4). This model can be used for selecting children for a particular sport. The use of discriminant analysis in sports selection is supported by numerous studies demonstrating its high accuracy in classifying athletes by sport [46, 47, 48]. According to the analysis of psychophysiological indicators of boys (n = 17) who took part in testing the model, it is possible to recommend boys numbered 3, 4, 5, and 15 to try football (predicted probability: 98%). Boys numbered 1, 2, 7, 9, 10, 13, 14, 16, and 17 should be advised to join a judo section (predicted probability: 88%). The remaining children (numbers 6, 8, 11, and 12) exhibited mixed characteristics, so the model's predictive reliability for a particular sport was low (Fig. 4).

The results of the discriminant analysis require further research with larger samples to improve the accuracy of the model and its adaptation to different sports disciplines.

## Conclusions

Situational sports, which include team games and martial arts, require athletes to demonstrate a high level of executive functions. The formation of these functions occurs according to specific patterns influenced by the nature of sports activity. The peculiarities of short-term visual memory and spatial perception in football, judo, and taekwondo athletes have been identified. Based on the discriminant analysis of the psychophysiological testing results of the studied athletes, a model with a predictive reliability of 72.5% was created, which allows for the classification of respondents into the corresponding groups (football, judo, taekwondo). The analysis of variance made it possible to determine that statistically significant differences between the studied groups are found in indicators characterizing athletes' spatial perception. It has been shown that spatial perception exhibits specific features depending on the type of sport.

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## Conflict of Interest

The authors declare no conflict of interest.

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### Information about the authors:

**Vyacheslav Romanenko**; Phd (Physical Education and Sport), Associate Professor; <https://orcid.org/0000-0002-3878-0861>; [slavaromash@gmail.com](mailto:slavaromash@gmail.com); Department of Martial Arts, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

**Yrui Tropin**; Phd (Physical Education and Sport), Associate Professor; <https://orcid.org/0000-0002-6691-2470>; [tropin.yurij@gmail.com](mailto:tropin.yurij@gmail.com); Department of Martial Arts, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

**Leonid Podrigalo**; (Corresponding author); Professor; <https://orcid.org/0000-0002-7893-524X>; [leonid.podrigalo@gmail.com](mailto:leonid.podrigalo@gmail.com); Department of Sport Medicine and Gygiene, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

**Natalya Boychenko**; Phd (Physical Education and Sport), Associate Professor; <https://orcid.org/0000-0003-4821-5900>; [natalya-meg@ukr.net](mailto:natalya-meg@ukr.net); Department of Martial Arts, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

**Anatoly Abdula**; Phd (Physical Education and Sport), Associate Professor; <https://orcid.org/0000-0002-3832-3716>; [anatoliy.ab12@gmail.com](mailto:anatoliy.ab12@gmail.com); Department of Football and Hockey, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

**Nataliia Sereda**; Phd (Physical Education and Sport), Associate Professor; <https://orcid.org/0000-0002-8320-3000>; [sereda\\_nataliya86@ukr.net](mailto:sereda_nataliya86@ukr.net); Department of Physical Education Management, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

**Yaroslav Yatsiv**; Phd (Physical Education and Sport), Associate Professor; <https://orcid.org/0000-0003-2474-0401>; [yatsiv64@gmail.com](mailto:yatsiv64@gmail.com); Faculty of Physical Education and Sports, Vasyl Stefanyk Precarpathian National University; Ivano-Frankivsk, Ukraine.

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## The effect of animal movement exercises on improving upper and lower body muscles in children with down syndrome

Muhammad Asrul Sidik<sup>1ABDE</sup>, Adi Pranoto<sup>1,2BCD</sup>, Fransisca Januarumi Marhaendra Wijaya<sup>1BD</sup>, I Made Sri Undy Mahardika<sup>1BD</sup>, Andri Suyoko<sup>1BD</sup>, Bayu Agung Pramono<sup>1BCD</sup>, Achmad Rizanul Wahyudi<sup>1BD</sup>, Mohammad Faruk<sup>1BD</sup>, Nuril Sri Wulandari<sup>1BD</sup>, Bekir Erhan Orhan<sup>3CD</sup>

<sup>1</sup>Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya, Indonesia

<sup>2</sup>Sport and Exercise Research Center, Universitas Negeri Surabaya, Indonesia

<sup>3</sup>Faculty of Sports Sciences, Istanbul Aydin University, Turkey

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

### Abstract

**Background and Study Aim** Exercise is crucial for individuals with Down syndrome (DS) as it significantly enhances their physical fitness, motor skills, and overall well-being. Therefore, the aim of this study is to evaluate the effects of animal movement exercises on upper and lower body muscle strength in children with Down syndrome.

**Material and Methods** This study used a pre-experimental one-group pretest-posttest design. It involved twelve male participants with Down syndrome, aged seven to fourteen years (mean age: 10.25 ± 2.31 years). They received an animal movement exercise intervention over six weeks, with a frequency of three sessions per week. Each session lasted one hour and included a warm-up, main activity phase, and cool-down. Exercises were performed at moderate intensity (60–70% HRmax), and heart rate was monitored using the Polar H10 device. Leg muscle strength, grip strength, coordination, and balance were assessed at baseline (pre) and after six weeks (post). Statistical analysis was conducted using the paired sample t-test with a 5% significance level.

**Results** The results showed a significant increase in leg muscle strength (kg) between baseline and post-intervention ( $p = 0.000$ ; ES = 0.955; 95% CI: -2.83, -1.84). Grip strength (kg) also increased significantly ( $p = 0.000$ ; ES = 1.169; 95% CI: -3.34, -2.49). Coordination (repetitions) showed improvement ( $p = 0.000$ ; ES = 1.404; 95% CI: -3.08, -2.25). Balance (seconds) increased as well ( $p = 0.000$ ; ES = 0.715; 95% CI: -2.71, -1.13).

**Conclusions** Animal movement exercises represent a developmentally appropriate and engaging form of physical activity for children with Down syndrome. Their playful, functional nature aligns well with inclusive approaches to therapy and education, and they may offer practical value in diverse settings, including those with limited resources.

**Keywords:** animal movement exercises, down syndrome, upper body muscle, lower body muscle

### Introduction

Down syndrome (DS) is a genetic condition commonly associated with characteristic physical and cognitive challenges. These include muscle hypotonia, reduced strength, and impaired motor coordination. Such limitations can negatively affect mobility, postural control, and participation in daily activities. Therefore, exercise is not only beneficial but also essential for promoting functional independence and improving the overall well-being of individuals with DS.

A growing body of research supports the implementation of targeted exercise interventions to address motor deficits in individuals with Down syndrome. Strength training, in particular,

has been shown to produce positive outcomes in muscle development and motor skills. Kashi et al. [1] demonstrated that structured physical exercise improved upper-limb strength and coordination. Raharjo et al. [2] reported significant increases in hand muscle strength following a range of motion training program. Gupta et al. [3] further highlighted the combined benefits of strength and balance exercises in enhancing both muscle capacity and postural stability in individuals with DS.

Beyond traditional modalities, recent attention has shifted to more dynamic and engaging approaches that appeal to younger populations or individuals with lower motivation thresholds. One such approach is animal movement exercises (AMEs), which are inspired by the natural locomotion patterns of animals such as frogs, bears, crabs, and ducks. These movements require coordinated actions across multiple joints and muscle groups, making them inherently full-body exercises. AMEs

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are designed to be both playful and purposeful, combining functional fitness with imaginative play. This dual focus may be especially beneficial for individuals with DS, who often respond more positively to activities presented in an enjoyable and familiar context.

Despite anecdotal reports and their increasing use in occupational and physical therapy, empirical research on the impact of animal movement exercises (AMEs) in individuals with Down syndrome remains limited. Most existing studies focus on conventional training programs. This leaves a significant gap in the literature regarding alternative, play-based modalities that may offer similar or even greater benefits.

Supporting evidence for diverse forms of exercise is steadily growing. Puspitosari [4] showed that general physical activity interventions improved balance performance. Gupta et al. [3] confirmed that well-designed programs combining strength and balance components significantly enhanced motor function. Modesto et al. [8] reported improvements in both upper and lower limb strength following a 12-week intervention among young individuals with Down syndrome. These results highlight the cumulative effects of regular and targeted training. In addition, the findings of Raharjo [2] emphasized that even short-term programs, when implemented consistently, can contribute to measurable strength gains.

From a physiological standpoint, muscle weakness in individuals with Down syndrome has been associated with impaired muscle regeneration due to dysfunctional muscle stem cell activity [6]. This makes long-term strength-building programs not only beneficial but also necessary. Saquette et al. [7] provided evidence that non-traditional training methods, such as whole-body vibration, can enhance both muscle function and bone density. Furthermore, accessibility plays a key role in exercise adherence. Community-based programs, as observed by Shields et al. [9], have successfully increased participation rates and physical strength in individuals with Down syndrome. These findings suggest that engaging and socially inclusive interventions hold particular promise.

An analysis of existing studies has shown that various forms of physical exercise positively influence motor function, strength, and balance in individuals with Down syndrome. The authors highlight the importance of structured, goal-oriented interventions and point to the potential benefits of non-traditional, play-based approaches such as animal movement exercises. Despite these findings, there remains a clear need for more in-depth investigation into the specific effects of such alternative methods.

Therefore, the aim of this study is to evaluate the effects of animal movement exercises on upper and

lower body muscle strength in children with Down syndrome.

## Materials and Methods

### *Participants*

This study used a pre-experimental one-group pretest-posttest design. It involved twelve male children with Down syndrome, aged between seven and fourteen years. Anthropometric data such as body weight, height, and Body Mass Index (BMI) were recorded but are presented separately in the results section. The calculation of the required sample size was conducted using the Higgins–Kleinbaum formula, based on reference values from previous similar studies, resulting in a minimum sample size of twelve participants.

### *Study Design*

In this study, a structured animal movement exercise (AME) protocol was used as the intervention program. AMEs are a form of functional movement training that mimic the natural locomotion patterns of animals. They are designed to improve strength, mobility, coordination, and balance. The following is a general outline of the protocol, which can be adjusted according to age, fitness level, or specific training objectives:

1. *Bear Crawl*. Crawling on hands and feet while keeping the hips low and the core engaged. This exercise improves coordination, strength, and stability in the core, shoulders, and legs.
2. *Frog Jumps*. Starting from a squat position, the participant jumps forward with hands touching the floor, landing softly. This movement enhances lower body strength, explosiveness, and coordination.
3. *Crab Walk*. Sitting on the floor with knees bent and feet flat, the participant places hands behind the body and walks forward or backward using both hands and feet while keeping the torso elevated. This exercise improves upper body strength, coordination, and core stability.
4. *Duck Walk*. The participant squats low, lifts the heels, and walks forward while maintaining the squat position. This targets the lower body, especially the quadriceps, and improves balance.
5. *Kangaroo Jumps*. Performing repeated two-footed jumps forward and backward, landing softly. This develops lower body strength, agility, and power.

