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Dear Readers

We are pleased to present the March 2026 issue of the Montenegrin Journal of Sports Science and Medicine, which once again reflects the multidisciplinary strength and international character of our journal. The current volume brings together original scientific contributions spanning performance analysis in elite basketball and football, innovative applications of artificial intelligence in sport analytics, and position-specific physiological profiling in competitive athletes. In addition, this issue highlights clinically relevant research addressing exercise interventions for lumbar spinal stenosis, obesity management, sleep quality in collegiate athletes, and psychomotor therapy for children with autism spectrum disorder. The diversity of methodological approaches demonstrates the dynamic evolution of contemporary sport science and medicine. Collectively, these studies deepen our understanding of athletic performance, health optimization, rehabilitation strategies, and data-driven decision-making in sport. We extend our sincere appreciation to the authors, reviewers, and editorial board members whose expertise ensures the continued scientific quality and global relevance of our journal.

Finally, we warmly invite researchers, practitioners, and students to join us at the upcoming Annual Scientific Conference organized by the Montenegrin Sports Academy, which will be held in Budva, Montenegro (April 16–19, 2026), where we will continue fostering dialogue, collaboration, and innovation in sport science and medicine.

Editors

ORIGINAL SCIENTIFIC PAPER

Load Dynamics in Basketball: Insights from Wins and Losses

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Abstract

The purpose of the present study was to: determine differences in external and internal load in professional male basketball players between winning and losing game outcomes during official in-season games; identify differences in external and internal loads between backcourt and frontcourt players in both winning and losing games; and examine if load variables impact the Performance Index Rating (PIR). Using the performance monitoring system (Kinexon), 20 player load metrics were analysed for eight athletes. Paired sample t-tests or their nonparametric equivalents, independent sample t-tests or their nonparametric equivalents, and stepwise regression analysis were used to examine statistically significant differences and determine the association of load variables with PIR. The results revealed no significant differences between the winning and losing game outcomes in external and internal load metrics on a general and partial level. However, significant differences were observed between backcourt and frontcourt players in both winning and losing matches. Training impulse, average heart rate, and Sprints explained 53% (adjusted R^2=0.53, p<0.001) of the variance in PIR of backcourt players, while Accumulated Acceleration Load and number of Accelerations explained 46% (adjusted R^2=0.462, p=0.02) of the variance in PIR of frontcourt players. While player loads did not directly impact game outcomes, they did affect players' PIR and varied by playing position. These insights are valuable for the head coach and the team's strength and conditioning personnel and could aid in the development of tailored training programs to enhance player performance and recovery.

Keywords: *backcourt players, frontcourt players, PIR, Kinexon, performance analysis*

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Introduction

Monitoring training load is essential to maximize performance, prevent overreaching, and reduce injury risks (Aoki et al., 2017). Prioritizing the use of game-collected data is essential to accurately determine training loads, particularly for designing individually tailored training programs (Svilar et al., 2018). Obtaining the player load values for games is challenging due to various contextual factors influencing the game demands, such as game location (e.g., home or away) and game outcome (i.e., win or loss) (Fox et al., 2020). Previous research

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Conflict of interest: None declared.

on the external and internal load of basketball players has followed three main directions.

The first group of studies focused on the external and internal load of basketball players in various contexts (Fox et al., 2020; Sansone et al., 2021; Svilar et al., 2018). Fox et al. (2020) reported significant differences in player loads in away vs. home games, balanced vs. unbalanced, and wins vs. loses. Considering the influence of individual characteristics and contextual factors on game performance, Sansone et al. (2021) emphasized the significance of conditions where players experience high and low loads. High loads included being a guard, having high experience, medium minutes per game, during the early season, and their combinations, while low loads meant situations like low minutes per game or facing a high-level upcoming opponent.

The second group of scientific articles has examined the differences between backcourt (i.e., guards) players and frontcourt (i.e., forwards and centers) players in their external and internal load (Salazar et al., 2020; Vázquez-Guerrerol et al., 2018; Williams et al., 2021). Vázquez-Guerrero1 et al. (2018) emphasized the greater importance of deceleration over accelerations in basketball players, whereby frontcourt players exhibited higher acceleration-to-deceleration ratio of over 3 m/s2. Using the principal component analysis, Salazar et al. (2020) found that components of external load rank differently between playing positions, with accelerations and decelerations being the most dominant. Williams et al. (2021) found that frontcourt players experienced greater external and internal loads in games compared to training. Authors concluded that position specific strategies may be needed to optimize players performance. The third group of studies investigated the impact of various player performances on the Performance Index Rating (PIR) (Fox et al., 2022; Sansone et al., 2021; Zarić et al., 2018).

To the best of our knowledge, there is a lack of research addressing external and internal load of professional basketball players in official winning vs. losing matches. Therefore, the first aim of this study was to determine whether there are differences in the external and internal load of professional male basketball players in winning and losing matches. The second aim was to identify differences between backcourt players and frontcourt players in the external and internal load in winning and losing matches. The third aim was to investigate whether the variables of external and internal load influence the PIR of basketball players in winning and losing matches. Accordingly, we hypothesized that there would be no significant differences in any selected variables of external and internal load in winning and losing matches; that backcourt and frontcourt players would not differ in the external and internal load in winning and losing matches; and that there would be an impact of external and internal load on the PIR of basketball players in winning and losing matches.

Methods

A prospective observational research design was adopted to examine external and internal load of an elite male basketball team playing in the Hungarian First League Championship. Data were collected using the Kinexon System (KINEXON Precision Technologies, Munich, Germany) during eight home games (i.e., wins = 5, losses = 3) of the 2023/2024 season, from October to January. Kinexon is an ultra-wideband local positioning system (LPS) with sub-10 cm accuracy and 20 ms latency. It offers over 300 real-time metrics by pairing wearable sensors with Wi-Fi-connected anchors. Utilizing ultra-wideband signals, its small sensors track players' real-time positions with the frequency of 20Hz. The system precisely measures 2D and 3D movements, directional changes, and performance/load metrics for all players. Its validity and reliability were shown to be acceptable (Fleureau et al., 2020; Gamble et al., 2023). Players wore inertial measurement unit sensors in a manufacturer-designed vest, on their back, and a Suunto sensor to deliver data of heart rate changes. System was set to measure movements on the court not on the bench, while heart rate sensor data were collected both on the bench and on the court during the whole training session or game. The ethical approval was obtained by a Human Research Ethics Committee of the Faculty of Physical Education and Sports, University of Banja Luka (No. 11/505-2/23). The study is conducted following the Helsinki Declaration (Williams, 2008).

Subjects

Data from eight male professional basketball players (mean±SD, age = 24.5±4.8 years; height = 199.2±7.6 cm; body mass = 95.4±10.8 kg) in the Hungarian Basketball League 2023/2024 Championship were analysed. All athletes were cleared for participation in training and competition by their respective medical and strength and conditioning staff. None of the players participated in the observed games while sick or injured. Only athletes that played >8 min per game were included in the study analysis procedures. This was recommended by the head coach as players who played <8 min per game typically involved young players with specific roles or those in recovery, neither of whom significantly contributed to the team (2.44% of total playing time). Following Russell et al. (2020), players were classified as frontcourt players (n = 3; centers) and backcourt players (n = 5; forwards and guards).

Procedures

Kinexon is an ultra-wideband local positioning system (LPS) with sub-10 cm accuracy and 20 ms latency. It offers over 300 real-time metrics by pairing wearable sensors with Wi-Fi-connected anchors. Utilizing ultra-wideband signals, its small sensors track players' real-time positions with the frequency of 20Hz. The system precisely measures 2D and 3D movements, directional changes, and performance/load metrics for all players. Its validity and reliability were shown to be acceptable (Blauberger et al., 2021; Gamble et al., 2023). Players wore inertial measurement unit sensors in a manufacturer-designed vest, on their back, and a Suunto sensor to deliver data of heart rate changes. System was set to measure movements on the court not on the bench, while heart rate sensor data were collected both on the bench and on the court during the whole training session or game.

Variables

The following variables were analysed:

Distance Covered

Player's total distance covered during the game (Distance [m]) was calculated as the sum of minimum distances

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updated within a minimum time frame of 0.5 meters and 1.0 second intervals. The distance covered was relativized to time (Distance [m/min]) to provide an indication of player's locomotion intensity.

On-court Speed

The speed of a player was collected at each single instant of time based on the differentiation of filtered positions. Average running speed ($Speed_{Avg}$ [km/h]) and maximum running speed ($Speed_{Max}$ [km/h]) during the game were extracted for the analysis.

Number of Sprints

A sprint event was triggered when a player maintains a speed over a given speed threshold during a minimum duration. Speed threshold was 15.12 km/h and the minimum duration was 0.5 s. A total number of sprints (Sprint [No]) and relativized number of sprints per minute spent on the court (SprintsN [No/min]) were extracted for the analysis.

Acceleration and Deceleration events

Acceleration and deceleration events occurred when a player sustained acceleration above a threshold (1.5 m/s^2) for a minimum duration of 0.5 seconds. For this study, we extracted total counts of accelerations (Accelerations [No]) and decelerations (Decelerations [No]), as well as their respective rates per minute ($Accelerations_N$ [No/min] and $Decelerations_N$ [No/min]). The maximum deceleration of the player (Deceleration max [m/s^2]) was calculated by performing filtering and double differentiation of position data.

Accumulated Acceleration Load

This metric provides the accumulated load of the player during the entire game (Boyd et al., 2011). It adds up the differentials of accelerometer data in a single number, providing an overview of the load of the player produced by 2D-motion, jumps, impacts. The instantaneous acceleration load is based on the player load formula defined elsewhere (Boyd et al., 2011).

Number of Jumps

This variable assesses the total number of jumps (Jumps [No]) and relativized number of jumps (JumpsN [No/min]) during the player's in-game time. Each jump exceeding a minimum airtime is detected via accelerometer data, accurately pinpointing the start and end of the jump. Jump height can be computed from airtime using the formula: Height = (0.5g * airtime + (height difference between take-off and landing height / airtime))^2 / 2g. The minimum airtime was 0.3s.

Jump Load per Player's Body Mass

The energy estimation is based on the jump height for each individual jump. The jump load of a single jump is calculated using the potential energy formula: Jump Load (J/kg) = gravity constant * jump height. Jump Load (J) = mass of the player in kg * gravity constant * jump height. The jump load of every single jump performed by a player is added to yield an overall jump load for that player.

Heart rate

The heart rate data for each player is measured by Suunto sensors worn in the Kinexon vest. Average values (HRavg [b/min]) obtained during the game were assessed. In addition, heart rate relative to the personal maximal value (HRmax [%]) obtained on treadmill at the beginning of season was also calculated for each game. We updated the values if the measured maximum heart rate was higher for more than three times.

Training Impulse

We used Training Impulse (TRIMP) as an indicator of overall game load and metabolic functionality (Stagno et al., 2007). The TRIMP formula is the following: fractionalElevation = (HRi - HRmin) / (HRmax - HRmin) TRIMP = SUM (0.1225 * e3.9434 * fractionalElevation) * sessionTime where: "HRi" is the instantaneous (current) heart rate of the player (in bpm); "HRmin" is the minimum heart rate of the player (in bpm;) "HRmax" is the maximum heart rate of the player (in bpm); "sessionTime" is the duration of the training/game in minutes (Stagno et al., 2007).

Statistical analyses

Statistical procedures were performed using JASP statistical software (v 0.18.1, University of Amsterdam, Netherlands). The descriptive statistics were shown for mean, standard deviation, minimum, and maximum. The Shapiro-Wilk test was performed to test the normality of data distribution. For variables with violated normality of distribution, non-parametric tests were performed. The difference between games won and games lost was tested using the paired sample t-test (Wilcoxon signed-rank for non-parametric data). An independent sample t-test (Mann-Whitney test for non-parametric data) was used to test the differences between backcourt and frontcourt players. The regression analysis with stepwise model was utilized to determine the association of external and internal load variables with PIR. This model was selected to reduce the number of variables to those that best predict the PIR. The significance was set at $p<0.05$. The effect sizes were calculated for differences (Cohen's d) as $d < 0.2$ (trivial), d = 0.2-0.5 (small), d = 0.5-0.8 (moderate), 0.8-1.2 (large), and $d > 1.2$ (large) and for the coefficient of determination (r^2) as r^2 = 0.04-0.25 (small), r^2 = 0.25-0.64 (moderate), and $r^2 > 0.64$ (large) (Sullivan & Feinn, 2012). G*Power (v 3.1.9.4, Kiel University, Germany) was used to determine the required effect size for the given sample size.

Results

There was no significant difference between winning and losing game outcomes in indicators of external and internal load on a general level (p = 0.5–0.95, d = 0.02–0.37), as well as on a partial level. The descriptive statistics for won and lost games are presented in Tables 1 and 2, respectively. The normality of distribution was violated for PIR, Jumps, and HRmax in games lost; and for PIR, Jumps, JumpLoadPerMass, and HR in games lost. Thus, the non-parametric statistical tests were used for those variables. The effect size analysis also did not indicate difference of considerable size in these indicators (Cohen's d = 0.01–0.37). Considering the difference between the backcourt and frontcourt players in winning and losing matches, significant differences occurred in a number of variables (Table 1 and Table 2).

The stepwise regression analysis determined significant association of external and internal load indicators with the

Table 1. Descriptive statistics and between-position differences for games won.

Group Descriptives	Backcourt players		Frontcourt players		p	d	95% CI for d	
	Mean	SD	Mean	SD				
PIR	9	9.27	20.31	7.3	p < 0.001	-1.29	-1.97	-0.59
Distance (m)	3761	1346.33	5030.85	1083.47	p < 0.001	-0.99	-1.66	-0.31
DistanceN (m/min)	71.06	6.19	68.69	3.07	0.2	0.43	-0.22	1.07
$Speed_{Avg}$ (km/h)	4.27	0.38	4.12	0.18	0.18	0.45	-0.2	1.09
$Speed_{Max}$ (km/h)	24.22	1.95	23.77	0.94	0.43	0.26	-0.38	0.9
Sprints (No)	38.65	16.81	37.69	5.86	0.84	0.06	-0.57	0.7
$Sprints_N$ (No/min)	0.73	0.22	0.53	0.12	p < 0.001	1.02	0.34	1.69
Accelerations (No)	338.12	122.58	455	102.38	p < 0.001	-0.99	-1.66	-0.32
$Accelerations_N$ (No/min)	6.39	0.55	6.2	0.32	0.25	0.38	-0.26	1.03
Decelerations (No)	323.21	116.11	425.15	90.65	p < 0.001	-0.93	-1.59	-0.26
$Decelerations_N$ (No/min)	6.12	0.6	5.81	0.39	0.09	0.56	-0.09	1.21
$Deceleration_{max}$ (m/s2)	-3.82	0.49	-3.46	0.37	0.02	-0.76	-1.42	-0.1
AccumAccelLoad (J)	375.87	132.19	489.2	95.38	p < 0.001	-0.92	-1.58	-0.25
$AccumAccelLoad_N$ (/min)	7.12	0.55	6.7	0.33	0.01	0.83	0.17	1.49
Jumps (No)	38.62	22.43	77	22.3	p < 0.001	-1.71	-2.44	-0.98
$Jumps_N$ (No/min)	0.7	0.23	1.05	0.15	p < 0.001	-1.66	-2.37	-0.92
JumpLoadPerMass (J/kg)	2.33	0.78	3.37	0.46	p < 0.001	-1.47	-2.17	-0.75
HRavg (bpm)	134.56	15.25	142.46	7.47	0.08	-0.58	-1.23	0.07
HRmax (bpm)	187.38	17.62	185.46	3.43	0.7	0.13	-0.51	0.77
HR% (% of max.)	68.38	7.33	73.23	5.93	0.04	-0.69	-1.35	-0.04
TRIMP	117.52	61.71	168.82	52.41	0.01	-0.86	-1.52	-0.2

Table 2. Descriptive statistics and between-position differences for games lost.

Variables	Backcourt players		Frontcourt players		p	d	95% CI for d	
	Mean	SD	Mean	SD				
PIR	7.05	16.43	7.44	14.22	0.03	-0.99	-1.88	-0.07
Distance (m)	3423.9	1111.24	4593.14	1257.56	0.03	-1.02	-1.91	-0.1
$Distance_N$ (m/min)	72.05	9.11	66.57	4.58	0.14	0.66	-0.22	1.54
$Speed_{Avg}$ (km/h)	4.32	0.55	3.99	0.27	0.14	0.66	-0.22	1.54
$Speed_{Max}$ (km/h)	23.82	1.89	24.26	1.07	0.57	-0.25	-1.12	0.61
Sprints (No)	37.75	17.12	35.71	8.48	0.77	0.13	-0.73	0.99
$Sprints_N$ (No/min)	0.8	0.29	0.53	0.11	0.03	1.03	0.11	1.93
Accelerations (No)	304.35	103.3	420.29	112.84	0.02	-1.1	-2	-0.18
$Accelerations_N$ (No/min)	6.37	0.73	6.1	0.48	0.38	0.39	-0.48	1.25
Decelerations (No)	288.25	98.25	400.57	113.04	0.02	-1.1	-2	-0.18
$Decelerations_N$ (No/min)	6.04	0.8	5.77	0.42	0.4	0.37	-0.5	1.24
$Deceleration_{max}$ (m/s2)	-3.55	0.45	-3.52	0.48	0.87	-0.07	-0.93	0.79
AccumAccelLoad (J)	341.54	112.59	460.11	130.61	0.03	-1.01	-1.91	-0.1
$AccumAccelLoad_N$ (/min)	7.17	0.86	6.63	0.33	0.13	0.69	-0.2	1.57
Jumps (No)	35.3	15.34	66.86	25.32	p < 0.001	-1.73	-2.7	-0.73
$Jumps_N$ (No/min)	0.73	0.18	0.95	0.17	0.01	-1.19	-2.1	-0.26
JumpLoadPerMass (J/kg)	2.43	0.64	3.01	0.42	0.03	-0.98	-1.88	-0.07
HRavg (bpm)	134.25	12.49	138.86	18.23	0.46	-0.33	-1.19	0.54
HRmax (bpm)	188.2	13.11	172.43	29.89	0.06	0.85	-0.05	1.73
HR% (% of max.)	68	7.53	71.43	11.9	0.38	-0.39	-1.25	0.48
TRIMP	102.45	42.75	179.77	61.66	p < 0.001	-1.61	-2.57	-0.63

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PIR (adjusted $R^2 = 0.58$, $F = 26.61$, $p = 0.01$). The best model of prediction included TRIMP, Jumps, HRavg, and Sprints. However, considering that backcourt and frontcourt players were different in most of the variables and produced different PIR, the regression analysis was performed for each group separately as well. In both groups, external and internal load indicators were significant predictors of PIR (Figure 1). The prediction coefficients and multicollinearity are shown in Table 3. The regression analysis for backcourt players showed that 53% of the variation in PIR is determined by TRIMP, HRavg, and Sprints (adjusted $R^2 = 0.53$, $F = 20.890$, $p < 0.001$). Somewhat lower association was found in in frontcourt players (adjusted $R^2 = 0.462$, $F = 9.148$. $p = 0.02$) with 46% of explained variance in PIR by AccumAccelLoad and Accelerations_N. The variance inflation factor was indicated acceptable multicollinearity.

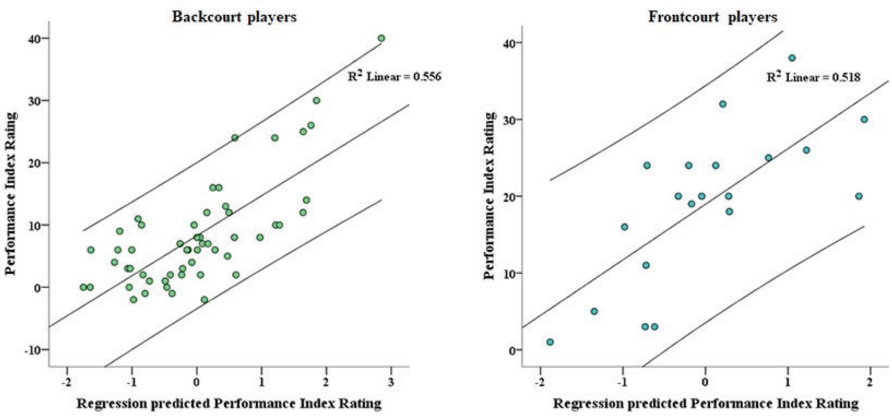

Figure 1. Scatterplot for backcourt and frontcourt players.

Table 3. Regression coefficients for perimeter and post players.

Model		Unstandardized coefficients		95% confidence interval		VIF
		B	Std. Error	Lower Bound	Upper Bound	
All players combined	(Constant)	-36.19***	9.76	-55.67	-16.72	
	TRIMP	0.05*	0.02	0.01	0.10	3.2
	Jumps	0.11*	0.05	0.01	0.20	2.6
	HRavg	0.31***	0.09	0.13	0.49	2.6
	Sprints	-0.17*	0.07	-0.32	-0.03	1.9
Perimeter players	(Constant)	-39.92	9.82	-59.65	-20.19	
	TRIMP	0.08***	0.02	0.04	0.12	1.8
	HRbpm	0.34***	0.09	0.16	0.52	2.4
	Sprints	-0.17*	0.07	-0.32	-0.02	2.4
Post players	(Constant)	53.95	29.20	-7.65	115.55	
	AccumAccelLoad	0.06**	0.02	0.02	0.09	1.0
	AccelerationsN	-10.10*	4.52	-19.64	-0.55	1.0

Note: *Significant at $p < 0.05$, **Significant at $p < 0.01$, ***Significant at $p < 0.001$. VIF - variance inflation factor.

Discussion

The purpose of the present study was to: a) determine differences in external and internal load in professional male basketball players between winning and losing game outcomes during official in-season games, b) identify differences in external and internal loads between backcourt and frontcourt players in both winning and losing games, and c) examine if external and internal load variables impact the PIR. Key findings suggest that player loads have no impact on game outcomes (i.e., wins vs. losses). However, significant differences were present in loads and PIR between player positions, supporting the initial two study's hypotheses. Furthermore, a significant association was found between player loads and performance (PIR), with load indicators varying across positions, confirming the third study hypothesis.

Given the absence of statistically significant distinctions across the 20 analysed indicators suggests that alternative determinants such as caliber of adversaries, psychological variables, and technical-tactical facets may have wielded a substantial impact on game outcomes. This is not unexpected, given the level of athletes examined in the present investigation (i.e., Hungarian First League). This suggests that players from the present study provided their best physical performance regardless of winning or losing and that this context did not play a role in players' commitment. In the investigation conducted by Ferioli et al. (2021), the internal workloads, as quantified through subjective session rating of perceived exertion (s-RPE), remained unchanged ($p > 0.05$) between playoff matches and regular season encounters. Notably, their cohort of athletes comprised professional basketball players from the First Italian League, suggesting a consistent level of effort across competitive phases due to their vocational commitment. Con-

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versely, the findings by Koyama et al. (2024) revealed playing against stronger opponents produced higher external load, a trend not observed in our investigation. Intriguingly, the internal loads assessed via RPE were lower following matches against stronger teams compared to those against weaker ones. It is essential, however, to note that the participants in Koyama et al. (2024) study were collegiate-level players, potentially introducing variability due to their ongoing development and not yet reaching peak basketball performance.

Considering both backcourt and frontcourt players, it can be noted that the team analysed in this study exhibited certain specificities. Frontcourt players exhibited heightened involvement across a spectrum of performance metrics in both winning and losing scenarios. Despite occasional superior performance by guards, it is evident that frontcourt players carried a greater workload during gameplay. Frontcourt players covered a greater distance than backcourt players in both winning and losing matches, but there were no significant differences between them in distance covered per minute. Of note is that the distance covered by our sample was greater than that of the Spanish ACB league team analysed by Feu et al. (2023) but lower than in players analysed by Puente et al. (2017). This indicates that the basketball players in our study were on par with the top European teams in distance covered. In terms of speed measures, significant differences in SprintsN favour backcourt players in both winning and losing matches, which is not surprising considering the nature of their playing position (Stojanović et al., 2018).

The acceleration and deceleration data did not show consistent findings and preclude conclusions about activities related to accelerations and decelerations. This is in contrast with the findings of Vázquez-Guerrerol et al. (2018) and Salazar et al. (2020), who unequivocally state that backcourt players have higher player load in games. Conversely, frontcourt players performed better in all three jump variables in both winning and losing matches, which is consistent with their tasks in the game (Gamonales et al., 2023; Ibáñez et al., 2023). Compared to backcourt players, frontcourt players achieved higher values of HR% in winning games, as well as TRIMP in both winning and losing matches. TRIMP, as a measure of player exhaustion, further proves that frontcourt players of this team were more engaged than backcourt players. Modern basketball tactics impose numerous tasks on centers including sprinting in offense and defence, pick-and-roll play, and offensive and defensive rebounds. Within the highest levels of basketball, evidence suggests that the most efficient players tend to expend the least energy to achieve the most productive results (Caparrós et al., 2018; Sampaio et al., 2015). Thus, frontcourt-players seem to be more efficient in our team.

In the present investigation, it has been found that PIR correlated with both external and internal load indicators. When considering the entire team, TRIMP, Jumps, HRavg, and Sprints emerged as the most significant predictors of PIR. This information holds particular importance for team data analysts and head coaches. Given the distinct roles and physical demands placed on backcourt and frontcourt players, we conducted separate regression analyses, offering valuable insights for strength and conditioning coaches as well. TRIMP emerged as the most influential predictor of PIR for backcourt players. This suggests that the ability to tolerate or delay exhaustion played a crucial role in achieving higher PIR among backcourt players. Additionally, HRavg and the number of sprints during the game were identified as significant predictors. These parameters collectively reflect repeated sprint ability (Girard et al., 2011; Rodríguez-Fernández et al., 2019), indicating that superior cardiac function and the capacity for repetitive sprinting contributed to higher PIR. For frontcourt players, Accumulated Acceleration Load, representing metabolic work, emerged as a crucial factor influencing PIR. Notably, the frequency of accelerations was the second-best predictor of PIR. This underscores the importance of both the frequency of accelerations and the ability to either recover quickly or withstand performance fatigue (Edwards et al., 2018; Enoka & Duchateau, 2016) while executing on-court tasks for frontcourt players' PIR.

In summary, this study investigated external and internal load variations in basketball games between winning and losing game outcomes, as well as differences among backcourt and frontcourt players, aiming to establish associations with overall basketball performance. The findings suggest that while player loads do not directly impact game outcomes, they do correlate with player's PIR and vary across player positions. Our analysis identified TRIMP, Jumps, HRavg, and Sprints as significant predictors of PIR for the entire team. Separate regression analyses for backcourt and frontcourt players revealed distinct factors influencing PIR. For backcourt players, TRIMP, HRavg, and sprint frequency were crucial, emphasizing the importance of endurance and repeated sprint ability. On the other hand, Accumulated Acceleration Load and acceleration frequency emerged as key factors influencing PIR for frontcourt players, highlighting the importance of metabolic work and the ability to withstand performance fatigue. These insights are valuable for team management staff, and strength and conditioning practitioners, and can aid in the development of tailored training programs to enhance player performance and recovery. The statistical approach in the present study also offers a framework to navigate among the large number of variables that come from the player monitoring system.

Lastly, a limitation inherent in this study pertains to its reliance on a singular team for analysis, thereby restricting the generalizability of the findings and subsequent implications to other teams. However, it does provide the methodology on how to analyse a single team. It is advisable for future investigations to engage in concurrent longitudinal surveillance of multiple teams during matches, facilitating comparative analyses. The integration of internal-external load monitoring with PIR emerges as a promising methodology for assessing player quality, potentially representing an optimal or advantageous approach. Further research is warranted to determine if the findings of the present study are sex-specific (male vs. female) as well as if they remain applicable to other levels of basketball competition (e.g., collegiate).

Conclusions and practical application

The findings of this study offer several practical applications for basketball coaches, strength and conditioning practitioners, and sports scientists. Firstly, basketball coaches could use the proposed methodology to detect the main indicators of PIR in their team and individual players. This would help them design tailored training programs based on position-specific insights. Secondly, load management strategies could be optimized by monitoring key load indicators that emerged as game-important. For instance, in this study, to optimize game

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performance TRIMP, HRavg, sprint frequency for backcourt players, and Accumulated Acceleration Load, acceleration frequency for frontcourt players were of importance. In teams with different player characteristics different indicators could be of importance, which could be accounted for using the methodology from the present study. Thirdly, coaches could develop game plans and tactics that leverage the strengths of each player position, informed by their game workload and performance characteristics.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aoki, M. S., Ronda, L. T., Marcelino, P. R., Drago, G., Carling, C., Bradley, P. S., & Moreira, A. (2017). Monitoring Training Loads in Professional Basketball Players Engaged in a Periodized Training Program. *The Journal of Strength & Conditioning Research*, *31*(2), 348. https://doi.org/10.1519/JSC.0000000000001507

Blauberger, P., Marzilger, R., & Lames, M. (2021). Validation of Player and Ball Tracking with a Local Positioning System. *Sensors*, *21*(4), Article 4. https://doi.org/10.3390/s21041465

Boyd, L. J., Ball, K., & Aughey, R. J. (2011). The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *International Journal of Sports Physiology and Performance*, *6*(3), 311–321. https://doi.org/10.1123/ijspp.6.3.311

Cabarkapa, D., Philipp, N. M., Cabarkapa, D. V., & Fry, A. C. (2023). Position-specific differences in countermovement vertical jump force-time metrics in professional male basketball players. *Frontiers in Sports and Active Living*, *5*, 1218234. https://doi.org/10.3389/fspor.2023.1218234

Cabarkapa, D. V., Cabarkapa, D., Eserhaut, D. A., & Fry, A. C. (2023). Relationship between internal and external load metrics in professional male basketball players. *Journal of Human Sport and Exercise*, *18*(4), Article 4. https://doi.org/10.14198/jhse.2023.184.01

Caparrós, T., Casals, M., Solana, Á., & Peña, J. (2018). Low External Workloads Are Related to Higher Injury Risk in Professional Male Basketball Games. *Journal of Sports Science & Medicine*, *17*(2), 289–297.