All participants completed a six-week AME intervention, with training sessions held three times per week. Each session lasted one hour and included a warm-up, main exercise phase, and cool-down. The warm-up and cool-down periods each lasted five minutes and were performed at light intensity (50% HRmax). Exercise intensity during the sessions was maintained at a moderate level

(60–70% HRmax) and was monitored using the Polar Heart Rate Monitor H10.

*Data collection*

Assessments of upper and lower body muscles, including leg muscle strength, grip muscle strength, coordination, and balance, were conducted at baseline (pre) and after six weeks (post). A leg dynamometer was used to measure leg muscle strength, while a hand dynamometer was used to assess grip muscle strength. Coordination was evaluated using a ball tossing and catching test. Balance was measured through a standardized balancing test.

*Statistical analysis*

The normality of the data was tested using the Shapiro–Wilk test. Differences between pre- and post-intervention values for leg muscle strength, grip muscle strength, coordination, and balance were analyzed using a parametric paired sample t-test with a significance level of 5%. The effect size was evaluated using Cohen’s *d*. Data are presented as mean ± standard deviation (SD).

**Results**

The characteristics of the research subjects are presented in Table 1. The study included twelve male children with Down syndrome, aged between seven and fourteen years. As shown in the table, participants displayed considerable variability in anthropometric parameters such as body height, weight, and Body Mass Index (BMI). On average, the group was within a healthy BMI range for their age, though individual values reflected a broad spectrum of physical development. This diversity underscores the importance of tailoring physical interventions to accommodate differing body compositions and growth stages among children with Down syndrome.

**Table 1.** Characteristics of research subjects

Parameters	n	Minimum	Maximum	Mean	Std. Deviation
Age, yrs	12	7.00	14.00	10.25	2.31
Body height, m	12	0.93	1.47	1.17	0.37
Body weight, kg	12	13.10	38.50	25.72	7.91
Body mass index, kg/m <sup>2</sup>	12	14.10	18.15	16.12	1.50

**Table 2.** Assessment of upper body and lower body muscles baseline (pre) and 6 weeks (post)

Parameters	n	Animal Movement Exercises		95% CI	p-value	ES
		Pretest	Posttest			
Leg muscle strength (kg)	12	8.83±2.37	11.17±2.52*	-2.83, -1.84	0.000	0.955
Grip muscle strength (kg)	12	7.75±2.34	10.67±2.64*	-3.34, -2.49	0.000	1.169
Coordination (repetitions)	12	3.67±1.72	6.33±2.06*	-3.08, -2.25	0.000	1.404
Balance (seconds)	12	5.58±2.24	7.50±3.06*	-2.71, -1.13	0.000	0.715

Note: CI - Confidence interval; ES = Effect size. \*Significant difference from baseline (pre) at  $p \leq 0.001$ . Data are presented as mean ± standard deviation (SD). *p*-values were calculated using the paired sample *t*-test.

Assessments of upper and lower body muscle strength at baseline (pre) and after six weeks (post) are presented in Table 2. The results indicate significant improvements following the animal movement exercise intervention. Leg muscle strength (kg) increased significantly from baseline to post-intervention ( $p = 0.000$ ;  $ES = 0.955$ ). Grip muscle strength (kg) also showed a significant increase between baseline and six weeks ( $p = 0.000$ ;  $ES = 1.169$ ). Similarly, coordination (repetitions) improved significantly over the intervention period ( $p = 0.000$ ;  $ES = 1.404$ ). Balance (seconds) also increased significantly after six weeks of training ( $p = 0.000$ ;  $ES = 0.715$ ). As shown in Table 2, the effect sizes for all parameters ranged from moderate to large, suggesting that animal movement exercises had a substantial impact on muscular strength, coordination, and balance in children with Down syndrome.

**Discussion**

The present study aimed to evaluate whether animal movement exercises (AMEs) could serve as a practical and engaging strategy to improve motor performance in individuals with Down syndrome. The findings suggest positive changes in strength, coordination, and balance over the six-week intervention period. These outcomes are generally consistent with previous studies that support the role of structured physical activity in this population [11, 12, 13]. However, unlike prior interventions that rely on conventional gym-based routines or specialized therapy settings, AMEs offer a flexible and imaginative alternative that mimics natural animal movements. This approach may enhance participation and enjoyment, particularly among younger individuals.

Individuals with Down syndrome typically face

challenges such as hypotonia, which can lead to reduced muscle strength and impaired balance [14, 15]. In this study, participants demonstrated increases in leg muscle strength (from 8.83 kg to 11.17 kg), grip strength (from 7.75 kg to 10.67 kg), and coordination scores (from 3.67 to 6.33 repetitions). These statistically significant improvements reflect meaningful gains in functional performance. Notably, the effect sizes for coordination (1.404) and grip strength (1.169) are considered large. In clinical contexts, such effect sizes are relatively uncommon in short-term interventions, which may highlight the motivational and integrative potential of AMEs.

Nevertheless, these outcomes should be interpreted with caution. External factors such as participant motivation, facilitator support, natural growth, or unrecorded physical activity may have contributed to the observed improvements. Moreover, the absence of a control group limits the ability to attribute changes solely to the intervention.

Regular physical activity is essential not only for enhancing muscle strength but also for promoting overall health and reducing the risk of obesity, which is prevalent among individuals with Down syndrome [4, 16, 17, 18]. Balance, a fundamental component of daily mobility and independence, also improved in this study, with static balance time increasing from 5.58 to 7.50 seconds. This change is particularly relevant given the elevated risk of falls associated with postural instability in individuals with Down syndrome [12, 19]. Similar improvements have been reported in structured programs that specifically target balance and motor control [20, 21].

Several previous studies support the broader finding that physical interventions can improve motor capabilities among individuals with Down syndrome. Moraes et al. [22] found that hippotherapy significantly improved postural balance, dynamic balance, and functional task performance, reinforcing the therapeutic value of sensorimotor activities. Piñar-Lara et al. [23], in a systematic review and meta-analysis, demonstrated that virtual reality-based therapy significantly enhances balance and muscular endurance in children and adolescents with Down syndrome. Kolibylu Raghupathy et al. [24] reported that traditional Indian dance forms such as Bharatanatyam led to improvements in locomotor skills and balance. Similarly, McGuire et al. [25] observed that adapted dance programs enhanced motor abilities and increased participation.

These studies emphasize the importance of engaging, structured, movement-based interventions. However, most require specialized equipment, trained facilitators, or controlled environments. In contrast, animal movement exercises (AMEs) represent a low-cost, accessible, and playful alternative that can be implemented in schools or community settings without the need

for sophisticated tools. Rather than proposing an entirely new paradigm, the present study contributes by contextualizing established motor-play approaches into a format that is practical, adaptable, and developmentally aligned with children's natural movement tendencies.

The practical implications of these findings are particularly relevant in low-resource environments. The imaginative and dynamic nature of animal movement exercises (AMEs) may foster motivation and consistency, which are critical factors for success in pediatric therapy. By integrating functional training with playful elements, AMEs offer a holistic and enjoyable motor experience that may support not only physical outcomes but also emotional engagement.

#### *Study Limitations*

However, several limitations of this study must be acknowledged. The small sample size limits the generalizability of the findings, and the absence of a control or comparison group reduces internal validity and prevents causal interpretation. Although the study was exploratory in nature, future research should employ more rigorous designs to confirm these results. In addition, the relatively short duration of the intervention and the lack of follow-up assessments limit the ability to draw conclusions about the long-term sustainability of the observed improvements. The study also did not control for potential confounding variables such as home routines, nutritional status, emotional support, or unmonitored physical activity outside the intervention, all of which may have influenced the outcomes.

To build a stronger evidence base, future studies should employ randomized controlled trial designs with larger and more diverse samples. Longitudinal follow-ups would help assess the persistence of motor improvements over time. Incorporating qualitative methods, such as feedback from participants and caregivers, could provide deeper insights into the acceptability, motivation, and perceived benefits of animal movement exercises. Moreover, integrating AMEs into broader developmental programs that target cognitive, behavioral, or social skills may enhance their value as part of multidisciplinary intervention strategies for children with Down syndrome.

Overall, the findings of this study support the feasibility and effectiveness of animal movement exercises as a functional and engaging intervention for improving motor performance in children with Down syndrome. The observed improvements in strength, coordination, and balance suggest that such exercises may serve as a valuable component within pediatric motor development programs, particularly when implemented in accessible and child-friendly environments.

## Conclusions

This study highlights the potential of animal movement exercises (AMEs) as a developmentally appropriate and engaging physical activity strategy for children with Down syndrome. As a playful and adaptable approach, AMEs align with inclusive education and therapy goals and may contribute meaningfully to multidisciplinary support programs aimed at improving functional outcomes and quality of life in this population.

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## Conflict of interest

The authors declare that they have no conflicts of interest.

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**Information about the authors:**

**Muhammad Asrul Sidik:** (Corresponding author); <https://orcid.org/0009-0004-4282-1007>; [muhammadsidik@unesa.ac.id](mailto:muhammadsidik@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Adi Pranoto:** <https://orcid.org/0000-0003-4080-9245>; [adipranoto@unesa.ac.id](mailto:adipranoto@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Fransisca Januarumi Marhaendra Wijaya:** <https://orcid.org/0000-0002-3417-1305>; [fransiscajanuarumi@unesa.ac.id](mailto:fransiscajanuarumi@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**I Made Sri Undy Mahardika:** <https://orcid.org/0000-0003-3280-513X>; [madeundy@unesa.ac.id](mailto:madeundy@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Andri Suyoko:** <https://orcid.org/0000-0001-6836-8731>; [andrisuyoko@unesa.ac.id](mailto:andrisuyoko@unesa.ac.id); Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Bayu Agung Pramono:** <https://orcid.org/0000-0002-9308-1289>; [bayupramono@unesa.ac.id](mailto:bayupramono@unesa.ac.id); Departemen of Sport Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Achmad Rizanul Wahyudi:** <https://orcid.org/0000-0002-3499-0941>; [achmadrizanul@unesa.ac.id](mailto:achmadrizanul@unesa.ac.id); Departemen of Sport Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Mohammad Faruk:** <https://orcid.org/0000-0001-6334-4298>; [mohammadfaruk@unesa.ac.id](mailto:mohammadfaruk@unesa.ac.id); Departemen of Sport Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Nuril Sri Wulandari:** <https://orcid.org/0009-0005-2609-5815>; [nuril.23356@mhs.unesa.ac.id](mailto:nuril.23356@mhs.unesa.ac.id); Departemen of Sport Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Jawa Timur, Indonesia.