Edwards, T., Spiteri, T., Piggott, B., Bonhotal, J., Haff, G. G., & Joyce, C. (2018). Monitoring and Managing Fatigue in Basketball. *Sports*, *6*(1), Article 1. https://doi.org/10.3390/sports6010019

Enoka, R. M., & Duchateau, J. (2016). Translating Fatigue to Human Performance. *Medicine and Science in Sports and Exercise*, *48*(11), 2228–2238. https://doi.org/10.1249/MSS.0000000000000929

Ferioli, D., Scanlan, A. T., Conte, D., Tibiletti, E., & Rampinini, E. (2021). The Business End of the Season: A Comparison Between Playoff and Regular-Season Workloads in Professional Basketball Players. *International Journal of Sports Physiology and Performance*, *16*(5), 655–662. https://doi.org/10.1123/ijspp.2020-0405

Feu, S., García-Ceberino, J. M., López-Sierra, P., & Ibáñez, S. J. (2023). Training to Compete: Are Basketball Training Loads Similar to Competition Achieved? *Applied Sciences*, *13*(22), Article 22. https://doi.org/10.3390/app132212512

Fleureau, A., Lacome, M., Buchheit, M., Couturier, A., & Rabita, G. (2020). Validity of an ultra-wideband local positioning system to assess specific movements in handball. *Biology of Sport*, *37*(4), 351–357. https://doi.org/10.5114/biolsport.2020.96850

Fox, J. L., Stanton, R., O'Grady, C. J., Teramoto, M., Sargent, C., & Scanlan, A. T. (2022). Are acute player workloads associated with in-game performance in basketball? *Biology of Sport*, *39*(1), 95–100. https://doi.org/10.5114/biolsport.2021.102805

Fox, J. L., Stanton, R., Sargent, C., O'Grady, C. J., & Scanlan, A. T. (2020). *The Impact of Contextual Factors on Game Demands in Starting, Semiprofessional, Male Basketball Players*.

Gamble, A. S. D., Bigg, J. L., Pignanelli, C., Nyman, D. L. E., Burr, J. F., & Spriet, L. L. (2023). Reliability and validity of an indoor local positioning system for measuring external load in ice hockey players. *European Journal of Sport Science*, *23*(3), 311–318. https://doi.org/10.1080/17461391.2022.2032371

Gamonales, J. M., Hernández-Beltrán, V., Escudero-Tena, A., & Ibáñez, S. J. (2023). Analysis of the External and Internal Load in Professional Basketball Players. *Sports*, *11*(10), Article 10. https://doi.org/10.3390/sports11100195

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-sprint ability - part I: Factors contributing to fatigue. *Sports Medicine (Auckland, N.Z.)*, *41*(8), 673–694. https://doi.org/10.2165/11590550-000000000-00000

Ibáñez, S. J., Piñar, M. I., García, D., & Mancha-Triguero, D. (2023). Physical Fitness as a Predictor of Performance during Competition in Professional Women's Basketball Players. *International Journal of Environmental Research and Public Health*, *20*(2), 988. https://doi.org/10.3390/ijerph20020988

Koyama, T., Nishikawa, J., Yaguchi, K., Irino, T., & Rikukawa, A. (2024). A comparison of the physical demands generated by playing different opponents in basketball friendly matches. *Biology of Sport*, *41*(1), 253–260. https://doi.org/10.5114/biolsport.2024.129474

Puente, C., Abián-Vicén, J., Areces, F., López, R., & Del Coso, J. (2017). Physical and Physiological Demands of Experienced Male Basketball Players During a Competitive Game. *Journal of Strength and Conditioning Research*, *31*(4), 956–962. https://doi.org/10.1519/JSC.0000000000001577

Rodríguez-Fernández, A., Sanchez-Sanchez, J., Ramirez-Campillo, R., Nakamura, F. Y., Rodríguez-Marroyo, J. A., & Villa-Vicente, J. G. (2019). Relationship Between Repeated Sprint Ability, Aerobic Capacity, Intermittent Endurance, and Heart Rate Recovery in Youth Soccer Players. *The Journal of Strength & Conditioning Research*, *33*(12), 3406–3413. https://doi.org/10.1519/JSC.0000000000002193

Salazar, H., Castellano, J., & Svilar, L. (2020). Differences in External Load Variables Between Playing Positions in Elite Basketball Match-Play. *Journal of Human Kinetics*, *75*, 257–266. https://doi.org/10.2478/hukin-2020-0054

Sampaio, J., McGarry, T., Calleja-González, J., Jiménez Sáiz, S., Schelling I Del Alcázar, X., & Balciunas, M. (2015). Exploring Game Performance in the National Basketball Association Using Player Tracking Data. *PloS One*, *10*(7), e0132894. https://doi.org/10.1371/journal.pone.0132894

Sansone, P., Gasperi, L., Tessitore, A., & Gomez, M. (2021). Training load, recovery and game performance in semiprofessional male basketball: Influence of individual characteristics and contextual factors. *Biology of Sport*, *38*(2), 207–217. https://doi.org/10.5114/biolsport.2020.98451

Stagno, K. M., Thatcher, R., & van Someren, K. A. (2007). A modified TRIMP to quantify the in-season training load of team sport players. *Journal of Sports Sciences*, *25*(6), 629–634. https://doi.org/10.1080/02640410600811817

Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. *Sports Medicine*, *48*(1), 111–135. https://doi.org/10.1007/s40279-017-0794-z

Sullivan, G. M., & Feinn, R. (2012). Using effect size—Or why the *P* value is not enough. *Journal of Graduate Medical Education*, *4*(3), 279–282. https://doi.org/10.4300/JGME-D-12-00156.1

Svilar, L., Castellano, J., Jukic, I., & Casamichana, D. (2018). Positional Differences in Elite Basketball: Selecting Appropriate Training-Load Measures. *International Journal of Sports Physiology and Performance*, *13*(7), 947–952. https://doi.org/10.1123/ijspp.2017-0534

Vázquez-Guerrero, J., Suarez-Arrones, L., Casamichana Gómez, D., & Rodas, G. (2018). Comparing external total load, acceleration and deceleration outputs in elite basketball players across positions during match play. *Kinesiology*, *50.*(2.), 228–234. https://doi.org/10.26582/k.50.2.11

Williams, J. R. (2008). The declaration of Helsinki and public health. *Bulletin of the World Health Organization*, *86*(8), 650–652. https://doi.org/10.2471/BLT.08.050955

Williams, M. N. C., Dalbo, V. J., Fox, J. L., O'Grady, C. J., & Scanlan, A. T. (2021). Comparing Weekly Training and Game Demands According to Playing Position in a Semiprofessional Basketball Team. *International Journal of Sports Physiology and Performance*, *16*(6), 772–778. https://doi.org/10.1123/ijspp.2020-0457

Zarić, I., Dopsaj, M., & Marković, M. (2018). Match performance in young female basketball players: Relationship with laboratory and field tests. *International Journal of Performance Analysis in Sport*, *18*(1), 90–103. https://doi.org/10.1080/24748668.2018.1452109

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ORIGINAL SCIENTIFIC PAPER

Effects of an Individually Structured Exercise Program on Walking Ability in Patients with Lumbar Spinal Stenosis: A Pilot Study

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Abstract

A limited number of studies in our systematic review suggest that physical exercise may significantly enhance walking ability. Based on these findings, we developed an individualized exercise program primarily incorporating spinal stabilization exercises, mobility drills, and stretching techniques. The objective of this study was to assess the effects of a 12-week supervised and individually tailored exercise program on walking ability in patients with lumbar spinal stenosis (LSS). A total of 26 patients were included at baseline, with 13 randomly allocated to the experimental group and 13 to the control group. Participants underwent physical performance assessments, including the 6-Minute Walk Test (6MWT), the Sit and Reach Test, and McGill's Torso Muscular Endurance Test Battery. A general linear model with repeated measures was employed to analyse differences between groups. Although no statistically significant differences were observed between the experimental and control groups for the 6MWT (p = 0.069), a significant improvement was detected within the experimental group over time. Specifically, a notable increase in walking ability was observed between the first and final measurements (p = 0.001). However, a decline observed in the control group over time, may have influenced the between-group comparisons. While the results indicate significant improvements in walking ability and physical performance tests within the experimental group, it is too early to draw definitive conclusions due to the small sample size and a decline observed in the control group. These results warrant confirmation in larger randomized controlled trials examining long-term functional outcomes.

Keywords: *spinal stenosis, program, performance tests, walking ability, motivation*

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Introduction

Lumbar spinal stenosis (LSS) is a medical condition where the spinal canal narrows in the lower back (lumbar spine), putting pressure on the spinal cord and/or nerve roots. This can lead to pain, numbness, or weakness especially in the legs. The most common cause of lumbar spinal stenosis include degenerative changes and is a very common cause of pain, disability and loss of independence in older adults (Chow et al., 2019).

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Patients usually feel relief of pain when sitting or leaning forward (for example; leaning on shopping cart). As populations worldwide continue to grow older, increasing demand is to be expected on health care systems, including surgery-related resources (Marchand et al., 2021). There has been dramatic rise in spine surgery rates over recent decades, with spinal stenosis being the most common diagnosis associated with spinal surgery in adults over 60 years of age (Macedo et al., 2013). Lumbar spinal stenosis surgery is almost always an elective procedure. A referral for special investigations (advanced imaging, neurological and/or vascular investigations) and/or surgical consultation is recommended if the patient presents with severe intermittent claudication (walking less than 100 meters), new or progressive lower limb weakness, and failure to respond to an appropriate/intensive course of nonsurgical care, as determined by the patient's quality of life and expectations (Bussières et al., 2021; Dobkin, 2019). Although LSS is the most common reason for spine surgery in older adults, most people with neurogenic claudication receive non-operative care. It is also recommended prior to receiving surgical intervention. In an updated systematic review for non-operative treatments for LSS, there are explained evidences that mild to moderate cases often respond well to conservative care. Non-surgical management of lumbar spinal stenosis is generally recommended as the initial step of treatment due to its lower risk profile and cost-effectiveness. Conservative interventions—such as physical therapy can alleviate symptoms in many patients without exposing them to the inherent risks associated with surgical procedures (Ammendolia et al., 2022), but the remaining comparisons provide either low-quality or very low-quality evidence. This lack of evidence limited our ability to make conclusions on the effectiveness of most non-operative treatments.

It is the reason why aim of this pilot study was to develop and pilot an individually tailored 12- week experimental controlled program to compare with control group in which participants continue with their daily routines and usual care. Usual care also included any physiotherapy treatments through public health care. The main aim was to improve patient's daily step count average and walking distance of 6- Minute walk test.

There is now moderate evidence that a multimodal structured 6-week programme consisting of manual therapy and exercise with or without education is an effective treatment approach. A recent systematic review and meta-analysis of randomised controlled trials (RCTs) evaluating conservative therapies for LSS also concluded that manual therapy and supervised exercises significantly improve outcomes compared with self-directed or group exercises (Comer et al., 2024; Macedo et al., 2013; Marchand et al., 2021; Minetama et al., 2019). A multimodal approach to the treatment of LSS would appear to be a rational approach given the complexity of neurogenic claudication with underlying physical, functional and psychosocial factors impacting recovery (Ammendolia et al., 2022). The differing pathophysiology may require different treatment approaches (Bagley et al., 2019).

In the last systematic review from Comer et al. (2024) more than 75% exercise interventions of the included trials were supervised exercises, land-based exercises, some form of lumbar lordosis reducing/flexion-based exercises and some form of aerobic fitness exercises (walking, cycling, or general fitness). Exercise interventions which were included, were performed at least twice a week and lasted from 6-11 weeks. Supervised exercises were delivered once to twice weekly and home exercises prescribed daily or twice daily. With home exercises, the frequency of contact with clinicians varied widely. Studies published in the last 5 years were less likely to include passive modalities and more likely to include a psychologically informed approach. The treatment effects of various exercise intervention components varied across the three outcomes of symptom severity, physical function, and walking capacity. Research to date investigating physical activity is effective for improving pain and function. In the study Norden et al. (2017) preliminary data suggest that a pedometer-based physical activity intervention is effective for improving pain, mental health, and fat mass in people with LSS. The gaps in current non-operative interventions are lack of high-quality comparative evidence, heterogeneity in treatment protocols, limited long-term effectiveness, understudies patients stratifications and inadequate integration of multimodal approaches. Therefore, the aim of this pilot study was to evaluate how was our individually structured program successful when implemented it into practise.

Methods

Study design

This study was conducted as a pilot, single-centre, prospective, randomised, blind, controlled experiment.

Patients

Inclusion criteria for entering the study were: 1) age between 50 and 80 years, 2) a diagnosis of lumbar spinal stenosis (LSS) confirmed by magnetic resonance imaging (MRI), 3) clinical symptoms associated with LSS (neurogenic claudication), 4) the ability to reach the gold standard of walking distance (250 m), 5) being an appropriate candidate for LSS surgery as determined by an orthopaedic surgeon and 6) signed consent for participating in the study. Exclusion criteria were: 1) early onset of stenosis symptoms (disability to walk 250 m), 2) associated spinal defects (spondylolisthesis of a high degree), 3) vascular claudication, 4) diabetic polyneuropathy, 5) presence of a neurological disease affecting the patient's functionality, 6) patients with fibromyalgia or systemic inflammatory diseases.

All participants were patients of an orthopaedic department within a university hospital in Ljubljana and were invited over a telephone call to participate in the study. Twenty-six patients (17 women and 9 men) consented to participation. After the first measurements the randomization was done by Research Randomizer version 4.0 over Chrome.

This study was approved in advance by Ministry of Health, The Commission for Medical Ethics of the Republic of Slovenia. Each participant voluntarily provided written informed consent before participating.The effect size was calculated a priori, as this pilot study forms part of a doctoral research project. The number of subjects before randomization for the research should be 76 subjects, based on the calculated sample size. 38 in the control and 38 in experimental group. At the outset of the study, we selected 26 patients for inclusion in the initial group, which was designated as the pilot cohort. This pilot group was used to evaluate the feasibility of the study protocol, refine data collection procedures, and inform potential modifications for the larger-scale investigation.

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Interventions

Kinesiotherapy training and supervision

Participants were assigned to small, homogeneous groups of four individuals. Sessions were conducted twice per week at a movement studio.

During the first two weeks, training focused on body repositioning techniques to promote optimal posture and reduce lumbar lordosis. To facilitate adherence, participants were permitted to record exercise demonstrations on their mobile devices for reference during home practice. They were instructed to perform the prescribed exercises as frequently as necessary, with a minimum requirement of once per day.

Each session lasted between 60 and 75 minutes and included treadmill or outdoor walking as a warm-up, aimed at improving overall physical condition and increasing daily step count. Over the course of the 12-week intervention, exercises were progressively intensified by increasing repetitions, sets, or complexity, depending on individual progress. Previously introduced exercises were reviewed at each session, and new exercises were systematically incorporated. A maximum of three to six new exercises were introduced per session.

To enhance proprioception and movement awareness, various different accessories were utilized. The program emphasized not only physical conditioning but also the development of movement control and body awareness to support long-term symptom management and functional improvement.

Their abilities were measured at baseline, at 8 and 12 weeks using different parameters. In this pilot study we would like to verify if patient's step count, strength of the trunk stabilizers and flexibility improve over 12 weeks.

Walking-diary

As part of the intervention, participants systematically monitored their daily step count using a walking diary. Those who owned a smartwatch utilized it for step tracking, while others acquired different pedometers to record their daily walking activity. During the first week, participants documented their total daily step count and/or walking distance. This initial monitoring phase enabled us to assess participants baseline activity levels and identify individuals requiring additional guidance on walking strategies.

Based on established recommendations in the literature, participants whose baseline daily step count was fewer than 7,500 steps were classified as requiring additional intervention. During the first two weeks, these participants were instructed to progressively increase their baseline step count by at least 500 steps on a minimum of three days per week. Furthermore, they received structured guidance on optimizing their walking routine, including considerations regarding the timing, location, and potential walking companions.

In weeks three and four, participants were encouraged to increase their baseline step count by 500 steps on at least five days per week. In weeks five and six, the target was raised to an additional 1,500 steps on a minimum of three days per week. From the seventh to the twelfth week, participants were advised to further increase their baseline step count by 1,500 steps on at least five days per week. At the final assessment, participants reported their average step count for the last week of the program to evaluate overall improvements in physical activity levels.

Measurements

All measurements were performed at Faculty of Sports, University of Ljubljana. For the purpose of measurements, we required students from the Faculty of Sports to help us with patients. At each station, two students from the Faculty of Sports were assigned to conduct the test across all measurement sessions. This approach ensured that they were familiar with the test and helped prevent deviations in the results.

6- Minute walk test

The test was performed on 30 m long track with markings at 5 meters. The distance covered over a time of 6 minutes is used as the outcome by which to compare changes in performance capacity. If the participant stops at any time prior, they can also continue walking whenever they feel able.

Sit and reach test

This test is one of the linear flexibility tests which helps to measure the extensibility of the hamstrings and lower back. The distance reached is recorded to assess flexibility, with longer reaches indicating greater flexibility. We used the level of the feet as level zero, so that any measure that does not reach the toes is negative, and any reach past the toes is positive measure how far the participant reaches forward.

McGill's torso muscular endurance test battery

This test battery consists of 3 tests. Trunk flexor endurance test, trunk lateral endurance test on both sides and trunk extensors endurance test. They are all timed tests involving a static, isometric contraction of muscles, stabilizing the spine until the individual exhibits fatigue and can no longer hold the assumed position. Each individual test is not a primary indicator of current or future back problems. Stuart McGill has shown that the relationships among the tests are more important indicators of muscle imbalances that can lead to back pain.

Results

From September 2024 to December 2024, 8 of 26 participants did not complete the follow up. 7 of them were in control group and 1 in experimental group. All of them did not attend their second measurement. 3 of them did not provide a reason for withdrawal. Other reasons for declining enrolment included time and family commitments, other health issues or deterioration in their condition. See Figure 1 for the CONSORT diagram regarding patient flow through the study.

Table 1 demonstrates the baseline characteristics of all participants in comparison to outcome measures after 12-weeks program. Patients in experimental group using walking diaries (self-recorded using a pedometer) increased their daily step count by an average of 2572 steps per day which is significant improvement ($p = 0.002$), especially for people who start with a low baseline step count (Lang et al., 2021). As we see the results of 6-Minute walk test (6MWT, $p = 0.004$), the walking distance increased from 366 meters to 479 meters. Significant improvements were observed in flexibility (SART, $p = 0.038$), and core endurance (McGill tests, all $p < 0.05$). No significant change was found in BMI ($p = 0.812$), suggesting that body weight remained stable throughout the intervention. The largest improvements were in McGill flexors ($p = 0.001$) and 6MWT distance ($p = 0.004$), indicating significant gains in core endurance and walking ability.

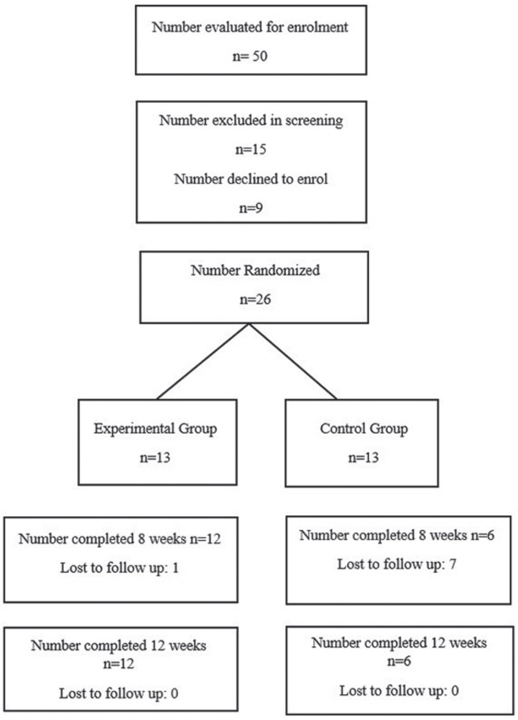

Figure 1. CONSORT Diagram

Table 1. Baseline comparison for personal, anthropometric and outcome measures

	Baseline (n=26) Mean (SD)	Outcome (n=18) Mean (SD)	p-value
Age	67.5 (6.33)	66 (3.23)	-
BMI (kg/m2)	30.94 (5.26)	30.70 (5.28)	0.812
Gender			
Female	17	11	
Male	9	7	
Daily steps	2748.69 (1123.44)	5320.75 (2761.91)	0.002
6-Minute Walk Test (6MWT, meters)	365.88 (109.99)	478.67 (97.52)	0.004
Sit and Reach Test (SART, cm)	11.11 (12.39)	16.93 (10.37)	0.038
McGill's Torso Muscular Endurance Test (seconds)			
Flexors	45.03 (36.67)	95.88 (54.39)	0.001
Extensors	28.02 (20.76)	50.57 (36.22)	0.012
Right side	31.73 (28.35)	56.26 (35.37)	0.015
Left side	32.67 (36.53)	56.48 (38.89)	0.019

Note. BMI: Body mass index

Table 2 demonstrates differences within control and experimental group for 6-Minute walk test. The experimental group shows consistent and significant improvement in walking performance over time. The control group shows some early improvement (1 to 2, p= 0,028), but over time there is no significant improvement (2 to 3, p= 0,388). The most significant improvement is between second and third measurement (p= 0,000) in experimental group, probably because from the seventh to the twelfth week, participants were advised to further increase their baseline step count by 1,500 steps on at least five days per week.

In Table 3 both groups improved early on (1 to 2), but only the experimental group shows sustained, statistically significant improvement from start to an end of the intervention (p= 0,000).

Table 2. Differences within groups: 6- Minute walk test

	p	
	Control Group	Experimental Group
6MWT_1& 6MWT_2	0.028	0.004
6MWT_2& 6MWT_3	0.388	0.000
6MWT_1& 6MWT_3	0.099	0.001

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Table 3. Differences within groups: Sit and reach test

	p	
	Control Group	**Experimental Group**
SART_1& SART_2	0.006	0.002
SART_2& SART_3	0.852	0.117
SART_1& SART_3	0.051	0.000

Table 4. Differences within groups: McGill flexors test

	p	
	Control Group	**Experimental Group**
Flex_1& Flex_2	0.552	0.392
Flex_2& Flex_3	0.023	0.001
Flex_1& Flex_3	0.120	0.001

In Table 4 there is only one significant change in control group between second and third measurement (p=0,023) and no significant long-term change. In experimental group there is no significant improvement between first and second measurement (p=0,392) probably because in first two weeks the intervention is more focused in body repositioning and not as much in strength improvement.

Table 5 demonstrates us significant improvements across all timepoints in experimental group. Participants in this study were presented with weak core extensor muscles due to their condition, the exercise program was primarily designed to target and strengthen the deep core musculature. Emphasis was placed on improving the stability and endurance of these foundational muscles to support overall functional movement and postural control (Lurie & Tomkins-Lane, 2016; Peterson et al., 2021).

Table 5. Differences within groups: McGill extensors test

	p	
	Control Group	Experimental Group
Exte_1& Exte_2	0.028	0.030
Exte_2& Exte_3	0.201	0.032
Exte_1& Exte_3	0.092	0.003

Table 6. Differences within groups: McGill right and left side plank test

	p	
	Control Group	**Experimental Group**
Rside_1& Rside_2	0.170	0.001
Rside_2& Rside_3	0.771	0.172
Rside_1& Rside_3	0.511	0.010
Lside_1& Lside_2	0.192	0.005
Lside_2& Lside_3	0.750	0.235
Lside_1& Lside_3	0.323	0.018

In Table 6 the experimental group showed clear and statistically significant core strength improvements on both sides over time, especially early on, on the right side (p= 0,001) and on the left side (p=0,005). The control group didn't show any significant changes. This pattern aligns with what we can see in results of all tables above: the experimental intervention appears to be effective, with early gains that are sustained over time.

Discussion

The main aim of the present pilot study was to investigate whether patients could improve their walking distance after having completed a walking program. The results of the present study demonstrate that the program indeed improved all performance parameters. The average maximum walking distance (6- Minute walk test) improved from 366 m to 479 m, and as reported in the diaries from 2749 to 5321 steps per day. Mean daily baseline step count was similar to values reported in a systematic review on pedometer interventions for chronic low back pain which ranged from 2337 to 5563 steps (Vanti et al., 2019) and is similar to the step count findings published by McDonough et.al (2010). The second aim of the study was to assess whether a personalized and progressively advanced exercise program would lead to improvements in patient's flexibility and core strength. Significant improvements were observed in flexibility (SART, $p = 0.038$), and core endurance (McGill tests, all $p < 0.05$). To date, no studies have been identified that directly compare the same assessment tests as those employed in our pilot study. To our knowledge, this is the first pilot study comparing individually tailored program which includes also walking program and structured home-based exercises compared with usual care or no treatment. All other studies evaluating non-operative interventions provided insufficient quality evidence (Ammendolia et al., 2022). The majority of exercise interventions in the trials we reviewed relied on theoretical rationales. These rationales include theory-driven recommendations of flexion-based/lordosis-reducing exercises and trunk muscle control exercises for relieving the posture-related symptoms of lumbar spinal stenosis and neurogenic claudication. Despite these limitations, non-operative treatments are often justified based on their biomechanical and functional rationale. Targeted physical therapy and exercise programs aim to improve lumbar spine stability, posture, and muscular support, thereby reducing mechanical compression on neural structures. Additionally, interventions that promote pelvic alignment, core strengthening, and improved gait mechanics can alleviate neurogenic claudication and enhance functional capacity without directly altering anatomical stenosis. However little or no detail was provided to explain the selection of specific exercise intervention parameters and components (Chow et al., 2019; Comer et al., 2024; Marchand et al., 2021; Minetama et al., 2019).

Limitations

This pilot study had several limitations. The sample size was relatively small due to challenges in patient recruitment, which included strict eligibility criteria, limited patient availability, and reluctance to participate. Probably because of older population who is less willing to change their daily routine. We also have some logistical issues because measurement sessions and intervention were executed in Ljubljana and recruited patients were from all over the Slovenia. Additionally, an unexpected decline in the control group potentially introduced bias and affected the comparability of the results.

Despite its limitations, this study has several strengths. It provides valuable insights into characteristics of lumbar spinal stenosis patients, their symptoms and overall physical condition including ability to walk, flexibility and core muscles strength. Additionally, the findings offer potential clinical implications, which will guide a future research and improve patient care. Our intention is to include more patients in research, but due to the unexpected decline in the control group we first need new strategies to retain patients in the study. We start with regular check-ins which include phone calls, emails or short in-person meetings to give them full support. We try with motivation techniques as providing positive reinforcement and emphasizing their importance in the study. We are also offering them individual consultations to teach them some exercises which they can perform at home. One part of new strategy is also delayed intervention. We inform them that they will have access to the full exercise program after the study concludes.

Conclusion

The pilot study results suggest that the programme is feasible, acceptable, and potentially useful for improving walking capacity, flexibility and core muscles strength. Further work is needed to assess the clinical differences between control and experimental group and larger sample size to give more reliable subgroup analysis. This study supports the feasibility of individualized structured exercise programs in improving functional outcomes in LSS and highlights the need for their integration in conservative management pathways. Enhancing these physical parameters can improve functional mobility, reduce pain, and potentially delay or avoid surgical intervention. A structured, individualized approach may offer superior outcomes compared to generic physiotherapy or unsupervised activity. By comparing against real-world standard care, this study provides practical evidence on whether personalized programs offer added value in typical clinical settings, supporting informed decision-making in treatment planning. The overarching aim of this research is to contribute to the alleviation of burden on the healthcare system by supporting the implementation of effective non-operative treatment strategies for lumbar spinal stenosis in clinical practice. By demonstrating the feasibility and potential benefits of conservative management, this study seeks to promote evidence-based, accessible, and cost-effective care pathways for patients with degenerative spinal conditions.