**Bekir Erhan Orhan;** <https://orcid.org/0000-0002-3149-6630>; [bekirerhanorhan@aydin.edu.tr](mailto:bekirerhanorhan@aydin.edu.tr); Faculty of Sports Sciences, Istanbul Aydin University; Istanbul, Turkey.

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# The effect of core training on speed, agility, strength and jumping performance in 10-12 year old female badminton players

Muhammed Zahit Kahraman<sup>1ABCDE</sup>, Serkan Kızılcıca<sup>2ABDE</sup>

<sup>1</sup> Department of Coaching Education, Faculty of Sports Sciences, Bitlis Eren University, Turkey

<sup>2</sup> Department of Physical Education and Sports, Faculty of Sports Sciences, Bitlis Eren University, Turkey

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

## Abstract

### Background and Study Aim

Core training has gained prominence as a crucial component in improving athletic performance, particularly in sports that demand high levels of coordination, balance, and explosive power. Badminton, which requires rapid directional changes, agility, and lower-body strength, may particularly benefit from such training methods. The aim of this study is to determine the effects of a four-week core training program on speed, agility, strength and jumping performance in 10 to 12 year old female badminton players.

### Material and Methods

This study was designed as a pre-test-post-test control group experimental research using quantitative methods. Twenty-two female badminton athletes who participated voluntarily were randomly divided into an experimental group (n = 11) and a control group (n = 11). The experimental group performed a core training program twice a week for four weeks in addition to regular badminton training. The control group performed only regular badminton training during this period. Sprint tests (10 m and 20 m), T agility test, leg strength, hand grip strength, and countermovement jump (CMJ) tests were administered to all participants before and after the training period. The normality of the data was assessed using the Shapiro-Wilk test. Data with normal distribution were analyzed using repeated measures analysis of variance (ANOVA).

### Results

According to the findings, there were no significant differences between the pre-test values of the groups ( $p > 0.05$ ). Over time, significant improvements were observed in the T agility test ( $p = .047$ ;  $\eta^2 = .18$ ) and the CMJ test ( $p = .024$ ;  $\eta^2 = .23$ ). Both results indicated large effect sizes. No significant differences were observed in the 10 m and 20 m sprint, leg strength, or hand grip strength tests ( $p > 0.05$ ). Regarding the interaction between time and group, significant differences were again found in the T agility test ( $p = .045$ ;  $\eta^2 = .19$ ) and the CMJ test ( $p = .014$ ;  $\eta^2 = .26$ ), both indicating large effect sizes. No significant time  $\times$  group interactions were found for sprint, leg strength, or hand grip strength variables ( $p > 0.05$ ).

### Conclusions

The four-week core training program applied to youth female badminton players had positive effects on agility and jumping performance. Based on these results, incorporating core training into the routine practice of youth athletes is recommended to enhance agility and explosive power in sports that require rapid directional changes.

**Keywords:** badminton, speed, agility, strength, core training

## Introduction

Badminton is a popular sport played by approximately 200 million people worldwide in outdoor, garden, or beach environments [1]. Its widespread participation highlights the significance of this sport at both recreational and professional levels. Badminton players must perform fast and precise movements, including sudden changes of direction, jumping, and running under varying conditions. The successful performance of athletes directly depends on their physical fitness levels. Studies have shown that the abdominal muscles provide proximal stability for distal mobility [2]. Sports scientists are increasingly interested in using different training protocols to enhance athletic performance. To improve performance in badminton players, various training methods are

used to develop biomotor abilities, especially in sports where speed, agility, strength, and jumping are essential [3]. Core exercises, which have gained increasing attention from sports scientists in recent years, help develop basic balance in athletes and are applied to enhance overall performance [4]. Core training strengthens the muscle groups primarily responsible for maintaining trunk stability, enabling athletes to improve their balance, posture, and movement control [5].

Badminton is a sport played under physically demanding conditions and at a high level of competition, where athletes require advanced speed, agility, and explosive power. To succeed in this sport, athletes must make quick and timely movements while maintaining strong stability. One of the key factors contributing to success is a strong abdominal region [6]. Strength, speed, and agility are all essential in badminton. Given the influence

of core training on the development of these motor skills, it has become an increasingly important area of focus for researchers. Regular core training in children is known to support the development of basic motor skills and enhance overall performance [7]. Badminton players cover the entire court in a very short time, execute strokes, and return to the center. To reach the area where the opponent hits the shuttle and respond effectively, athletes must possess high levels of strength, speed, and agility. After making a stroke, it is crucial for athletes to return to position in a balanced, fast, and coordinated manner. The legs should be placed shoulder-width apart, and the body should remain oriented toward the opponent's court without swaying to either side. Badminton players must maintain strong stabilization [8].

The word "core" refers to the central part of something. In the human body, the core region is the central area that also contains the body's center of gravity [9]. Core exercises reduce the risk of injuries in the lower extremities and knee joints and help prevent their occurrence. Today, core training is widely used not only to enhance athletic performance but also to minimize injury risk in athletes, improve the physical fitness of sedentary individuals, and support the treatment of patients with back pain [10]. Studies have shown that athletes who include core exercises in their training programs experience improvements in balance, agility, and strength. Increased core strength enables more controlled movements and allows athletes to react more quickly to sudden changes in motion [11, 12]. It is believed that a strong core ensures that the forces generated by the lower extremities are efficiently transferred through the torso to the upper body. Conversely, a weak core may disrupt this energy transfer, reducing sports performance and increasing the risk of injury to distal limbs or underdeveloped muscle groups.

Analysis of previous research results has shown that core training plays a significant role in improving athletic performance by enhancing balance, agility, strength, and injury prevention. Researchers have emphasized the importance of a strong core in supporting the transfer of force between the lower and upper body segments. They also highlight the role of core stability in maintaining postural control and movement efficiency during sports activities. However, despite the growing number of studies on this topic, there remains a clear need for more in-depth investigations, particularly focusing on specific populations such as young athletes. Further research is needed to evaluate the effects of core training protocols on performance parameters in children, where developmental and physiological differences may lead to varied outcomes.

**Hypothesis:** Based on the analysis of previous research findings, it is hypothesized that a four-week core training program will significantly improve

speed, agility, muscular strength and jumping performance in 10 to 12 year old female badminton players.

The aim of this study is to determine the effects of a four-week core training program on speed, agility, strength and jumping performance in 10 to 12 year old female badminton players.

## **Materials and Methods**

### *Participants*

The study group consisted of 22 female badminton athletes aged 10 to 12 years with prior badminton experience in the Tatvan district of Bitlis province, Turkey, who voluntarily agreed to participate in the study. Block randomization was used to assign participants to groups in this pre-test–post-test control group experimental design. Since there were two groups, the block size was set at four, with two participants randomly allocated to each group within each block. A total of six blocks were created, resulting in an equal distribution of 11 participants in each group. To minimize bias, the randomization process was performed by an independent individual who was not part of the research team. Prior to the study, ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Bitlis Eren University (approval date: 02.01.2025; decision number: 16; protocol number: 2024/9). Additionally, the study was conducted in accordance with the Declaration of Helsinki.

### *Research Design*

General information about the study was provided to both the participating athletes and their parents. Detailed explanations were also given regarding the training program to be implemented and the data collection procedures. It was clearly communicated that participation in the study was voluntary, that there was no obligation to participate, and that only athletes who consented voluntarily would be included. A voluntary consent form was obtained from the participating athletes, and a parental consent form was signed by their parents. Athletes with chronic diseases, musculoskeletal injuries, or those requiring regular medication were excluded from the study. Considering the young age of the participants, both athletes and parents were instructed to ensure consistent sleep patterns, maintain regular eating habits, and refrain from using any ergogenic aids or stimulants during the study period. Additionally, during the data collection phase, participants were advised to avoid intense physical activity and abstain from caffeine consumption for 24 hours prior to testing. Alongside their regular badminton training, athletes in the experimental group participated in core strength training for four weeks, two days per week. The control group received only routine badminton training during the same period.

### *Data Collection Tools*

**Countermovement Jump (CMJ) Test.** The CMJ test was used to assess leg strength, jumping ability, and alactacid anaerobic power. Measurements were conducted using a Smart Jump mat (Fusion, Australia), an electronic device designed to record jump height. All athletes were instructed to stand on the mat with their hands placed on their waists. When ready, they performed a maximal vertical jump, landing back on the mat immediately after takeoff. Each athlete was given two trials. Jump heights were recorded in centimeters, and the best result was used for analysis [13].

**5m and 10m Sprint Tests.** Athletes' 5-meter and 10-meter sprint performances were assessed on a polyurethane-coated indoor sports hall floor using a Smart Speed system (Fusion Sport, Australia). The floor was checked to ensure it was dry prior to testing. Photocell timing gates with 0.01-second precision were positioned at both the start and finish lines for each distance. Athletes began the sprint from a standing position 50 cm behind the start line, starting the run when they felt ready. Timing began when the athlete crossed the first gate and ended upon passing through the final gate. Each athlete performed two trials with a three-minute rest interval between attempts. The best time was recorded for analysis.

**Leg-Strength Test.** Leg strength was measured using a back and leg dynamometer (Takei, TKK 5402 model, Japan). Following a five-minute warm-up, athletes positioned their feet on the dynamometer platform with knees bent. With arms extended, backs straight, and bodies slightly leaning forward, they grasped the dynamometer bar with both hands and pulled it vertically upward using maximum effort through their legs. All measurements were conducted using standardized testing procedures.

**Hand Grip Strength Test.** Hand grip strength was measured using a hand dynamometer (Takei, TKK 5101 model, Japan). Participants could be tested in either a standing or sitting position. The dynamometer was adjusted to fit the hand size of each athlete. While the participant's arm remained straight and the shoulder was positioned at an angle of 10 to 15 degrees from the torso, maximal grip strength was measured starting with the right hand. Each participant performed four trials in total — two with the right hand and two with the left hand. Sufficient rest was provided between trials. After each trial, the dynamometer needle was reset before starting the next measurement. All values were recorded, and the best result for each hand was used for analysis. Results were tabulated to compare the strength of the dominant and non-dominant hands. The highest value obtained during the trials was considered the final result.