References

Ammendolia, C., Hofkirchner, C., Plener, J., Bussières, A., Schneider, M. J., Young, J. J., Furlan, A. D., Stuber, K., Ahmed, A., Cancelliere, C., Adeboyejo, A., & Ornelas, J. (2022). Non-operative treatment for lumbar spinal stenosis with neurogenic claudication: an updated systematic review. *BMJ Open*, *12*(1). https://doi.org/10.1136/BMJOPEN-2021-057724

Bagley, C., Macallister, M., Dosselman, L., Moreno, J., Aoun, S., & Ahmadieh, T. El. (2019). Current concepts and recent advances in understanding and managing lumbar spine stenosis [version 1; referees: 3 approved]. *F1000Research*, *8*, 1–9. https://doi.org/10.12688/f1000research.16082.1

Bussières, A., Cancelliere, C., Ammendolia, C., Comer, C. M., Zoubi, F. Al, Châtillon, C. E., Chernish, G., Cox, J. M., Gliedt, J. A., Haskett, D., Jensen, R. K., Marchand, A. A., Tomkins-Lane, C., O'Shaughnessy, J., Passmore, S., Schneider, M. J., Shipka, P., Stewart, G., Stuber, K., … Ornelas, J. (2021). Non-Surgical Interventions for Lumbar Spinal Stenosis Leading To Neurogenic Claudication: A Clinical Practice Guideline. *Journal of Pain*, *22*(9), 1015–1039. https://doi.org/10.1016/j.jpain.2021.03.147

Chow, N. W., Southerst, D., Wong, J. J., Kopansky-Giles, D., & Ammendolia, C. (2019). Clinical Outcomes in Neurogenic Claudication Using a Multimodal Program for Lumbar Spinal Stenosis: A Study of 49 Patients With Prospective Long-term Follow-up. *Journal of Manipulative and Physiological Therapeutics*, *42*(3), 203–209. https://doi.org/10.1016/j.jmpt.2018.11.004

Comer, C., Williamson, E., McIlroy, S., Srikesavan, C., Dalton, S., Melendez-Torres, G. J., & Lamb, S. E. (2024). Exercise treatments for lumbar spinal stenosis: A systematic review and intervention component analysis of randomised controlled trials. *Clinical Rehabilitation*, *38*(3), 361–374. https://doi.org/10.1177/02692155231201048

Dobkin, B. H. (2019). Provocative Walking Test of Strength for Diagnosis, Management, and Outcome Assessment of Symptomatic Lumbar Spinal Stenosis. *Neurorehabilitation and Neural Repair*, *33*(12), 1003–1007. https://doi.org/10.1177/1545968319876256

Lang, A. E., Hendrick, P. A., Clay, L., Mondal, P., Trask, C. M., Bath, B., Penz, E. D., Stewart, S. A., Baxter, G. D., Hurley, D. A., McDonough, S. M., & Milosavljevic, S. (2021). A randomized controlled trial investigating effects of an individualized pedometer driven walking program on chronic low back pain. *BMC Musculoskeletal Disorders*,

DOI 10.26773/mjssm.260302

22(1). https://doi.org/10.1186/S12891-021-04060-8

Lurie, J., & Tomkins-Lane, C. (2016). Management of lumbar spinal stenosis. *BMJ (Online)*, *352*. https://doi.org/10.1136/bmj.h6234

Macedo, L. G., Hum, A., Kuleba, L., Mo, J., Truong, L., Yeung, M., & Battié, M. C. (2013). *Physical Therapy Interventions for Degenerative Lumbar Spinal Stenosis: A Systematic Review*. https://academic.oup.com/ptj/article/93/12/1646/2735353

Marchand, A. A., Houle, M., O'Shaughnessy, J., Châtillon, C. É., Cantin, V., & Descarreaux, M. (2021). Effectiveness of an exercise-based prehabilitation program for patients awaiting surgery for lumbar spinal stenosis: a randomized clinical trial. *Scientific Reports*, *11*(1), 1–13. https://doi.org/10.1038/s41598-021-90537-4

McDonough, S. M., Tully, M. A., O'Connor, S. R., Boyd, A., Kerr, D. P., O'Neill, S. M., Delitto, A., Bradbury, I., Tudor-Locke, C., Baxter, D. G., & Hurley, D. A. (2010). The back 2 activity trial: education and advice versus education and advice plus a structured walking programme for chronic low back pain. *BMC Musculoskeletal Disorders*, *11*. https://doi.org/10.1186/1471-2474-11-163

Minetama, M., Kawakami, M., Teraguchi, M., Kagotani, R., Mera, Y., Sumiya, T., Nakagawa, M., Yamamoto, Y., Matsuo, S., Koike, Y., Sakon, N., Nakatani, T., Kitano, T., & Nakagawa, Y. (2019). Supervised physical therapy vs. home exercise for patients with lumbar spinal stenosis: a randomized controlled trial. *Spine Journal*, *19*(8), 1310–1318. https://doi.org/10.1016/j.spinee.2019.04.009

Norden, J., Smuck, M., Sinha, A., Hu, R., & Tomkins-Lane, C. (2017). Objective measurement of free-living physical activity (performance) in lumbar spinal stenosis: are physical activity guidelines being met? *Spine Journal*, *17*(1), 26–33. https://doi.org/10.1016/j.spinee.2016.10.016

Peterson, S., Mesa, A., Halpert, B., & Bordenave, L. (2021). How people with lumbar spinal stenosis make decisions about treatment: A qualitative study using the Health Belief Model. *Musculoskeletal Science & Practice*, *54*. https://doi.org/10.1016/J.MSKSP.2021.102383

Vanti, C., Andreatta, S., Borghi, S., Guccione, A. A., Pillastrini, P., & Bertozzi, L. (2019). The effectiveness of walking versus exercise on pain and function in chronic low back pain: a systematic review and meta-analysis of randomized trials. *Disability and Rehabilitation*, *41*(6), 622–632. https://doi.org/10.1080/09638288.2017.1410730

ORIGINAL SCIENTIFIC PAPER

Acute effect of time and set configuration of squat exercise on jump performance of male soccer players: a randomized crossover study

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Abstract

This study aimed to examine the acute effects of squat exercise performed with different set configurations on jump performance of U19 male soccer players. Seventeen male soccer players from a U19 elite soccer league team participated in the study. In a randomized crossover manner (with 72-hour rest between testing sessions), participants performed four different squat (80% one repetition maximum) set configurations. The set configurations included a traditional set configuration [(TSC); 6 repetitions × 3 sets with 180 seconds rest between sets] and three rest redistribution methods: RR_1 (3 repetitions × 6 sets, 20 seconds rest between repetitions, 150 seconds rest between sets), RR_2 (2 repetitions × 9 sets, 20 seconds rest between repetitions, 120 seconds rest between sets), and RR_3 (1 repetition × 18 sets, 20 seconds rest between repetitions). The rest duration was equalized across all set configurations. Countermovement jump was performed at pre-test, and 15 seconds, 4 minutes, 8 minutes, and 12 minutes post squat exercise. A two-way ANOVA [4×5 (set configuration × time)] was used for statistical analysis. The findings indicated that all RR methods proved effective in acutely enhancing performance when employed with 4–8 minute intervals. In addition, the RR methods appear to be more effective than TSC. In conclusion, practitioners may prioritize using the RR method over TSC to acutely improve the jump performance, with 4 minutes being optimal recovery between the squat and jump.

Keywords: *plyometric exercise, resistance training, warm-up exercise, human physical conditioning*

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Introduction

High-intensity actions such as sprinting, jumping, and/or changing direction are strong predictors of competitive success in modern soccer (Castagna & Castellini, 2013; Wragg et al., 2000). Therefore, training methods that enhance these high-intensity actions are crucial. Indeed, different training methods can induce acute and chronic adaptation to improve these actions (de Hoyo et al., 2016; Janz & Malone, 2008). Post activation performance enhancement (PAPE) is a strategy to induce acute performance improvement (Blazevich & Babault,

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2019; Hodgson et al., 2005; Ulloa-Sánchez et al., 2024), by using conditioning exercises during warm-up (Hodgson et al., 2005; Ulloa-Sánchez et al., 2024).

PAPE is suggested to occur when an activity requiring sub-maximal to maximal contraction (e.g., squat) acutely improves a biomechanically similar low-load activity (e.g., countermovement jump) (Blazevich & Babault, 2019; Hodgson et al., 2005; Prieske et al., 2020). However, performing sub-maximal to near-maximal effort may also lead to fatigue, which may overlay the potentiation effects (Tillin & Bishop, 2009). Therefore, the net effect on performance is determined by the balance between potentiation and fatigue. Indeed, studies have highlighted the importance of manipulation of different variables on balancing potentiation and fatigue, thereby inducing PAPE (Chiu et al., 2003; Gourgoulis et al., 2003; Kilduff et al., 2008). For example, some key variables affecting this balance are the participant's muscle strength (Gourgoulis et al., 2003), muscle fiber type distribution, and training level (Chiu et al., 2003); while the intensity (Gołaś et al., 2017), recovery time (Kilduff et al., 2008), number of sets (Wilson et al., 2013), and set configuration (Boullosa et al., 2013; Dello Iacono et al., 2020) may also affects this balance.

Amongst the aforementioned key variables, recovery period between the high-load and low load activity helps understand the balance between fatigue and potentiation (Dobbs et al., 2019), with studies reporting different recovery intervals (usually varying between 4 and 16 minutes) favorable for PAPE (Blazevich & Babault, 2019). Of note, the recovery period to induce PAPE may be moderated by both the characteristics of the participant and conditioning exercises, respectively. For example, a previous study showed that experienced athletes required less recovery time to induce the PAPE effects (Jo et al., 2010). In this context, cluster set organization uses shorter recovery intervals instead of longer recovery periods, and may help optimize the PAPE effects (Tufano et al., 2017). For example, a previous study has reported cluster set configuration to be effective in improving acute performance with a shorter recovery period, when compared to a traditional set configuration (TSC) (Boullosa et al., 2013). In addition, Hardee et al. (2012) also reported that including rest intervals between sets (i.e., cluster set configuration) resulted in a lower rating of perceived exertion compared to performing the same load using a TSC.

Moreover, the cluster set configurations can be applied using four different rest allocation methods (i.e., basic cluster set, equal work-rest ratio, rest pause, and rest redistribution [RR]) (Tufano et al., 2017). Amongst the four methods, the basic cluster set, equal work-rest ratio, and rest pause methods require a longer completion time compared to the RR method, for an equalized volume (González-Hernández et al., 2020; Tufano et al., 2017). The lower completion time in the RR method is obtained by dividing the rest duration between sets to smaller and frequent rest intervals (Tufano et al., 2017). While, in other cluster set methods, the rest duration between sets is similar to traditional resistance set configuration and only additional rest duration is added within sets (i.e., repetitions) (Tufano et al., 2017). Therefore, the RR method may be a viable option to implement as it provides similar benefits as other three methods, whilst requiring lesser completion time (González-Hernández et al., 2020).

However, no previous research has studied the effects of different RR strategies with overall equalized rest period (i.e., requiring similar overall completion time, albeit using different repetition and rest strategies) to induce acute performance enhancement. Therefore, the aim of this study was to examine the acute effects of squat exercises performed with traditional and different RR methods on jump performance. Based on available literature (Boullosa et al., 2013; Dello Iacono et al., 2020; Tufano et al., 2017), the authors hypothesized that the RR method would improve jump performance, compared to the TSC.

Materials and methods

Experimental approach to the problem

The study was conducted over a period of three weeks. The participants performed back squat and countermovement jump (CMJ) as a part of their regular training routine, and hence no familiarization session was conducted. Anthropometric measurements (height and body mass) were recorded at the start of the study. Thereafter, the participants were randomly divided into four groups, with each group performing different set configuration procedures on separate days separated by 72 hours in a randomized crossover manner. On each testing day, the participants performed CMJ before (baseline) and 15 seconds, 4 minutes, 8 minutes, and 12 minutes after the completion of the experimental protocols (Figure 1). A standardized 10-minute warm-up protocol was implemented before the experimental protocols. The warm-up programme comprised a 5-minute general warm-up on a bicycle ergometer with 50 revolutions per minute, followed by a soccer-specific dynamic stretching program as described in Ayala et al. (2017).

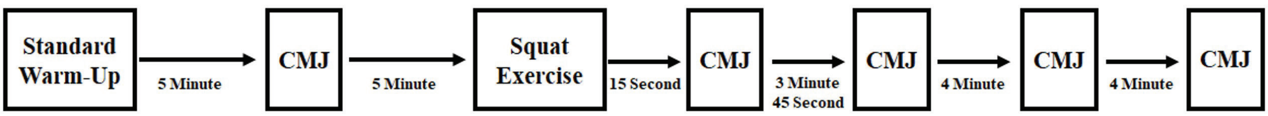

Figure 1. Schematic representation of the study's testing day plan. Note: CMJ – countermovement jump.

Participants

Seventeen male outfield soccer players were recruited from a team competing in the U19 elite soccer leagues (age: 18.6±0.2 years; height: 180.7±5.3 cm; body mass: 70.9±5.0kg; training age: 8.5±2.6 years; 1RM squat: 73.8±6.8 kg). The data collection was conducted during the first competition period of the season, and the participants were actively engaged in training sessions (70–90 minutes duration, 5 days/week) and participated in official competitions on the weekends. Additionally, the participants were free from injuries in the previous six months. The potential risks and challenges associated with the study were explained to each participant and thereafter informed consent forms were signed. Furthermore, ethical approval was obtained from the Local University Faculty of Medicine's Non-Interventional Clinical Research Ethics Committee Commission

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(decision dated 16/08/2022, numbered 12 (E-60116787-020-245291). This study was conducted in accordance with the Declaration of Helsinki.

Traditional set configuration (TSC) protocol

Three sets of squats were performed with a load of 80% 1RM, with each set comprising six repetitions. The rest interval between sets was 180 seconds (Figure 2).

Rest redistribution (RR) protocol

In rest redistribution (RR) protocols, the total number of repetitions and total recovery time were equalized, while the repetitions and recovery times were allocated proportionately. In RR_1, six repetitions were divided into two subsets (3+3) with 20 seconds of rest between each set, and the remaining recovery time was distributed as 150 seconds. In RR_2, the six repetitions were divided into three subsets (2+2+2), with 20 seconds of recovery allocated between each set, and the remaining recovery time was distributed as 120 seconds. In RR3, 18 repetitions were performed, and a 20-second rest period was allocated between each repetition, and a 30-second rest period was provided after the 6th and 12th repetitions. A detailed description of repetitions, sets, and recovery allocation is presented in Figure 2.

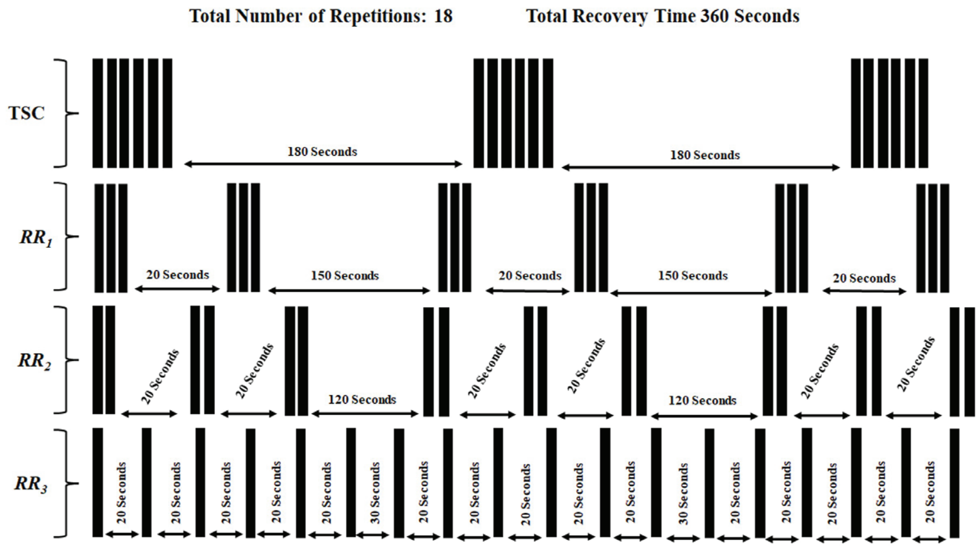

Figure 2. Schematic representation of different set configurations used in the study. TSC: Traditional set configuration; RR_1: First rest redistribution; RR_2: Second rest redistribution; RR_3: Third rest redistribution.

One repetition maximum

Prior to the commencement of the 1RM testing, each participants were required to perform a standardized warm-up protocol. To obtain the 1RM values, participants started with attempting five repetitions with 20%, followed by three repetitions at 50%, two repetitions at 75%, and finally one repetition at 85% of their last known 1RM. After that, the participants attempted the 1RM by using incremental loads, with a 3-minute rest period between the incremental loads. Participants were given a second attempt for their last unsuccessful lifts, with the load in the last successful lift expressed as the participant's 1RM. An observer was present on both sides of the weight bar during squat repetitions as a precautionary measure.

Countermovement Jump (CMJ)

The CMJ test was performed by the participants after the instructions from the researcher and was conducted on a portable jump mat (SmartSpeed; Fusion Sport, Brisbane, Australia). During the testing, the athletes were instructed to keep their hands on their waist and their torsos upright. The participants were asked to jump as high as possible immediately after squatting downwards rapidly, with self-selected squat depth. Verbal cues such as 'jump explosively' were provided to the participant. Two trials were conducted, and the highest jump height was recorded for analysis.

Statistical Analysis

All performance test scores are presented as means and standard deviations. Before performing the statistical analyses, the data set was assessed for normal distribution using the Shapiro-Wilk test. A two-way repeated measures analysis of variance (4 protocols × 5 time points) was applied to analyze the effects of protocols at different time points on countermovement jump performance. For significant differences, post hoc analyses using the Bonferroni correction method were used to identify the specific location of the difference between protocols or time points. The analyses were conducted using the SPSS v21.0 (IBM SPSS, Chicago, IL, USA) package programme. Partial eta squared values (ηp2; small < 0.0588, medium > 0.0588, large > 0.1379) were used as effect sizes for the ANOVA output (Cohen, 1988). In addition, Hedge's g effect size (g; trivial< 0.2; 0.2<small<0.6; 0.6<moderate<1.2; 1.2<large<2) was also calculated for between-protocol or time-point significant differences (Hopkins et al., 2009). Furthermore, intraclass correlation coefficients (ICC) were calculated to assess the reliability of the measurements. For all the analyses, the significance level was set at $p < 0.05$.

Results

Table 1 and Table 2 present the mean and standard deviation and statistical analysis results, respectively. Figure 3 presents a graphical representation of individual jump data across different protocol. The ICC for test-retest of CMJ was 0.96-0.97. The two-way repeated measures analysis of variance reported a significant main effect of time (F=14.32; p=<0.01; η_p^2=0.47; large effect size) and interaction effect

(F=3.003; p=0.021; η_p^2=0.158; large effect size) on the CMJ performance. Further, Bonferroni corrected post hoc analysis revealed no significant difference in the CMJ values at 15th seconds (36.2±4.4 cm), 4th minute (38.6±4.6 cm), 8th minute (38.9±4.6cm), and 12th minute (38.0±4.1 cm) compared to the baseline values (36.5±3.9) for TSC. However, for RR1, a significant difference was observed between the CMJ height at baseline (36.4±4.0 cm) and at 4th (40.5±5.0 cm) and 8th minute (39.4±4.7 cm) (4th minute: p=0.014, Hedge's g=0.89 and 8th minute:p=0.027, Hedge's g=0.67). No significant difference was found in the CMJ values at 15th seconds (38.55±4.25 cm) and 12th minutes (38.65±4.02 cm) compared to the baseline for RR_1. In addition, for RR_2, a significant difference was found between the CMJ height at baseline (36.5±3.8 cm) and at 4th (40.0±4.8 cm) and 8th minute (39.5±4.9 cm) (4th minute: p=0.008, Hedge's g=0.68 and 8th minute: p=0.022, Hedge's g=0.66). However, no significant difference was found in the CMJ values at 15th seconds (38.9±4.7 cm) and 12th minutes (38.6±4.7 cm) compared to the baseline (36.5±3.8) after RR_2. Lastly, for RR_3, a significant difference was found between the CMJ height at baseline (36.5±3.9 cm) and at 4th (39.4±4.2 cm) (p=0.024, Hedge's g=0.70). However, no significant difference was found in the CMJ values at 15th seconds (38.3±4.1 cm), 8th minute (39.4±4.2 cm), and 12th minutes (38.3±4.2 cm) compared to the pretest (36.5±3.9) for RR_3.

When the protocols were compared, a significant difference was observed between TSC and RR_2 for the CMJ height at 15th second, favouring the RR_2 (p=0.020, Hedge's g=0.60). There was no significant difference between the protocols at other time points.

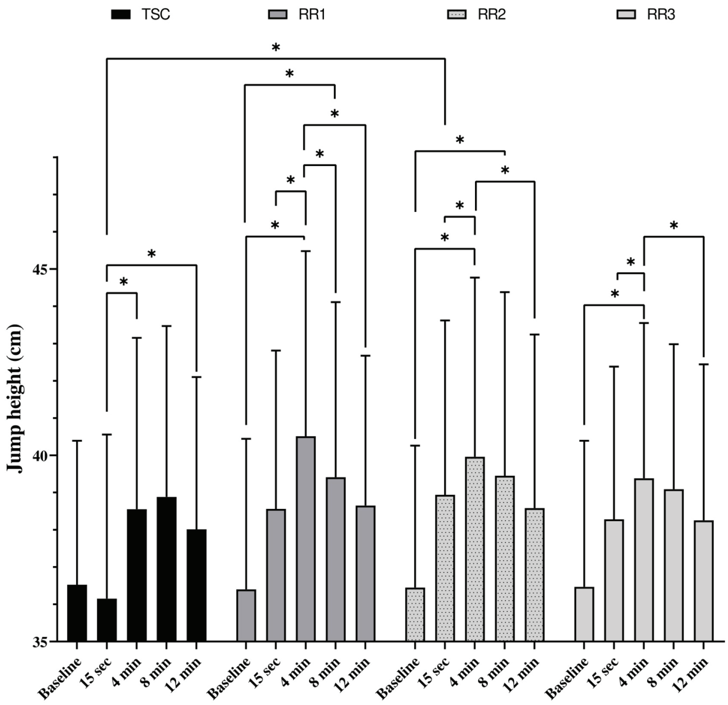

Figure 3. Graphical representation of countermovement jump performance before and after the protocols at specific time points. TSC: Traditional set configuration; RR_1: First set sonfiguration; RR_2: Second set configuration; RR_3: Third set configuration

Table 1. Mean and standard deviation of CMJ heights at different recovery times after squat exercise performed with different set configurations.

Protocols	Baseline		15th second		4th minute		8th minute		12th minute	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TSC	36.53	3.86	36.15	4.40	38.55¶	4.60	38.88¶	4.59	38.01¶	4.09
RR_1	36.39	4.04	38.55	4.25	40.51†¶¥§	4.97	39.4†	4.7	38.65	4.02
RR_2	36.45	3.81	38.94#	4.68	39.95†¶§	4.81	39.45†	4.93	38.58	4.66
RR_3	36.46	3.92	38.28	4.1	39.38†¶§	4.17	39.09	3.89	38.25	4.19

TSC: Traditional set configuration; RR_1: First set configuration; RR_2: Second set configuration; RR_3: Third set configuration; SC: Set Configuration; SD: Standard deviation; †: Significantly different from baseline; ¶: Significantly different from 15th second; ¥: Significantly different from 8th minute; §: Significantly different from 12th minute; #: Significantly different from traditional set configuration; ICC: intraclass correlation coefficient

Discussion

The aim of this study was to examine the acute effects of squat exercise performed with TSC and three different RR methods on CMJ performance at different recovery times. Compared to the baseline, significant within-condition improvements were observed after all RR methods at the 4th minute, and after RR_1 and RR_2 at the 8th minute. Of note, a significant decline in CMJ performance was observed after the 4th minute in all the RR protocols. However, no within-condition improvement was observed after TSC when compared to baseline. Moreover, when protocols were compared, a significant difference was observed only between TSC and RR_2 at the

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15th second, favoring RR_2. No between-protocol differences were observed at other time points.

One of the key findings of this study was that all RR protocols significantly improved the CMJ performance compared to baseline, whereas no such effect was observed following the TSC protocol. However, when compared to 15th seconds, the TSC as well as the RR protocols improved the CMJ performance at the 4th minute. Another trend observed across all the RR protocols was the attainment of peak performance at 4-8 minutes duration and a temporal decline at 12th minutes. These findings highlight the complex intricacies associated with fatigue-potentiation between the conditioning activities and performance. The significant improvement in the CMJ performance at 4-8 minutes duration may be due to the acute physiological changes associated with PAPE, such as phosphorylation of myosin light chain, an increase in muscle temperature, calcium ion sensitivity (due to increase in muscle temperature, decrease in muscle pH, increase in blood flow and water content in the muscles), increased neural drive, or increased muscle-tendon stiffness (Blazevich & Babault, 2019). While the significant decline in performance at the 12th minute compared to the 4th minute in all RR protocols is indicative that PAPE effects do decline after a certain period of time.

Furthermore, although non-significant, the CMJ performance declined at 15th seconds for TSC, while an increase in performance (non-significant) was observed for all the RR protocols (Figure 3). This is indicative that TSC induced greater fatigue than potentiation in the initial 15 seconds, while the RR resulted in a trend showing positive improvement in performance. Previous studies that incorporated TSC as conditioning exercise have consistently reported a decline in performance immediately but had improved performance after a longer (e.g., ≥4 minute) recovery period (Crewther et al., 2011; Dello Iacono et al., 2020; Kilduff et al., 2008). Kilduff et al. (2008) also reported a significant decrease in CMJ height immediately (~15 seconds) after performing conditioning exercise using 87% of 1RM squat using TSC configuration, but showed improved performance after 8 minutes of recovery. Another study by Crewther et al. (2011) also reported a significant decrease at ~15 seconds but a subsequent increase in the CMJ performance after 4-, 8-, and 12-minute periods of performing 3RM squats using TSC. These differences in how participants' immediate response differed between TSC and RR protocol, favoring RR, may be due to the short rest period embedded within the RR protocols that resulted in less fatigue accumulation at the end of the completion of the sets. In a similar study conducted by Dello Iacono et al. (2020), the authors reported that the participants were able to maintain 95% of their relative mean propulsive power during cluster set configuration, whereas in TSC, the participants were able to maintain only 85%. Indeed, early proponents of cluster set configurations have suggested a similar rationale of lesser fatigue compared to TSC, leading to higher quality of technique execution (Haff et al., 2008).

Moreover, when TSC and RR protocols were compared, a significant difference was observed at 15th seconds, favoring the RR_2 protocol. This is again in line with the findings of Dello Iacono et al. (2020) that reported a significant difference between cluster set configuration and TSC post 30 seconds recovery, favoring the cluster set configuration, even if there were no improvements compared to baseline. This finding indicates a higher fatigue with the TSC protocol compared to the RR protocol. Moreover, Boullosa et al. (2013) also reported that peak CMJ performance occurred significantly earlier (3.6±2.9 minutes vs. 6.1±3.3 minutes) after the cluster set compared to the traditional 5RM set, indicating the effectiveness of cluster set configuration in mitigating fatigue. Indeed, González-Hernández et al. (2020) reported greater mechanical, metabolic, and perceptual fatigue, whereas cluster set configurations highlighted the importance of rest distribution in optimizing performances.

While this novel study contributes to the existing literature by comparing TSC and three different RR protocols on acute performance enhancement of CMJ performance at four different rest periods, it is important to consider the limitations of the study. One major limitation of this study was that it did not examine fatigue during the performance of squats at different set configurations. Using commercially available velocity-based training devices to determine the decrease in velocity of squat at each set configuration could provide vital information about the fatigue response of participants to perform the exercise. In addition, the use of the rating of perceived exertion scale or the collection of biomarkers (e.g., creatine kinase) to determine physiological fatigue would have provided insight into the internal response due to different set configurations. Therefore, the precise physiological advantage of RR compared to TSC remains speculative. Furthermore, the study was limited to male soccer players, and therefore, the findings should not be extrapolated to females or athletes from other sports.

Conclusion

In conclusion, the findings suggest that performing squats using RR protocols may be effective in improving the acute performance of CMJ. Moreover, the improvement in performance can also be observed post 4-minute recovery period with all the protocols. However, the RR protocols, specifically the RR2 protocol, were effective in reducing fatigue at shorter recovery times (i.e., 15 seconds) compared to the TSC protocol, while also improving the performance at the 4th minute. Practitioners may use different RR protocols as a part of the standard warm-up routine instead of TSC, which may help in reducing the fatigue effect observed immediately and also improve the performance of the athletes after a standard resting period of ≥4 minutes.

Conflicts of Interest

The authors declare no conflict of interest.

References

Ayala, F., Calderón-López, A., Delgado-Gosálbez, J. C., Parra-Sánchez, S., Pomares-Noguera, C., Hernández-Sánchez, S.,…De Ste Croix, M. (2017). Acute Effects of Three Neuromuscular Warm-Up Strategies on Several Physical Performance Measures in Football Players. *Plos One*, *12*(1), e0169660. https://doi.org/10.1371/journal.pone.0169660

Blazevich, A. J., & Babault, N. (2019). Post-activation Potentiation Versus Post-activation Performance Enhancement in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. *Frontiers in Physiology*, *10*, 1359. https://doi.org/10.3389/fphys.2019.01359

Boullosa, D. A., Abreu, L., Beltrame, L. G., & Behm, D. G. (2013). The acute effect of different half squat set configurations on jump potentiation. *Journal of Strength and Conditioning Research* , *27*(8), 2059-2066. https://doi.org/10.1519/JSC.0b013e31827ddf15

Castagna, C., & Castellini, E. (2013). Vertical jump performance in Italian male and female national team soccer players. *Journal of Strength and Conditioning Research*, *27*(4), 1156-1161. https://doi.org/10.1519/JSC.0b013e3182610999

Chiu, L. Z., Fry, A. C., Weiss, L. W., Schilling, B. K., Brown, L. E., & Smith, S. L. (2003). Postactivation potentiation response in athletic and recreationally trained individuals. *Journal of Strength and Conditioning Research*, *17*(4), 671-677. https://doi.org/10.1519/1533-4287(2003)017<0671:ppriaa>2.0.co;2

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Routledge.