**T Agility Test.** The T Agility Test, also known as the 5-10-5 shuttle or 20-yard shuttle test, is an effective

method for measuring change-of-direction speed. The test course consists of four cones arranged in a T-shape, as illustrated in Figure 1. At the start command, the participant begins at the starting point and runs straight to cone 1, touching it with the right hand. The participant then performs a lateral shuffle to the left to cone 3, touching it with the left hand, followed by a lateral shuffle to the right to cone 2, touching it with the right hand. After that, the participant returns laterally to cone 1, touching it with the left hand, and then completes the test by running backward to the starting point. The stopwatch is stopped as soon as the participant crosses the starting point. In this study, after full rest, each participant performed two maximal-effort trials, and the best time was recorded for analysis. To ensure data accuracy, timing was conducted using a Smart Speed electronic timing system (Fusion Sport, Australia). A photocell and reflector pair was placed 2 meters apart, with cone 1 positioned between them. The timer started when the participant passed through the photocell and reflector at the beginning and stopped when they passed through the same point again upon completion [14].

### *Training Protocol*

The duration of the core training protocol applied in this study was set at four weeks, in accordance with existing literature. Previous research, particularly involving child and youth athletes, has reported that even short-term training programs lasting four to six weeks can lead to significant improvements in physical performance [10, 15]. It has also been emphasized that short-term core-based training can support neuromuscular development and enhance motor skills [16]. A relatively short but effective duration was chosen to accommodate the limited attention span typical of athletes aged 10 to 12 and to promote consistent participation throughout the program. Therefore, the four-week training period was considered appropriate both in terms of alignment with existing studies and suitability for the developmental characteristics of the target age group.

The core training protocol was implemented for the experimental group two days per week over a period of four weeks (Table 1).

### *Statistical Analysis*

The data were analyzed using the SPSS software package. The normality of the data was assessed using the Shapiro–Wilk test, and all variables were found to be normally distributed ( $p > 0.05$ ). To confirm the suitability of parametric tests, the assumption of homogeneity of variances was evaluated using Levene's test. The results indicated that variances were homogeneous across groups for all variables ( $p > 0.05$ ). Accordingly, parametric tests were employed for both within-group and between-group comparisons. The analysis of normally

distributed data was conducted using repeated measures analysis of variance (ANOVA). Partial eta squared ( $\eta p^2$ ) values were interpreted as follows: small = 0.01, medium = 0.06, and large = 0.16. The significance level was set at 0.05.

**Results**

Descriptive statistics of the general characteristics of the female badminton players who participated in the study are presented in Table 2. The comparison of pre-test values for speed, agility, strength, and jump performance between the experimental and control groups is provided in Table 3.

As shown in Table 2, the experimental and

control groups were similar in terms of age, height, and body mass at baseline. The small differences in mean values between groups were minimal and within acceptable ranges, indicating that the groups were comparable before the intervention.

According to the findings presented in Table 3, there was no significant difference between the pre-test values of the experimental and control groups ( $p > 0.05$ ). Over time, improvements were observed in agility and jumping performance among female badminton athletes following a four-week core training program. In the T agility test, the mean score of the experimental group decreased from  $16.64 \pm 1.61$  seconds in the pre-test to  $15.70 \pm 1.77$  seconds

**Table 1.** Core training protocol

Exercise	Number of Sets (Weeks 0-2)	Number of Sets (Weeks 3-4)	Exercise Duration (sec)	Rest Between Exercises (sec)	Rest Between Sets (sec)
Plank	2	3	20	30	60
Side Plank	2	3	20	30	60
Crunch	2	3	20	30	60
Reverse Crunch	2	3	20	30	60
Superman	2	3	20	30	60
Squat	2	3	20	30	60

**Table 2.** Descriptive statistics of the general characteristics of the participants

General Characteristics	Experimental Group (n = 11)			Control Group (n = 11)		
	$\bar{X} \pm SD$	Min	Max	$\bar{X} \pm SD$	Min	Max
Age (years)	10.91 $\pm$ 0.94	10.00	12.00	10.82 $\pm$ 0.98	10.00	12.00
Height (cm)	139.09 $\pm$ 8.61	126.00	150.00	135.91 $\pm$ 10.79	121.00	151.00
Body Mass (kg)	32.47 $\pm$ 6.65	23.00	44.80	31.52 $\pm$ 6.94	24.65	44.00

Note.  $\bar{X}$  - mean; SD - standard deviation; Min - minimum; Max - maximum

**Table 3.** Comparison of pre- and post-intervention test values

Tests	Group	Pre Test	Post Test	Group		Time		Time*Group	
		$\bar{X} \pm SD$	$\bar{X} \pm SD$	p	$\eta p^2$	p	$\eta p^2$	p	$\eta p^2$
5m Sprint (sec)	CON	1.29 $\pm$ 0.10	1.26 $\pm$ 0.08	.835	.00	.416	.03	.438	.03
	EG	1.28 $\pm$ 0.11	1.28 $\pm$ 0.12						
10m Sprint (sec)	CON	2.34 $\pm$ 0.17	2.34 $\pm$ 0.15	.846	.00	.317	.05	.228	.07
	EG	2.31 $\pm$ 0.18	2.34 $\pm$ 0.17						
T Agility (sec)	CON	16.24 $\pm$ 1.58	16.25 $\pm$ 1.59	.912	.00	.047	.18	.045	.19
	EG	16.64 $\pm$ 1.61	15.70 $\pm$ 1.77						
Leg Strength (kg)	CON	46.27 $\pm$ 11.22	46.77 $\pm$ 10.37	.091	.14	.570	.02	.846	.00
	EG	55.86 $\pm$ 13.58	56.11 $\pm$ 14.72						
Dominant Hand Grip Strength (kg)	CON	14.57 $\pm$ 4.19	15.03 $\pm$ 4.82	.251	.07	.130	.11	.787	.00
	EG	16.48 $\pm$ 3.63	17.13 $\pm$ 3.47						
Non-Dominant Hand Grip Strength (kg)	CON	13.38 $\pm$ 4.27	13.56 $\pm$ 3.38	.415	.03	.142	.11	.361	.04
	EG	14.39 $\pm$ 3.35	15.15 $\pm$ 3.80						
CMJ (cm)	CON	21.61 $\pm$ 4.49	21.52 $\pm$ 3.66	.993	.00	.024	.23	.014	.26
	EG	20.61 $\pm$ 3.14	22.49 $\pm$ 3.92						

Note.  $\bar{X}$  - mean; SD - standard deviation; p - significant value;  $\eta p^2$  - partial eta squared

in the post-test. This change was statistically significant ( $p = .047$ ;  $\eta^2 = .18$ ), indicating a large effect size. Similarly, in the countermovement jump (CMJ) test, the mean score increased from  $20.61 \pm 3.14$  cm in the pre-test to  $22.49 \pm 3.92$  cm in the post-test, with a statistically significant improvement ( $p = .024$ ;  $\eta^2 = .23$ ), also indicating a large effect size. These results demonstrate that core training positively contributes to agility and jumping performance. No significant changes over time were observed in the 5 m and 10 m sprint tests, leg strength, or hand grip strength ( $p > 0.05$ ). Regarding the interaction between time and group, significant differences were identified in both the T agility test ( $p = .045$ ;  $\eta^2 = .19$ ) and the CMJ test ( $p = .014$ ;  $\eta^2 = .26$ ), again indicating large effect sizes. However, no significant time  $\times$  group interaction was found for the 5 m and 10 m sprint tests, leg strength, or hand grip strength ( $p > 0.05$ ).

## Discussion

This study examined the effects of a four-week core training program on speed, agility, strength, and jumping performance in badminton athletes aged 10 to 12 years. Following the training intervention, significant improvements were observed in agility and jumping performance among female participants. The results of the agility and countermovement jump tests suggest that core training is effective in enhancing motor skills relevant to dynamic movement and coordination. Furthermore, the observed effect size values indicate that these improvements were not only statistically significant but also practically meaningful. In contrast, no significant changes were found in sprint performance, leg strength, or hand grip strength. This may imply that short-term core training interventions are more effective for certain components of physical performance, particularly those involving balance, coordination, and neuromuscular control, rather than pure strength or linear speed. Overall, the findings suggest that core training can positively influence agility and jumping ability in young badminton players and may be a valuable component of training programs designed for this age group.

When reviewing studies in the literature that examine the effects of core training on performance, findings similar to those of the present study are frequently observed. Core exercises have been shown to have significant positive effects on postural stability and agility performance [4]. Additionally, core training has been reported to improve jumping ability [16]. These findings align with the current study and support the beneficial role of core training in enhancing dynamic sport-specific movements. In one study investigating the effects of core training on agility, speed, and vertical jump performance in female athletes,

improvements were observed across all parameters in favor of the experimental group [17]. These results support the current findings regarding agility and jumping performance. However, unlike our study, that research also reported improvements in speed performance. This discrepancy may be attributed to the longer duration of the core training program (six weeks) and the older age group of participants (18 to 25 years), which could influence the magnitude and nature of adaptations.

Core training has been shown to enhance athletic performance in various youth populations. For example, its application in young volleyball players resulted in significant improvements in vertical jump and agility in favor of the experimental group [18]. Similarly, in young male football players aged 12 to 13, core exercises were found to increase core muscle mass and improve vertical jump performance [19]. Among athletes aged 8 to 10, core training led to significant enhancements in biomotor performance parameters [20]. In addition, studies involving adolescent participants have reported that core training positively affects agility, vertical jump, and strength outcomes [21]. While these findings collectively support the effectiveness of core training across different youth age groups, it is important to recognize that pre-adolescent athletes possess unique physiological and developmental characteristics. These differences may affect training adaptations, neuromuscular coordination, and recovery processes, and therefore must be considered when designing training interventions for this population.

Several studies have demonstrated that core training has a positive impact on physical performance in athletes across different sports. For instance, core training programs incorporating Pilates-based exercises applied to elite male and female badminton athletes were found to significantly enhance agility, a key component of badminton performance [22]. Similarly, core training in soccer players led to notable improvements in vertical jump, anaerobic power, and agility [23]. In another study, a nine-week core training intervention resulted in significant gains in vertical jump, agility, and speed performance in the experimental group [24]. These findings support the current study's results regarding countermovement jump (CMJ) and agility performance. However, the improvements in speed reported in that study do not align with our findings. This discrepancy may be attributed to the longer duration of the core training program (nine weeks) compared to the four-week program in the present study. Further evidence from studies applying different core training protocols confirmed improvements in vertical jump and agility performance across groups [25]. In badminton players specifically, core training was shown to significantly enhance balance, agility, and strength

[26], while amateur badminton players also exhibited improvements in balance and agility following core exercise interventions [2]. Additionally, a positive correlation between core training and agility in badminton players was identified, suggesting that increased core stability contributes to better agility outcomes [27]. A study involving 65 badminton athletes also reported significant improvements in leg strength and agility after core training [28].