Crewther, B. T., Kilduff, L. P., Cook, C. J., Middleton, M. K., Bunce, P. J., & Yang, G. Z. (2011). The acute potentiating effects of back squats on athlete performance. *Journal of Strength and Conditioning Research* , *25*(12), 3319-3325. https://doi.org/10.1519/JSC.0b013e318215f560

de Hoyo, M., Gonzalo-Skok, O., Sañudo, B., Carrascal, C., Plaza-Armas, J. R., Camacho-Candil, F., & Otero-Esquina, C. (2016). Comparative Effects of In-Season Full-Back Squat, Resisted Sprint Training, and Plyometric Training on Explosive Performance in U-19 Elite Soccer Players. *Journal of Strength and Conditioning Research*, *30*(2), 368-377. https://doi.org/10.1519/jsc.0000000000001094

Dello Iacono, A., Beato, M., & Halperin, I. (2020). The Effects of Cluster-Set and Traditional-Set Postactivation Potentiation Protocols on Vertical Jump Performance. *International Journal of Sports Physiology and Performance*, *15*(4), 464-469. https://doi.org/10.1123/ijspp.2019-0186

Dobbs, W. C., Tolusso, D. V., Fedewa, M. V., & Esco, M. R. (2019). Effect of Postactivation Potentiation on Explosive Vertical Jump: A Systematic Review and Meta-Analysis. *Journal of Strength and Conditioning Research*, *33*(7), 2009-2018. https://doi.org/10.1519/jsc.0000000000002750

Gołaś, A., Wilk, M., Stastny, P., Maszczyk, A., Pajerska, K., & Zając, A. (2017). Optimizing Half Squat Postactivation Potential Load in Squat Jump Training for Eliciting Relative Maximal Power in Ski Jumpers. *Journal of Strength and Conditioning Research*, *31*(11), 3010-3017. https://doi.org/10.1519/jsc.0000000000001917

González-Hernández, J. M., García-Ramos, A., Castaño-Zambudio, A., Capelo-Ramírez, F., Marquez, G., Boullosa, D., & Jiménez-Reyes, P. (2020). Mechanical, Metabolic, and Perceptual Acute Responses to Different Set Configurations in Full Squat. *Journal of Strength and Conditioning Research*, *34*(6), 1581-1590. https://doi.org/10.1519/jsc.0000000000002117

Gourgoulis, V., Aggeloussis, N., Kasimatis, P., Mavromatis, G., & Garas, A. (2003). Effect of a submaximal half-squats warm-up program on vertical jumping ability. *Journal of Strength and Conditioning Research, 17*(2), 342-344. https://doi.org/10.1519/1533-4287(2003)017<0342:eoashw>2.0.co;2

Haff, G. G., Hobbs, R. T., Haff, E. E., Sands, W. A., Pierce, K. C., & Stone, M. H. (2008). Cluster Training: A Novel Method for Introducing Training Program Variation. *Strength and Conditioning Journal*, *30*(1).

Hardee, J. P., Triplett, N. T., Utter, A. C., Zwetsloot, K. A., & McBride, J. M. (2012). Effect of interrepetition rest on power output in the power clean. *Journal of Strength and Conditioning Research*, *26*(4), 883-889. https://doi.org/10.1519/JSC.0b013e3182474370

Hodgson, M., Docherty, D., & Robbins, D. (2005). Post-activation potentiation: underlying physiology and implications for motor performance. *Sports Medicine*, *35*(7), 585-595. https://doi.org/10.2165/00007256-200535070-00004

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Janz, J., & Malone, M. (2008). Training explosiveness: Weightlifting and beyond. *Strength and Conditioning Journal*, *30*(6), 14-22.

Jo, E., Judelson, D. A., Brown, L. E., Coburn, J. W., & Dabbs, N. C. (2010). Influence of recovery duration after a potentiating stimulus on muscular power in recreationally trained individuals. *Journal of Strength and Conditioning Research*, *24*(2), 343-347. https://doi.org/10.1519/JSC.0b013e3181cc22a4

Kilduff, L. P., Owen, N., Bevan, H., Bennett, M., Kingsley, M. I., & Cunningham, D. (2008). Influence of recovery time on post-activation potentiation in professional rugby players. *Journal of Sports Sciences*, *26*(8), 795-802. https://doi.org/10.1080/02640410701784517

Prieske, O., Behrens, M., Chaabene, H., Granacher, U., & Maffiuletti, N. A. (2020). Time to Differentiate Postactivation "Potentiation" from "Performance Enhancement" in the Strength and Conditioning Community. *Sports Medicine*, *50*(9), 1559-1565. https://doi.org/10.1007/s40279-020-01300-0

Tillin, N. A., & Bishop, D. (2009). Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Medicine*, *39*(2), 147-166. https://doi.org/10.2165/00007256-200939020-00004

Tufano, J. J., Brown, L. E., & Haff, G. G. (2017). Theoretical and Practical Aspects of Different Cluster Set Structures: A Systematic Review. *Journal of Strength and Conditioning Research*, *31*(3), 848-867. https://doi.org/10.1519/jsc.0000000000001581

Ulloa-Sánchez, P., Hernández-Elizondo, J., Thapa, R. K., Sortwell, A., & Ramirez-Campillo, R. (2024). Post-activation performance enhancement methods in team sport athletes: a systematic review with meta-analysis. *German Journal of Exercise and Sport Research*, 1-29.

Wilson, J. M., Duncan, N. M., Marin, P. J., Brown, L. E., Loenneke, J. P., Wilson, S. M.,…Ugrinowitsch, C. (2013). Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. *Journal of Strength and Conditioning Research*, *27*(3), 854-859. https://doi.org/10.1519/JSC.0b013e31825c2bdb

Wragg, C. B., Maxwell, N. S., & Doust, J. H. (2000). Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *European Journal of Applied Physiology*, *83*(1), 77-83. https://doi.org/10.1007/s004210000246

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ORIGINAL SCIENTIFIC PAPER

Exploring possession games in women's football: A multidimensional approach

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Abstract

Possession games are among the most commonly used training drills by women's association football coaches worldwide. However, they overlook a relevant feature of the game: directionality. This study compares the effects of introducing scoring targets in possession games on the game's dynamics, the players' tactical and physical performance, and their enjoyment and perceived competence. Eighteen female footballers (age: 17.0±1.4 years; playing experience: 9.8±2.1 years) from the third team of a Spanish women's first division club played three 3 × 5-minute nine-a-side possession games on a 52 m long × 33 m wide pitch with no, two and four scoring objects. Game dynamics (total effective playing time and duration of ball possessions) from observational analysis, tactical (central tendency and entropy measures of collective and individual pitch-positioning-derived variables and synchronisation) and physical (total distance travelled and distances at different speeds) responses from GPS data, and players' perceptions of enjoyment and competence were assessed. The main findings indicate that the effective playing time and average duration of ball possession did not vary between the training scenarios ($p>0.05$); the inclusion of four targets led players to occupy less space ($p<0.05$; Cohen's $d>1.12$), positioning themselves near the targets, and to play in a more synchronised manner longitudinally ($p<0.05$; Cohen's $d=0.61$) than in the non-directional game; and the physical demands and players' perceptions of enjoyment and competence did not differ between the possession games ($p>0.05$). Placing targets to provide possession games with directionality encourages players to occupy less space and play more centred and synchronised, without impairing game dynamics, external load or their perceptions of enjoyment and competence.

Keywords: *team sports, soccer, observational analysis, tactical behaviour, external load, motivation*

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Introduction

Association football is a collective duel played with a ball, so there are two game phases: in possession of the ball and out of possession. The principles associated with each phase are different (Castellano, 2008; Gréhaigne & Godbout, 1995). The team with the ball tries to keep it, play on the move and create and exploit available space. The defending team aims to regain possession, stop the opponent's progression and de-

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fend the target. Possession games – playing-form activities with no goals (i.e. no directionality), in which the primary intention is for one team to keep possession of the ball from another team – are one of the training drills most commonly employed for focusing on principles like keeping the ball or playing on movement (Roca & Ford, 2020). For example, elite and academy female footballers spend over 20% and 10% of their training time on possession games, respectively (Emmonds et al., 2023), so the impact of these drills on this population is worth investigating. Possession games, however, ignore a relevant feature of football: goals. The absence of goals or scoring targets (e.g. scoring zones or objects) removes the game's directionality and leaves players without spatial references to help them position themselves on the pitch (Coutinho et al., 2024).

Football task design implies manipulating the relevant features of the game's internal logic (i.e. relationships to space, the ball, time, and other participants; Parlebas, 2013) while accounting for the consequences of these changes on players' performance. Thus, coaches can set scoring targets to provide direction for the game. While scholars have studied the acute effects of adding regular and mini goals in small- and large-sided games in men's football (Castellano et al., 2013; Clemente et al., 2019; Coutinho et al., 2024; Santos et al., 2024), studies conducted with women are still lacking. Assessing the impact of scoring targets on female footballers' performance may assist practitioners in planning their practice based on scientific evidence. Placing scoring objects inside the pitch, such as poles to knock down, can give the game a sense of direction, while still making scoring difficult enough to encourage players to prioritise the main objective of the task: retaining possession of the ball.

This study adopted a multidimensional approach (Folgado et al., 2019) to compare player performance in directional vs. non-directional possession games. The recording of effective playing time and possession duration can explain the dynamics of possession games with and without targets (Castellano, 2008). From a tactical perspective, variables derived from pitch position, such as surface area (SA, m^2), length-per-width ratio (lpwratio, arbitrary units), as well as stretch (SI, m) and spatial exploration (SEI, m) indices can provide practitioners with key insights to understand players' collective (i.e. SA) and individual (i.e. SEI) use of space or their dispersion on the pitch (i.e. SI) in different training scenarios (Coito et al., 2022). In addition, entropy and synchronisation measures can provide relevant information on behavioural regularity and coordination between teammates (Low et al., 2020). From a physical point of view, assessing the total distances travelled and the distances in different speed zones can reveal whether the game's directionality affects the external load of female footballers (de Dios-Álvarez et al., 2022). Perceptual variables, such as enjoyment and competence, can account for the subjective experience of players during possession games (Clemente, 2025; Papaioannou et al., 2006).

Therefore, this study assessed the impact of introducing scoring targets in possession games on female footballers' game dynamics, tactical and physical performance, and their perceptions of enjoyment and competence. We hypothesised that the addition of internal targets would lead players to use less space, play more synchronously and run less, without affecting their playing time or perceptions of enjoyment and competence.

Materials and methods

Participants

Eighteen Basque female footballers (age: 17.0±1.4 years; playing experience: 9.8±2.1 years) belonging to the third team of a Spanish women's first division club participated in the study during the first half of the 2023/2024 season. All available outfield players (i.e. without health problems, injuries or just returning to play) took part, while goalkeepers underwent specific training with the goalkeeper coach. Participants trained three times per week (on Tuesdays, Thursdays and Fridays) and usually competed on Saturdays. Training sessions typically included collective passing drills, small- and large-sided games with and without regular and mini goals, as well as build-up and finalisation actions. The team competed in the Basque league, ending the season in 7^{th} place out of 18 teams. Given that they received structured and regular training, developed their playing skills in a professional academy environment and competed in the first autonomous league, they were placed in the third tier of the participant classification framework (McKay et al., 2022): highly trained/national level.

All participants and, where appropriate, their legal guardians/next of kin, team coaches and club management were fully informed of the purpose and procedures of the study before giving written informed consent for voluntary participation. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013) and ethical approval was obtained from the Ethics Committee for Research involving Human Beings (GIEB in Basque) of the University of the Basque Country UPV/EHU (approval number: M10_2021_328; approval date: 25 November 2021).

Design

The study was conducted over three training sessions on non-consecutive days (Tuesdays and Thursdays) at the participants' usual training venue (i.e. artificial turf pitch) and time (i.e. 19:30). A rest period of at least 48 hours was allowed between sessions and before or after the match. Each of the three sessions began with a standard 10-minute warm-up. The team coach then formed two balanced groups, dividing the players according to their level and position (Gonzalez-Artetxe et al., 2022), to face each other in three 3 × 5-minute nine-a-side possession games on a 52 m long × 33 m wide pitch (95 m^2 × player; length/width relation: 1.6), with a 3-minute break between sets.

Figure 1 illustrates each possession game and how the scoring conditions were manipulated: (a) NO, possession game with no scoring targets, where players could score a point by completing ten consecutive passes; (b) 2T, possession game with two shared scoring objects (poles), where players could score a point by knocking down either pole; and (c) 4T, possession game with four shared scoring objects (poles), where players could score a point by knocking down any of the four poles. One experimental condition was implemented per session in a randomised order: 4T, NO, and 2T. Continuity of play was ensured by placing several balls around the pitch to allow for quick ball replacement when the ball went out. Coach intervention was minimised to that of the referee so as not to influence player conduct through feedback (Gonzalez-Artetxe et al., 2022).

Data collection

Effective playing time and average duration of ball possession and set pieces were quantified by video recording (GoPro HERO9, GoPro Inc., San Mateo, California, USA) using an ad

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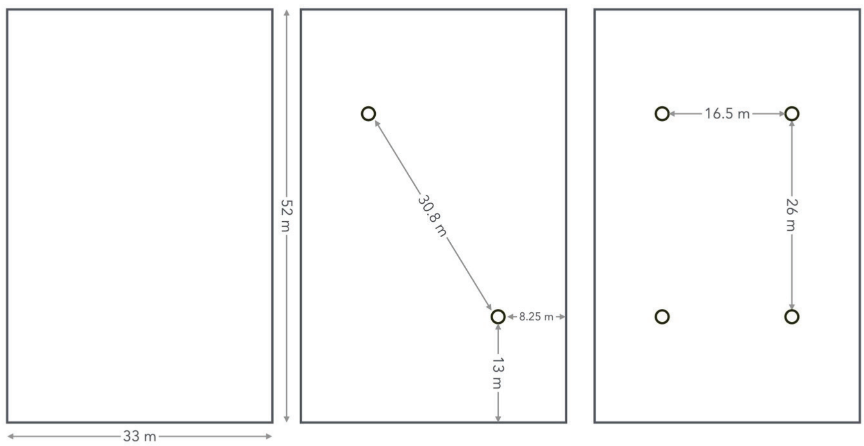

Figure 1. Representation of possession games with no (left), two (middle) and four (right) scoring objects.

hoc observation tool in LINCE PLUS (version 3.2.4 for macOS; Soto-Fernández et al., 2022). The criteria established by Castellano (2008) were used to determine when the ball was in play and which team was in possession. The same arbitrarily chosen set of a randomly selected experimental condition (11% of the sample) was observed twice, with 10 days between observations, and the intra-observer agreement, calculated using Cohen's kappa, was perfect (100%) for the alignment and almost perfect (97%) for the duration of ball possessions and set pieces.

Tactical and physical responses were assessed using positional data collected with a valid and reliable global positioning system (WIMU PRO, RealTrack Systems, Almeria, Spain) at a sampling frequency of 10 Hz (Bastida-Castillo et al., 2019). Tactical performance was assessed through central tendency and normalised approximate entropy (NApEn; Fonseca et al., 2012) measures of SA, lpwratio, SI and SEI. Entropy quantifies behavioural regularity: less entropy indicates greater regularity and vice versa. Longitudinal (Y-axis) and lateral (X-axis) synchronisation were also measured using the relative phase of the centroid, which was computed via the Hilbert transform. Players' external load was assessed by total distances travelled (m) and walking (below 2.00 m/s), jogging (2.00–3.46 m/s), high-speed running (3.46–5.29 m/s), very high-speed running (5.29–6.26 m/s) and sprinting (above 6.26 m/s) distances (m) travelled (Park et al., 2019). These speed thresholds were established specifically for senior female footballers by Park et al. (2019) and confirmed by Harkness-Armstrong et al. (2022). All calculations were performed in MATLAB (version 2018a for macOS, The MathWorks Inc., Natick, MA, USA).