On the other hand, it is noteworthy that core training did not produce significant improvements in speed, leg strength, or hand grip strength in the present study. This suggests that the direct impact of core training on speed-related performance may be limited. Previous research has indicated that core training tends to yield more substantial benefits in movements requiring balance and coordination [29]. In a similar study involving taekwondo athletes aged 10 to 12, significant improvements were observed in agility and jumping performance, while no significant changes were found in speed performance [30]. In this context, the lack of significant changes in strength-related parameters such as speed, leg strength, and hand grip strength may indicate that core training alone is not sufficient to improve these specific components of physical performance. Moreover, it has been emphasized that core training should be tailored to account for individual differences. Research in various sports disciplines has shown that the effects of core training may vary depending on athlete characteristics and sport-specific demands [31]. Therefore, implementing individualized core training programs in sports that rely heavily on agility and jumping, such as badminton, may help achieve more effective and targeted outcomes.

#### *Limitations of the Study*

One of the main limitations of this study is the relatively short duration of the core training intervention, which was limited to four weeks. This restricted the ability to evaluate the long-term effects of core training on athletic performance. Additionally, the study focused exclusively on female badminton players aged 10 to 12 years. As a

result, the generalizability of the findings is limited with respect to other age groups, genders, sports disciplines, and competitive levels.

To gain a more comprehensive understanding of the effects of core training, future studies should incorporate larger and more diverse samples, extended intervention periods, and participants across different developmental stages and skill levels. It is also recommended that methodological adaptations be tailored to the physiological and developmental characteristics of young athletes. These may include individualized training loads, progressive overload strategies adjusted to growth patterns, and age-appropriate exercise selection. Moreover, incorporating longer follow-up periods may be beneficial for assessing the sustainability of training-induced performance adaptations. Such approaches would enhance the scientific validity, practical applicability, and long-term impact of core training programs within youth athletic development frameworks.

## **Conclusions**

This study highlights the relevance of incorporating core training into the physical preparation of young athletes involved in sports that require rapid directional changes and postural control, such as badminton. Core training may serve as a valuable component of long-term athlete development by supporting movement efficiency, coordination, and overall functional capacity. Given the specific developmental needs of pre-adolescent athletes, structured and age-appropriate core training programs can contribute meaningfully to the physical foundation necessary for sport-specific skill acquisition. The integration of such training into regular practice routines offers potential benefits for improving physical literacy and supporting safe, effective athletic progression in youth sport settings.

## **Conflict of Interests**

The authors declare that there are no conflicts of interest related to this study.

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**Information about the authors:**

**Muhammed Zahit Kahraman**; (Corresponding author); <https://orcid.org/0000-0003-1295-7611>; [mzkahraman04@gmail.com](mailto:mzkahraman04@gmail.com); Department of Coaching Education, Faculty of Sports Sciences, Bitlis Eren University; Bitlis, Turkey.

**Serkan Kızılca**; <https://orcid.org/0000-0002-0030-7999>; [serkankizilca@hotmail.com](mailto:serkankizilca@hotmail.com); Department of Physical Education and Sports, Faculty of Sports Sciences, Bitlis Eren University; Bitlis, Turkey.

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# The effect of active exercise and relaxation-based on psychological well-being, functional ability, and independence in the older adults

Yulvia Miftachurochmah<sup>1ABCD</sup>, Cerika Rismayanthi<sup>2ABCDE</sup>, Rizki Mulyawan<sup>2BCDE</sup>,  
Gallant Pamungkas<sup>2BCD</sup>

<sup>1</sup> Department of Health and Sport, Universitas Negeri Yogyakarta, Indonesia

<sup>2</sup> Department of Sport Science, Universitas Negeri Yogyakarta, Indonesia

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

## Abstract

**Background and Study Aim** The global increase in the aging population presents significant challenges to public health systems. Older adults often face physical and psychological decline. These changes can negatively affect their independence and quality of life. The aim of this study is to evaluate the impact of a combined intervention involving active exercise and relaxation on psychological well-being, physical function, and independence in community-dwelling older adults.

**Material and Methods** A one-group pretest-posttest design was used. The study involved 47 older adults aged 60 years and above. The intervention consisted of 12 sessions conducted over several weeks. It integrated movement-based activities and relaxation techniques. Assessments included Ryff's Psychological Well-Being (PWB) scale, Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL), Chair Stand Test, Sit and Reach, and Hand Grip Strength (HGS). Data were analyzed using paired t-tests and Wilcoxon tests, depending on the distribution of the data.

**Results** Statistically significant improvements were observed across all measured domains. Psychological well-being increased significantly ( $t = 3.733$ ,  $p = 0.001$ ), reflecting a moderate effect. Functional gains were also noted in lower-body strength, flexibility, and hand grip performance. Notably, improvements in instrumental activities of daily living (IADL) reached high statistical significance ( $Z = -4.762$ ,  $p < 0.001$ ), indicating enhanced independence. These findings suggest that the intervention positively influenced both physical and psychological functioning in older adults.

**Conclusions** These findings suggest that short-term active and relaxation-based interventions can be effective promotive and preventive strategies in elderly healthcare. They may contribute to improved quality of life in aging populations.

**Keywords:** older adults, active exercise, relaxation, psychological well-being, functional ability, independence.

## Introduction

The process of aging brings a range of physical, cognitive, and emotional changes. These changes can increase vulnerability to disease, disability, and social isolation. As the global aging population continues to grow, there is an urgent need for effective strategies to support health, autonomy, and well-being in later life.

The aging process is inevitably accompanied by a range of physiological, psychological, and social changes that may adversely impact the quality of life in older adults [1, 2, 3]. Physiological decline, particularly in muscle strength and balance, often leads to a reduction in functional ability. This, in turn, limits the capacity to perform daily tasks independently. Psychological challenges such as loneliness, anxiety, and depression are also common among older individuals. These conditions contribute significantly to the deterioration of mental health [4, 5]. In this context, psychological well-being (PWB), functional ability, and independence emerge as

interrelated components that are vital to maintaining a high quality of life in later life [6, 7, 8]. These domains are closely interconnected and mutually reinforcing. A decline in one can negatively affect the others [9]. Given the growing proportion of the aging population worldwide, there is an urgent need to identify and implement preventive strategies that address these interconnected dimensions of well-being in older adults.

A substantial body of evidence supports the role of physical activity in preserving functional capacity and promoting independence among older adults. Structured exercise programmes, especially those that combine low-impact aerobic movements with flexibility training, have been shown to enhance mobility, muscular strength, balance, and other health indicators [10, 11, 12]. These improvements often lead to greater autonomy in performing activities of daily living (ADLs) and instrumental activities of daily living (IADLs) [13, 14]. In contrast, mindfulness-based interventions (MBIs) are consistently associated with mental health benefits. These include reduced anxiety and depressive symptoms, improved emotional regulation, and

higher self-esteem. However, several studies suggest that while physical exercise can improve functional ability and independence, its effect on psychological well-being is relatively modest when exercise and MBIs are applied separately [15].

Current literature indicates that most intervention studies have examined the effects of structured physical activity and mindfulness practice independently. Research on structured physical activity programmes has frequently focused on fitness outcomes [16], physical health [17], mobility [18, 19], independence [13], and other aspects related to physical function [13]. In contrast, studies on mindfulness-based interventions (MBIs) have primarily investigated psychological outcomes such as insomnia [20, 21], stress [22], depression [23], cognitive performance [15, 24], and emotional regulation [23]. However, few studies have explored psychological well-being (PWB). This separation of focus highlights a critical research gap, especially considering the complex and multidimensional nature of well-being in older adults [9]. Some studies have directly compared the effects of physical exercise and mindfulness training on vitality [25]. In addition, previous research [26] has shown that while physical activity alone can improve quality of life, its effect is less substantial than that of combined interventions integrating both physical exercise and mindfulness. This is particularly true when improvements in both physical and mental health dimensions are considered.

Although several recent studies have attempted to integrate physical and mental training, very few have systematically combined structured physical activity with mindfulness-based practice within a single, unified intervention framework. Most of these programmes have used walking as the primary form of exercise [27, 28, 29]. To the best of our knowledge, interventions that pair body-weight resistance training with mindfulness techniques are rare. Other studies have included both physical and mental components but delivered them sequentially rather than concurrently. For example, studies [24, 30] scheduled a structured exercise session followed by a mindfulness-based stress reduction component to examine effects on cognitive performance in older adults. Study [31] augmented a physical activity programme with health education and reminiscence therapy to evaluate its impact on spiritual well-being. Some research has delivered concurrent interventions that combine physical exercise with relaxation training, breathing exercises, or meditation techniques [32].

Analysis of previous studies has shown that both structured physical activity and mindfulness-based interventions offer distinct benefits for older adults. Researchers have found that physical activity enhances functional capacity and independence, while mindfulness practice improves various

aspects of mental health. Authors have emphasized the importance of addressing both physical and psychological dimensions of aging to support overall well-being. However, despite numerous investigations, there remains a clear need for more comprehensive research that integrates these two approaches within a single intervention. Overall, empirical evidence remains limited regarding the synergistic benefits of delivering structured physical activity and mindfulness practice simultaneously within a unified model. This is especially evident in studies targeting the interconnected domains of psychological well-being, functional ability, and independence.

The aim of this study is to evaluate the impact of a combined intervention involving active exercise and relaxation on psychological well-being, physical function, and independence in community-dwelling older adults.

## Materials and Methods

### *Participants*

The subjects of this study were older adults aged 60 to 70 years, selected through purposive sampling based on the following inclusion criteria:

1. Ability to communicate effectively and follow instructions.
2. Health condition permitting participation in light to moderate physical exercise.
3. Willingness to complete the entire research program and provide informed consent.

The exclusion criteria were as follows:

1. Presence of chronic illnesses or medical conditions that restricted physical activity.
2. Current participation in therapy or other interventions that could influence study outcomes.

Of the 61 individuals initially screened, 9 did not meet the inclusion criteria due to health limitations and communication difficulties. Additionally, 5 others declined to participate after being informed about the study procedures. Their withdrawal was primarily due to mobility-related concerns such as knee pain, shoulder discomfort, and other joint issues. As a result, a total of 47 participants were enrolled and successfully completed the intervention program. The average attendance rate was 91.3%. A total of 39 participants (82.9%) completed all sessions, while 8 participants (17.0%) attended at least 10 sessions. No participants withdrew from the study, resulting in a 0% attrition rate.

The characteristics of the participants are presented in Table 1. The sample consisted of older adults between 60 and 70 years of age. On average, participants were within the normal range for height, body weight, and BMI, although individual values showed considerable variability. Cardiovascular indicators such as blood pressure and heart rate also

varied widely, reflecting the expected heterogeneity in an aging population. Similarly, body composition parameters, including BMI and body fat percentage, indicated a broad range of physical conditions among participants. These descriptive statistics provide a general overview of the sample's demographic and health-related profile.

**Table 1.** Participant Characteristics

Indicator	N	Min	Max	Mean	SD
Age (years)	47	60.00	70.00	63.60	4.45
Height (cm)	47	145.00	160.00	152.80	4.29
Weight (kg)	47	38.90	83.50	59.89	11.98
Systolic BP (mmHg)	47	87.00	188.00	138.38	22.13
Diastolic BP (mmHg)	47	61.00	134.00	82.80	12.35
Heart Rate (bpm)	47	60.00	109.00	84.63	13.45
BMI (kg/m <sup>2</sup> )	47	16.70	37.60	25.70	5.02
Body Fat (%)	47	19.70	45.00	36.61	6.18

#### *Ethical Considerations*

This study received ethical approval from the Research Ethics Committee, Directorate of Research and Community Service, Universitas Negeri Yogyakarta (Approval No. T/6.23/UN34.9/KP.06.07/2024). All participants were informed about the study's purpose, procedures, potential risks, and benefits before providing written informed consent. Confidentiality and anonymity were strictly maintained throughout the research process. Participants were free to withdraw at any time without consequence. The study was conducted in accordance with established ethical research principles to protect the rights and dignity of all participants.

#### *Research Design*

This study employed a one-group pretest-posttest design to analyze the effects of active exercise and relaxation on psychological well-being (PWB), functional ability, and independence in older adults. Participants were assessed before and after a 12-session intervention conducted over four weeks. The intervention was implemented without a control group. It is important to note that the absence of a control group represents a significant limitation, as it introduces potential confounding variables and threats to internal validity. Despite this, the study serves as an initial exploratory effort intended to inform future research. Accordingly, the findings should be interpreted with caution. The study was conducted in a community setting for older adults located in Sleman Regency, Indonesia. Participants attended three sessions per week, each lasting approximately 60 minutes. All sessions were led by certified instructors specializing in exercise

and mindfulness. Participant safety was monitored throughout each session, and any adverse symptoms were recorded. Before enrollment, all individuals received a detailed explanation of the study's objectives, procedures, and potential risks. Adherence was tracked using attendance records throughout the intervention period.

This study involved three procedures: the initial measurement phase (pre-test), the intervention phase, and the final measurement phase (post-test). The same participants were evaluated in both the pre-test and post-test phases using identical measurement protocols to ensure within-subject comparison. The procedures are outlined as follows:

#### *1. Pre-test*

During the pre-test phase, baseline measurements were conducted to assess psychological well-being (PWB), functional ability, and independence. The same assessment protocols were applied again during the post-test phase to ensure consistency and comparability of results within participants.

#### *2. Intervention*

In this study, the intervention was delivered three times per week over the course of one month, with each session lasting approximately 60 minutes. The program combined physical (active) exercise, including stretching and bodyweight exercises, with relaxation exercises based on mindfulness training. Both formal and informal mindfulness approaches were incorporated. Formal mindfulness practice consisted of instructor-guided sessions delivered at specific points during the program. In contrast, informal practice involved gradually training participants to apply mindfulness cues independently during the core exercise phase, while remaining under continuous supervision and guidance. This informal component aimed to foster the habit of self-directed mindfulness during physical activity, such as maintaining awareness of breathing, bodily sensations, or muscle engagement during movement.

The mindfulness program, as shown in Table 2, was adapted and modified from the Mindfulness-Based Stress Reduction (MBSR) framework developed by Kabat-Zinn [33]. The active exercise component included stretching and bodyweight movements, along with selected postures commonly found in yoga. These exercises were designed to target major muscle groups typically engaged in flexibility, strength training, and posture-improvement programs for older adults [34, 35, 36].

The progression of exercises was deliberately structured to start with simpler movements and gradually increase in complexity and intensity toward the end of each session, as outlined in Table 3.

Each session was structured into three phases: opening, core activity, and closing. The opening phase included an introduction to basic mindfulness concepts and was conducted through formal

**Table 2.** Active Exercise Program

No	Session 1	Session 2	Session 3
0	Relaxation pose (sitting upright)	Relaxation pose (sitting upright)	Relaxation pose (sitting upright)
1	Shoulder Blade Squeeze	Floor Angel	Standing spinal twist
2	Seated Shoulder & Overhead Stretch	Supine chin tuck	Squat/Chair pose
3	Seated chin tuck	Dead Bug	Side to side butt kick
4	Standing up from chair	Heel touch	Standing heel raises
5	Heel Raises Chair	Bridge pose	Standing elbow to knee crunch
6	Wall Push Up	Standing up from floor	Shoulder press up
7	Tree poses*	Standing Knee to Chest*	Upward forward fold pose*
8	Warrior Poses II*	Split Squat	Crunches
9	Worlds greatest stretch	Warrior pose I*	Flutter kick
10	Standing forward bend*	Plank pose*	Double Leg Knee to Chest*
11	Seated Straddle	Kneeling Superman*	Side lying Thoracic rotation*
12	Butterfly pose*	Butterfly pose*	Cat and Cow Face
13	Reclining Bound Angle Pose*	Reclining Bound Angle Pose*	Child pose and Cobra pose*
0	Corpse pose (motivational prompts, etc.)	Corpse pose (motivational prompts, etc.)	Corpse pose (motivational prompts, etc.)

Note: \*) The exercise is performed in a timed count (in seconds).

**Table 3.** Mindfulness Practice Program

Type	Stage	Week 1	Week 2	Week 3	Week 4
FORMAL*	Opening	Basic Breathing	Mindful movement	Sitting with awareness	Looking at problems without making them worse
	Closing	Mindfulness of breathing	Full body scan	Walking meditation	Attitudes and Commitment
INFORMAL**	During exercise	Get in touch with what you are doing:			“Being an ally in your own life” and “Moment-to-moment awareness of daily experience”
		Am I Here now?			
		Am I Awake?			
		Do I Know what I am doing right now?			
		How does my body feel right now?			
		What is my mind up to?			
		Etc.			

Note: \*) Formal practice was conducted at the beginning and end of each session, before and after the active exercise component. \*\*) Informal practice was carried out during the active exercise phase.

guided practice. This phase aimed to promote mental calmness, enhance internal focus, and psychologically prepare participants for the session. The core phase involved active exercises, including stretching and bodyweight movements, integrated with informal mindfulness. Participants were guided to use specific cues such as focusing on their breath, muscle sensations, or movement patterns. This integration was intended to enhance mind–body awareness and support the psychological benefits of physical activity, in line with the principles of mindful movement, as practiced in mindful yoga and other forms of conscious exercise. The closing phase consisted of formal relaxation techniques led by the

instructor. These included practices such as mindful breathing, full body scans, or walking meditation. This phase was designed to deepen the mindfulness experience and support a return to parasympathetic nervous system dominance, a physiological state essential for health and recovery in older adults.

It should be noted that the mindfulness content varied across the four-week intervention. However, the training was delivered as a cumulative and integrated program, with each week’s content building upon the previous one. For example, the first week focused on basic breathing techniques and mindfulness of breathing, which served as the foundation for full body scan and mindful movement

practices introduced in the second week. Earlier practices were revisited and reinforced in later sessions to support skill retention and integration.

Week 4 differed slightly from the previous weeks, as the mindfulness program during this phase emphasized self-reflection on personal experiences, challenges, life goals, and how to view them more positively. This final week was designed to strengthen participants' confidence in facing challenges, making decisions, and acting in accordance with their personal values, which are key components of self-efficacy.

### 3. Post-test

Post-test measurements were conducted using the same instruments and procedures as in the pre-test phase. All assessments were administered to the same participants to enable within-subject comparison and evaluate changes in psychological well-being (PWB), functional ability, and independence following the intervention.

#### Measurement Instruments

Ryff's Psychological Well-Being Scales (Short Version) was used to measure PWB. This instrument is based on the psychological well-being model developed by Carol Ryff [37].

To assess functional ability, three indicators were used:

1. *Chair Stand Test* – This test measures lower body strength required for tasks such as climbing stairs, walking, and standing up from a chair, bathtub, or car. It is also used to estimate fall risk in older adults.
2. *Chair Sit and Reach* – A modified version of the traditional sit-and-reach test. It evaluates lower body flexibility by assessing how far the participant can reach toward the toes while seated.
3. *Handgrip Test* – This test measures handgrip strength and is widely used as an indicator of general health and well-being in older populations.

To measure independence, two additional instruments were used:

- *Activities of Daily Living (ADLs)* – This scale evaluates an individual's ability to perform basic self-care tasks essential for daily functioning [38].
- *Instrumental Activities of Daily Living (IADLs)* – This scale assesses the ability to perform more complex activities necessary for independent living within the community [39].

#### Statistical Analysis

This study included both parametric data (i.e., psychological well-being and functional ability) and non-parametric data (i.e., independence, as measured by ADL and IADL). Accordingly, two statistical approaches were applied. For parametric analyses, assumption testing was conducted to assess data normality using the Shapiro–Wilk test

and homogeneity of variances using Levene's test. A significance level of  $p > 0.05$  was used to confirm that assumptions for the paired sample t-test were met. In contrast, the ADL and IADL variables did not meet the normality assumption (Shapiro–Wilk  $p < 0.05$ ) and were therefore analyzed using the Wilcoxon signed-rank test, which does not require normality or homogeneity assumptions. Both the paired sample t-test and the Wilcoxon signed-rank test were used to evaluate differences between pre- and post-intervention scores within the same group. Statistical significance was set at  $p < 0.05$ . Effect sizes were also calculated: Cohen's  $d$  for the paired sample t-test and rank-biserial correlation for the Wilcoxon signed-rank test. Effect size interpretation followed conventional thresholds: 0.2 as small, 0.5 as moderate, and 0.8 as large. All statistical analyses were performed using IBM SPSS Statistics, version 26.

## Results

Descriptive statistics were used to summarize the pre-test and post-test scores for psychological well-being, independence, and functional ability among the older adult participants. These results are presented in Table 4.

As shown in Table 4, descriptive statistics were used to summarize the pre-test and post-test scores for psychological well-being, independence, and functional ability among older adult participants. Overall, these results indicate consistent improvements across all measured domains following the intervention. Psychological well-being, as measured by Ryff's PWB scale, showed a notable increase in mean score from pre- to post-test. Improvements were also observed in independence, with both ADL and IADL scores reflecting positive changes, particularly a substantial gain in IADL performance. Functional ability measures demonstrated enhanced outcomes as well. Participants performed more repetitions in the Chair Stand test, reached further in the Sit and Reach test, and showed marked increases in hand grip strength for both hands. These trends collectively suggest improvements in strength, flexibility, and daily functional capacity.

Before conducting the parametric statistical analysis to test the effect of active exercise and relaxation on psychological well-being, functional ability, and independence in older adults, a normality test was first performed using the Shapiro–Wilk test. This test is used to determine whether the data for each variable are normally distributed, which is a prerequisite for using parametric analysis. The results of the normality test are presented in Table 5.

Normality assumptions, as shown in Table 5, were evaluated using the Shapiro–Wilk test for each indicator variable. The results indicated that Ryff's Psychological Well-Being (PWB) score was

**Table 4.** Descriptive Statistic

Variabel	Indicator	Group	Mean±SD	Δ Mean ± SD
Psychological Well-Being	Ryff's PWB	Pre	76.06±6.56	3.36±6.17
		Post	79.42±5.48	
Independence	ADL	Pre	2.68±1.54	1.04±1.92
		Post	3.72±1.52	
	IADL	Pre	2.59±1.88	2.44±2.52
		Post	5.04±1.64	
Functional Ability	CS	Pre	10.02±3.31	2.17±4.32
		Post	12.19±3.20	
	S&R	Pre	-4.70±4.04	-2.21±5.22
		Post	-2.48±3.24	
	HGL	Pre	11.71±4.89	3.52±6.28
		Post	15.24±4.50	
HGR	Pre	14.09±4.28	3.58±5.93	
	Post	17.67±4.38		

Note. PWB – Psychological Well-Being; ADL – Activities of Daily Living; IADL – Instrumental Activities of Daily Living; CS – Chair Stand; S&R – Sit and Reach; HGL – Hand Grip Left; HGR – Hand Grip Right; Δ Mean ± SD – Mean difference between pre- and post-test scores with standard deviation.

**Table 5.** Normality Test Results

Variabel	Indicator	Shapiro-Wilk		
		Statistic	df	Sig.
Psychological Well-Being	Ryff's PWB	0.990	46	0.716
Independence	ADL	0.949	46	0.001
	IADL	0.962	46	0.008
Functional Ability	Chair Stand	0.981	46	0.184
	Sit and Reach	0.975	46	0.065
	Hand Grip (Left Hand)	0.974	46	0.062
	Hand Grip (Right Hand)	0.977	46	0.103

Note. PWB – Psychological Well-Being; ADL – Activities of Daily Living; IADL – Instrumental Activities of Daily Living

normally distributed,  $W(94) = .990$ ,  $p = .716$ , as were all indicators of functional ability, including Chair Stand,  $W(94) = .981$ ,  $p = .184$ ; Sit and Reach,  $W(94) = .975$ ,  $p = .065$ ; Hand Grip (Left),  $W(94) = .974$ ,  $p = .062$ ; and Hand Grip (Right),  $W(94) = .977$ ,  $p = .103$ . Since all p-values for these variables were greater than .05, the assumption of normality was satisfied. These variables were analyzed using parametric tests, specifically the paired sample t-test. In contrast, the indicators of independence, namely Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL), did not meet the normality assumption. Specifically, ADL,  $W(94) = .949$ ,  $p = .001$ , and IADL,  $W(94) = .962$ ,  $p = .008$ , showed statistically significant deviations from a normal distribution. Therefore, these variables were analyzed using a nonparametric test, the Wilcoxon signed-rank test.

After the normality test, the next step was to assess the homogeneity of variances across data groups. Levene's test was used to verify whether the variances of each variable were homogeneous. The results of the homogeneity test for all variables are presented in Table 6.

The results of the homogeneity of variances test were assessed using Levene's test for all variables. As presented in Table 6, Ryff's Psychological Well-Being (PWB) met the assumption of equal variances,  $F(1, 92) = 2.518$ ,  $p = .116$ . All indicators of functional ability also satisfied the homogeneity assumption: Chair Stand,  $F(1, 92) = 0.000$ ,  $p < .001$ ; Sit and Reach,  $F(1, 92) = 2.965$ ,  $p = .088$ ; Hand Grip (Left),  $F(1, 92) = 0.051$ ,  $p = .822$ ; and Hand Grip (Right),  $F(1, 92) = 0.078$ ,  $p = .781$ . The independence variables demonstrated homogeneity of variances as well. For ADL,  $F(1, 92) = 0.001$ ,  $p = .979$ , and for IADL,  $F(1, 92)$

= 0.773,  $p = .381$ . Since all  $p$ -values were greater than .05, the assumption of homogeneity of variances was considered met for all variables.

In summary, the assumption tests for psychological well-being and functional ability confirmed both normal distribution and equal variances. Therefore, these variables were analyzed using the parametric paired  $t$ -test to assess pre- and post-test differences. The results of this analysis are presented in Table 7.

In contrast, the assumption tests for the independence variables (ADL and IADL) indicated non-normal distribution based on the results of the Shapiro–Wilk test. Although Levene’s test confirmed homogeneity of variances, the violation of the normality assumption prevented the use of the paired  $t$ -test. Consequently, ADL and IADL were analyzed using the non-parametric Wilcoxon signed-rank test to evaluate pre- and post-test differences. The results of this analysis are presented in Table 8.

As shown in Table 7, a paired samples  $t$ -test was conducted to assess the effects of active exercise and relaxation on psychological well-being and functional ability in older adults ( $n = 47$ ). The results indicated statistically significant improvements across all measured indicators. Psychological well-being, as assessed by Ryff’s PWB scale, improved significantly, with a moderate effect size. Similarly, all measures of functional ability, including Chair Stand, Sit and Reach, and hand grip strength for both hands, showed statistically significant enhancements. Effect sizes ranged from small to moderate, with some classified as large. These findings reflect meaningful improvements in strength, flexibility, and overall physical performance. Overall, the results suggest that the intervention had a positive and measurable impact on both psychological and physical functioning in the older adult population.

Since the data for the independence variable in both the ADL and IADL indicators were not

**Table 6.** Homogeneity Test Results

Variabel	Indicator	Levene Statistic	df1	df2	Sig.
Psychological Well-Being	Ryff’s PWB	2.518	1	92	0.116
Independence	ADL	0.001	1	92	0.979
	IADL	0.773	1	92	0.381
Functional Ability	Chair Stand	0.000	1	92	0.983
	Sit and Reach	2.965	1	92	0.088
	Hand Grip (Left Hand)	0.051	1	92	0.822
	Hand Grip (Right Hand)	0.078	1	92	0.781

Note. PWB – Psychological Well-Being; ADL – Activities of Daily Living; IADL – Instrumental Activities of Daily Living

**Table 7.** Paired Samples  $t$ -Test Results

Variabel	Indicator	t-value	p value	Cohen d	95% CI	
					Upper	Lower
Psychological Well-Being	Ryff’s PWB	3.733	0.001	-0.544	-0.848	-0.235
Functional Ability	Chair Stand	3.440	0.001	-0.501	-0.802	-0.195
	Sit and Reach	-2.906	0.006	-0.423	-0.720	-0.123
	Hand Grip (Left Hand)	3.850	0.000	-0.561	-0.866	-0.251
	Chair Stand	4.137	0.000	-0.603	-0.911	-0.289
	Sit and Reach					
	Hand Grip (Left Hand)					

Note. PWB – Psychological Well-Being

**Table 8.** Wilcoxon Test Results for Independence in ADL and IADL of Older Adults Pre- and Post-Intervention

Indicator	N	Negative Ranks (n)	Positive Ranks (n)	Ties	Z - value	p value	r (effect size)
ADL	47	7	28	12	-3.169	0.002	-0.462
IADL	47	3	32	12	-4.762	< 0.001	-0.695

Note. ADL – Activities of Daily Living; IADL – Instrumental Activities of Daily Living

normally distributed, as determined by the Shapiro–Wilk test, the effect of the intervention on these two variables was analyzed using the Wilcoxon signed-rank test. This nonparametric test was applied to evaluate differences in scores before and after the intervention within the same group. The results of the analysis are presented in Table 8.

As shown in Table 8, the Wilcoxon signed-rank test was used to examine changes in independence among older adults before and after the intervention, based on Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL). The results revealed statistically significant improvements in both indicators. In ADL, most participants demonstrated positive changes, with a moderate effect size. Similarly, IADL scores showed a statistically significant increase, with the majority of participants reporting improved outcomes and a large effect size. These findings support the conclusion that the intervention had a meaningful and statistically significant impact on the independence of older adults. Combined with the results of the paired samples t-test, the data suggest improvements in both psychological and physical domains following the intervention.

## Discussion

This study aimed to evaluate the effects of a combined active exercise and mindfulness-based relaxation intervention on psychological well-being, functional ability, and independence among older adults. The findings revealed statistically and practically significant improvements across all target domains. Psychological well-being, as measured by Ryff's PWB scale, showed a significant increase,  $t(46) = 3.733$ ,  $p = .001$ , with a moderate effect size,  $d = 0.544$ . In terms of functional ability, significant enhancements were observed in multiple indicators. Chair Stand performance improved,  $t(46) = 3.440$ ,  $p = .001$ ,  $d = 0.501$ . Sit and Reach scores also increased,  $t(46) = -2.906$ ,  $p = .006$ , with an effect size of  $d = 0.423$ . Handgrip strength improved in both hands: left hand,  $t(46) = 3.850$ ,  $p < .001$ ,  $d = 0.561$ ; right hand,  $t(46) = 4.137$ ,  $p < .001$ ,  $d = 0.603$ . These results reflect moderate to large improvements in physical performance. Additionally, significant gains were observed in both basic and instrumental activities of daily living. ADL scores increased significantly,  $Z = -3.169$ ,  $p = .002$ , with a moderate effect size,  $r = 0.462$ . IADL scores also showed a statistically significant increase,  $Z = -4.762$ ,  $p < .001$ , with a large effect size,  $r = 0.695$ . Collectively, these results suggest that the intervention had a meaningful and multifaceted impact, promoting improved psychological functioning, enhanced physical capability, and increased functional independence in the participating older adults.

## Psychological Well-Being

The present study found that combining low-intensity exercise with mindfulness-based relaxation was associated with meaningful gains in psychological well-being (PWB) among community-dwelling older women. Similar gains have been reported in studies involving other light, supervised physical activities, including stretching [40, 41], yoga [42, 43], tai chi [44], and group-based aerobic exercise [45]. These interventions have been shown to reduce symptoms of depression and anxiety while enhancing social relationships and overall quality of life. Such benefits are believed to result from increased bodily awareness, greater self-confidence, and an enhanced sense of control over physical functioning [46, 47]. A systematic review by [48] further emphasizes that light, enjoyable, and socially engaging activities are particularly effective in promoting psychological well-being in later life.

Unlike the mindful yoga protocol used by [49], the present program combined stretching and bodyweight movements with continuous mindfulness cues delivered in a group setting, yet still produced comparable gains in psychological well-being (PWB). Mindful movement practices such as these enhance present-moment awareness, sharpen attention, reduce mind-wandering, and cultivate non-judgment, thereby supporting psychological well-being [50]. In addition, conducting the sessions in a community environment likely amplified these effects by promoting social interaction, emotional support, and a sense of belonging [51, 52, 53]. From a physiological perspective, it is well documented that physical activity can trigger favorable neuroendocrine responses, including increased endorphin release and reduced cortisol levels, both of which are associated with improved mood and reduced stress [54, 55, 56]. Mindfulness practice may complement these effects by downregulating hypothalamic–pituitary–adrenal (HPA) axis activity, promoting neuroplasticity, and reducing inflammation [57, 58, 59]. Since these biological mechanisms were not directly assessed in the present study, future randomized trials should incorporate biomarker or neuroimaging measures to confirm their potential mediating role.

## Functional Ability

The present program was associated with statistically and practically meaningful gains in functional performance. Participants demonstrated faster chair stand times, greater sit-and-reach flexibility, and stronger hand grip scores at post-test. These outcomes suggest that an integrated regimen of low-load resistance exercise combined with mindfulness-based movement can improve multiple domains of physical function in community-dwelling older women.

The bodyweight sequence (e.g., chair-assisted squats, split squats, heel raises, wall push-ups) was intentionally designed to target the quadriceps–hamstring complex, ankle stabilizers, core musculature, and shoulder girdle. These muscle groups are essential for everyday functions such as transfers, stair negotiation, and load carriage. Consistent with recent resistance training trials in older adults, such multijoint exercises appear to improve motor unit recruitment efficiency and reduce the neural activation cost required to perform submaximal tasks. They may also promote moderate hypertrophy and corresponding gains in functional strength [60, 61, 62, 63, 64]. In addition, the static and dynamic stretching components likely contributed to the observed improvement in sit-and-reach scores by increasing soft tissue compliance and joint mobility [65, 66]. Improved range of motion is closely linked to enhanced postural control and reduced fall risk in later life [67, 68]. Since falls are a leading cause of disability in older adults, even modest improvements in flexibility can have substantial public health implications. Furthermore, mindfulness cues embedded throughout the movement sequence may have enhanced proprioceptive acuity and body awareness, thereby complementing the mechanical training stimulus [69]. Neuroimaging studies have shown that mindful movement practices increase activation in the somatosensory and premotor cortices and strengthen sensorimotor connectivity. These neural adaptations are associated with improved balance and movement control [70, 71, 72]. Although such pathways were not assessed in this study, they provide a plausible explanation for the functional improvements observed.

Hand grip strength improved despite the absence of direct forearm exercises. This finding is consistent with cross-education research, which shows that unilateral or whole-body resistance training can induce strength gains in untrained limbs through central neural adaptations [73, 74]. However, the effectiveness of cross-education in older populations remains uncertain, as the magnitude of this effect tends to decline with age. Grip strength is a well-established surrogate marker of overall muscle function and healthy ageing [75, 76]. Its improvement in the present study therefore suggests broader gains in physical resilience. Recent evidence also links higher grip strength to more favorable inflammatory and immune profiles in older women [77], highlighting the clinical relevance of the observed changes. Complementary intervention studies have shown that yoga, with or without an explicit MBSR component, can preserve or maintain grip strength relative to non-exercise controls in older adults [78, 79]. Thus, the improvements in grip strength observed here may reflect broader enhancements in neuromuscular function and physical robustness.

### *Independence (ADL/IADL)*

The combined program of low-load resistance exercise, flexibility training, and mindfulness-based relaxation was associated with statistically significant gains in functional independence, as reflected in higher scores for Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) at post-test. Although the quasi-experimental design limits the ability to draw causal conclusions, the observed pattern of improvements aligns with the physical and psychological adaptations discussed previously.

The strength, flexibility, and balance gains documented in the chair stand, sit and reach, and hand grip tests provide a mechanical foundation for maintaining everyday autonomy. Prospective evidence indicates that faster chair stand times and stronger grip strength independently predict a reduced risk of future ADL and IADL dependence in older women [80, 81]. Therefore, the physical changes observed in this study likely translated into more efficient execution of basic self-care tasks such as dressing and bathing, as well as more complex activities like preparing meals and managing medications. Parallel improvements in psychological well-being, as discussed in the PWB section, may have further supported independence by enhancing self-efficacy, emotional regulation, and perceived control. Higher levels of psychological well-being have consistently been associated with sustained engagement in daily activities and greater resilience in coping with age-related challenges [9]. Mindfulness practice in particular strengthens intrinsic motivation and sense of purpose. These two factors mediate the relationship between psychological well-being and functional autonomy [82]. Growing evidence suggests that multicomponent programs integrating physical exercise with mindfulness result in greater improvements in functional independence compared with single-modality interventions [83]. The present findings are consistent with this pattern. Physiological adaptations may have made daily tasks physically easier to perform, while psychological gains likely increased participants' confidence and motivation to engage in those tasks. This combination helps explain the observed improvements in both ADL and IADL scores.

The 12-session mind and body program used in this quasi-experimental, community-based study was associated with small to moderate improvements in psychological well-being, functional performance (chair stand, sit and reach, grip strength), and self-reported independence (ADL and IADL) among community-dwelling older women. These outcomes likely reflect the deliberate combination of low-load resistance and flexibility exercises with mindfulness-based relaxation. This integrated approach targets both physical and

psychological domains, which previous studies have often examined separately. The sessions were conducted in a local community setting, required no specialized equipment, and achieved high attendance, suggesting that such programs can be implemented using modest resources. Outcomes were assessed using field-validated instruments that capture domains considered priorities for healthy ageing. All movements were maintained at a light intensity and were easily modifiable, which reduced the risk of injury while still producing measurable gains. Taken together, these features suggest that an integrated, low-cost program combining physical activity with mindfulness may provide a feasible option for promoting well-being and functional independence in similar non-clinical older adult populations.

Despite its strengths, several limitations of this study should be acknowledged. First, the use of a quasi-experimental pre-post design without a control group limits the internal validity of the findings and prevents definitive causal interpretations. Second, the study did not conduct an a priori power analysis to determine the optimal sample size, which may have reduced statistical power and limited the generalizability of the results. Third, important confounding factors such as dietary habits, medication use, and psychosocial stressors were not controlled, which could have influenced the outcomes. Additionally, the intervention lasted only four weeks, a period that may be insufficient to capture longer-term physiological or psychological adaptations. The absence of follow-up assessments further limits the ability to evaluate the sustainability of the observed effects. The lack of blinding in outcome assessment also introduces the possibility of measurement bias. Finally, the sample consisted exclusively of older adult women, which restricts the applicability of the findings to older men or mixed-gender populations.

To address the aforementioned limitations and advance this area of research, future studies should consider employing randomized controlled trial (RCT) designs to improve internal validity and enable causal inference, particularly in studies combining stretching, bodyweight exercise, and mindfulness

practice. Conducting a priori power analyses is also recommended to ensure sufficient sample size and statistical robustness. In addition, recruiting more diverse samples in terms of gender, age, and socio-demographic background would enhance the generalizability of findings. It is equally important to monitor or control potential confounding variables such as health status, medication use, and lifestyle behaviors. To better understand the underlying mechanisms, future controlled trials may incorporate physiological and neurocognitive measures such as electromyography, balance perturbation protocols, or neuroimaging. Extending intervention duration and conducting follow-up assessments would further clarify the long-term effects of integrated physical and mindfulness-based programs. Finally, future research should examine whether improvements in functional ability and psychological well-being mediate gains in independence. Advanced statistical techniques such as path analysis or structural equation modeling may help clarify these relationships and provide a more comprehensive explanatory framework.

## Conclusions

This quasi-experimental study demonstrated that a 12-session program combining low-impact stretching, bodyweight exercises, and mindfulness-based relaxation was associated with meaningful improvements in psychological well-being, functional capacity, and self-reported independence. The participants were community-dwelling older women. These findings suggest that integrating structured physical activity with mindfulness-based relaxation may be a feasible and low-cost strategy. Such an approach can help support overall well-being and functional autonomy in older adults.

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## Conflict of Interest

The authors declare no conflict of interest.

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### Information about the authors:

**Yulvia Miftachurochmah**; (Corresponding author); <https://orcid.org/0000-0002-2690-6762>; [yulviamifta@uny.ac.id](mailto:yulviamifta@uny.ac.id); Department of Health and Sport, Universitas Negeri Yogyakarta; Yogyakarta, Indonesia.

**Cerika Rismayanthi**; <https://orcid.org/0000-0002-6588-1983>; [cerika@uny.ac.id](mailto:cerika@uny.ac.id); Department of Sport Science, Universitas Negeri Yogyakarta; Yogyakarta, Indonesia.

**Rizki Mulyawan**; <https://orcid.org/0000-0002-0180-5025>; [rizkimulyawan@uny.ac.id](mailto:rizkimulyawan@uny.ac.id); Department of Sport Science, Universitas Negeri Yogyakarta; Yogyakarta, Indonesia.

**Gallant Pamungkas**; <https://orcid.org/0009-0002-6330-9649>; [gallantpamungkas.2022@student.uny.ac.id](mailto:gallantpamungkas.2022@student.uny.ac.id); Department of Sport Science, Universitas Negeri Yogyakarta; Yogyakarta, Indonesia.

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## **CONTACT INFORMATION**

Apt. 111, Blg. 8, Polyova Street, Kharkiv, 61068, Ukraine

e-mail: [sportart@gmail.com](mailto:sportart@gmail.com)

<https://sportpedagogy.org.ua>

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