Using the enjoyment and perceived competence scale validated by Arias-Estero et al. (2013) and previously used in women's football (Los Arcos, Gonzalez-Artetxe, Bayer-Perez, et al., 2025; Los Arcos, Gonzalez-Artetxe, Lombardero, et al., 2025), players rated how much they enjoyed each of the three possession games along with how they thought they had played. This 5-point Likert scale has three statements relating to enjoyment (2, 4 and 6) and four relating to perceived competence (1, 3, 5 and 7). The players responded individually for five minutes after the final set of each possession game, in silence and at least 2 metres from each other, to avoid peer influence on their ratings.

Analysis

The results are presented as the means ± standard deviations. First, a sensitivity power analysis was conducted using G*Power (version 3.1.9.6 for macOS; Faul et al., 2007) to determine the minimum detectable effect size for a repeated measures ANOVA with three conditions: NO, 2T and 4T. With an α of 0.05, a power of 0.80, and a sample size of 18, the analysis indicated a minimum detectable effect size of f = 0.31 (medium effect size, according to Cohen, 1988) for the main effect across conditions. This analysis guided the interpretation of the results. Observational analysis was implemented to contextualise the dynamics of the game. As the data did not meet the assumptions of normality and homoscedasticity, a non-parametric Kruskal–Wallis ANOVA test was used to compare the average duration of ball possession between the three training scenarios. The central tendency and NApEn measures of SA and lpwratio were compared between possession games as 'unrelated' because they are collective variables, while those of SI and SEI, as well as distances travelled, were compared as 'related' because of their individual nature. As the tactical variables were normally distributed and equal variances were confirmed, a one-way ANOVA and repeated measures ANOVA were used to analyse collective (central tendency and NApEn measures of SA and lpwratio) and individual (central tendency and NApEn measures of SI and SEI) variables, respectively. Synchronisation measures, physical variables and players' perceptions of enjoyment and competence were also compared between possession games using a repeated measures ANOVA, except for sprinting distances travelled, which did not follow a normal distribution, so the Friedman test was used. Practical differences were assessed using Cohen's d (trivial, <0.20; small, 0.50; medium, 0.80; and large, ≥0.80) and eta squared (η^2: trivial, <0.01; small, 0.06; medium, 0.14; and large, >0.14) effect sizes with 95% confidence intervals (CI) for parametric and non-parametric comparisons, respectively (Cohen, 1988). Statistical significance was set at $p<0.05$ and all analyses were performed using jamovi software, version 2.4.14 for macOS (The jamovi project, 2024, retrieved from https://www.jamovi.org).

Results

The effective playing time of the three possession games was 91%, and the mean duration (and amount) of set pieces was 3.3±1.9 s (25 set pieces), 2.4±1.5 s (34 set pieces) and 3.1±2.2 s (33 set pieces) for NO, 2T and 4T scenarios respectively. There were no significant differences ($p>0.05$) in the mean duration of ball possession between the possession game scenarios (Figure 2).

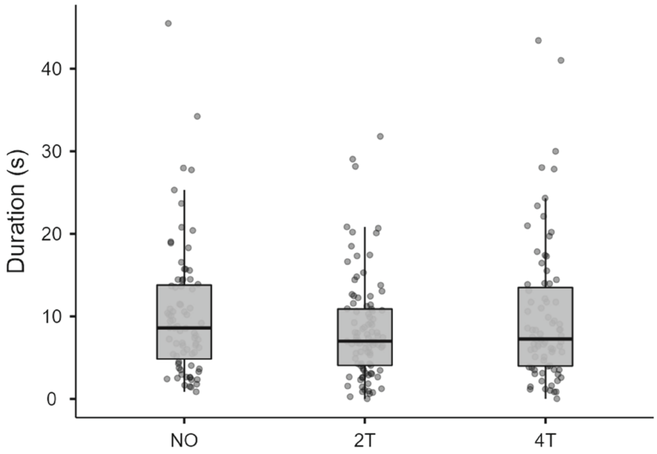

Figure 2. Duration of ball possessions among highly trained female footballers (means ± standard deviations and quartiles) for pairwise comparisons playing possession games with no (NO, 79 ball possessions), two (2T, 97 ball possessions) and four (4T, 79 ball possessions) scoring objects.

Table 1 shows the tactical and physical performance of highly trained female footballers and their perceptions of enjoyment and competence in the three possession games. Players occupied much less space when playing with four targets than when playing with no targets or two targets ($p<0.05$; Cohen's $d>1.12$). They were also more synchronised longitudinally when playing with four targets than when playing with none ($p<0.05$; Cohen's $d = 0.61$). No significant differences ($p>0.05$) were found between possession games in players' physical performance, nor in their perceptions of enjoyment and competence. Figure 3 illustrates the density of player positioning during each possession game, considering the different target locations or lack thereof. There is a clear tendency for players to remain closer to the targets when these were included.

Table 1. Highly trained female footballers' tactical and physical performance and perceptions of enjoyment and competence (means ± standard deviations) and effect sizes with 95% confidence intervals (CI) for pairwise comparisons playing possession games with no (NO), two (2T) and four (4T) scoring targets.

	Possession game conditions			Effect size (95% CI)		
	NO	2T	4T	NO vs 2T	NO vs 4T	2T vs 4T
Tactical performance						
SA (m^2)	526±51	480±62	412±60†‡	-0.81 [-0.84; -0.78]	-2.05 [-2.08; -2.01]	-1.12 [-1.15; -1.08]
NApEn (au)	0.077±0.012	0.084±0.014	0.085±0.010	0.54 [-1.09; 2.17]	0.72 [-0.93; 2.38]	0.08 [-1.52; 1.68]
lpwratio (au)	1.25±0.37	1.18±0.10	1.19±0.08	-0.26 [-0.29; -0.23]	-0.23 [-0.25; -0.20]	0.11 [0.08; 0.14]
NApEn (au)	0.141±0.022	0.108±0.017	0.134±0.026	-1.68 [-3.54; 0.18]	-0.29 [-1.90; 1.32]	1.18 [-0.55; 2.92]
SI (m)	12.0±1.83	11.7±2.21	10.8±1.98	-0.15, [-1.07; 0.78]	-0.63, [-1.58; 0.32]	-0.43, [-1.36; 0.51]
NApEn (au)	0.073±0.011	0.074±0.008	0.081±0.013	0.01 [-1.50; 1.71]	0.66 [-0.98; 2.31]	0.65 [-0.99; 2.29]
SEI (m)	11.1±1.44	10.6±1.18	10.8±1.14	-0.38 [-1.31; 0.55]	-0.23 [-1.16; 0.70]	0.17 [-0.75; 1.10]
NApEn (au)	0.093±0.013	0.089±0.010	0.091±0.009	-0.35 [-1.96; 1.27]	-0.18 [-1.78; 1.43]	0.21 [-1.14; 1.82]
Long sync (au)	0.57±0.14	0.58±0.15	0.64±0.08*	0.07 [-0.47; 0.60]	0.61 [0.07; 1.16]	0.50 [-0.04; 1.04]
Lat sync (au)	0.49±0.14	0.50±0.14	0.49±0.15	0.07 [-0.46; 0.61]	0.00 [-0.53; 0.53]	-0.07 [-0.99; 0.86]
Physical performance						
Total distance (m)	1628±72.3	1606±120	1626±123	-0.22 [-1.15; 0.71]	-0.02 [-0.94; 0.90]	0.17 [-0.76; 1.09]
Walking	651±45.8	663±47.4	657±32.9	0.26 [-0.67; 1.19]	0.15 [-0.78; 1.08]	-0.15 [-1.07; 0.78]
Jogging	625±93.4	595±109	615±106	-0.30 [-1.23; 0.63]	-0.10 [-1.03; 0.82]	0.19 [-0.74; 1.11]
High speed	320±50.0	312±75.8	314±59.4	-0.13 [-1.05; 0.80]	-0.10 [-1.03; 0.82]	0.03 [-0.90; 0.95]
Very high speed	24.8±18.7	28.5±14.9	31.3±18.0	0.22 [-0.71; 1.15]	0.35 [-0.58; 1.29]	0.17 [-0.76; 1.10]
Sprinting	9.71±12.5	6.38±8.75	7.12±7.17	0.00 [0.00; 0.03]	0.06 [0.00; 0.18]	0.05 [0.00; 0.17]
Perceptions						
Enjoyment (au)	4.32±0.73	4.44±0.58	4.42±0.63	0.18 [-0.74; 1.11]	0.15 [-0.74; 1.11]	-0.03 [-0.96; 0.89]
Competence (au)	3.83±0.78	3.61±0.65	3.77±0.71	-0.31 [-1.24; 0.62]	-0.08 [-1.01; 0.84]	0.24 [-0.69; 1.16]

Abbreviations: SA, surface area; lpwratio, length-per-width ratio; SI, stretch index; SEI, spatial exploration index; NApEn, normalised approximate entropy; Long sync, longitudinal synchronisation; Lat sync, lateral synchronisation; au, arbitrary units. Note: Superscripts indicate significant differences at $p<0.05$: * higher than NO condition; † lower than NO condition; ‡ lower than 2T condition.

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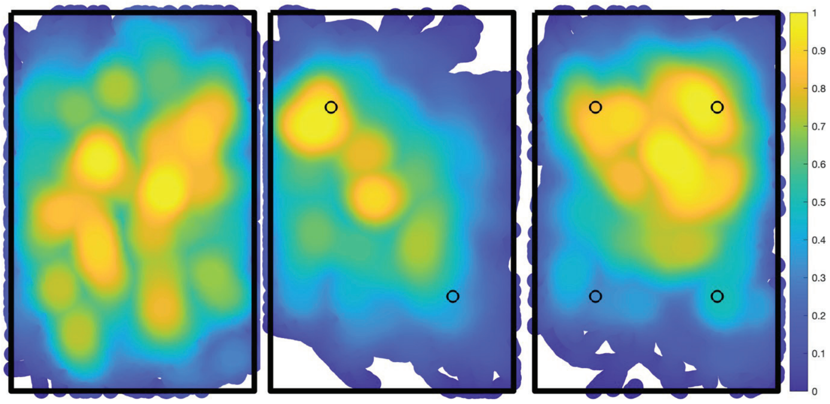

Figure 3. Density of player positioning during possession games with no (left), two (middle) and four (right) scoring objects. Density represents the relative frequency of player positions, with brighter areas indicating zones occupied more often and darker areas indicating zones occupied less often.

Discussion

Using a multidimensional approach, this study sought to assess the impact of adding scoring targets in women's football possession games. The results of this investigation show that (a) the effective playing time and average duration of ball possession did not vary between the training scenarios; (b) the inclusion of four targets led players to occupy less space, positioning themselves near the targets, and to play in a more synchronised manner longitudinally than in the non-directional game; and (c) the physical demands and players' perceptions of enjoyment and competence did not differ between the possession games.

Female footballers showed similar game dynamics across the three possession game conditions. The effective playing time with or without targets was a third higher than that of Girls' England Talent Pathway U14 and U16 league matches, which ranged from 57% to 61% (Harkness-Armstrong et al., 2023). Providing high playing time in training ensures ample motor engagement time, which is crucial for optimising training and furthering player development. The average duration of ball possession in the three training scenarios was also similar to that in elite female youth matches, ranging from 8.5 to 9.4 s (Harkness-Armstrong et al., 2023), which aligns these tasks more closely with match conditions (Roca & Ford, 2020). Since incorporating scoring targets did not reduce playing time or possession duration, possession games may include them to preserve a core element of football, such as directionality, without altering game dynamics.

As expected, players occupied less space and played closer to the targets in a more synchronised manner when multiple scoring objects were added. Their dispersion on the pitch, individual use of space, or entropy measures did not change. Along these lines, Coutinho et al. (2024) found that including two mini goals per team in four-a-side possession games decreased young male footballers' individual use of space (i.e. SEI) and increased the distances to their nearest teammates and opponents, with no change in entropy measures. The location of the targets can play a key role in shaping players' tactical behaviour. Positioning them on the end line resulted in less exploration and a greater separation between the nearest players (Coutinho et al., 2024), whereas the internal location elicited players' centring and synchronising on the pitch. In any case, providing directionality to the game seems to help players strategically position and organise themselves around the targets. The absence of changes in entropy measures indicates that the inclusion of targets did not affect behavioural regularity. The positive effects of directionality on player centring and synchronisation on the pitch, together with the lack of change in behavioural regularity and duration of ball possession, highlight the value of introducing scoring targets to boost collective tactical performance.

As players may adopt a more strategic way of playing with multiple targets – occupying less space and playing in a more synchronised way – a lower external load would be expected as a consequence. However, the physical performance of highly trained female footballers was similar with and without targets. In contrast, including regular and mini goals seems to impact the physical performance of young and senior male footballers in small- and large-sided games (Castellano et al., 2013; Clemente et al., 2019; Coutinho et al., 2024; Santos et al., 2024). Acute effects of regular goals were inconsistent: including them (and goalkeepers) increased total and running distances (3.88–5.55 m/s) of professional players in 10-a-side games (Clemente et al., 2019), decreased total distance of semi-professionals in seven-a-side games (Castellano et al., 2013), and did not affect total and high-speed running (above 5.83 m/s) distances of U23s in four-a-side games with an area per player near 100 m^2 (Santos et al., 2024). Adding mini goals in both the four- and seven-a-side formats resulted in young (Coutinho et al., 2024) and semi-professional (Castellano et al., 2013) players running less than in non-directional games. Unlike their male counterparts, women's football coaches can orientate possession games with multiple targets without worrying about altering their physical demands.

Incorporating scoring objects did not affect players' enjoyment or perceived competence, which remained above 4 and 3.5 out of 5, respectively, across all possession games. The results of this study are in line with previous studies with female academy footballers in which the relationship with space (Los Arcos, Gonzalez-Artetxe, Bayer-Perez, et al., 2025) or opponents (Los Arcos, Gonzalez-Artetxe, Lombardero, et al., 2025) was modified. They are also consistent with enjoyment reported by male team sport athletes in different activities, such as possession or small-sided games (Clemente, 2025): the manipulation of task conditions does not appear to affect participants' enjoyment. Similarly, perceived competence, another key component of motivation that is closely related to enjoyment (Papaioannou et al., 2006), did not change when scoring objects, pitch obstacles (Los Arcos, Gonzalez-Artetxe, Bayer-Perez, et al., 2025), or additional rules that alter oppositional interactions (Los Arcos, Gonzalez-Artetxe, Lombardero, et al., 2025) were introduced. These findings allow coaches to modify task conditions according to their training objectives without worrying about compromising the players' subjective experience.

This study combined different dimensions and levels of playing competence to contribute to a better understanding of the acute effects of manipulating the internal logic of the game in women's football training. Given its novelty, further studies are required to increase the sample size and extend the sampling to different age groups and levels of competition. In future investigations, it might be possible to integrate observational, tactical, physical and perceptual data, which would strengthen and enrich the multidimensional approach.

Conclusions

Placing targets in possession games provides the game with directionality – a relevant feature of football – and leads players to occupy less space and play more centred and synchronised, with no changes in game dynamics, external load or perceptions of enjoyment and competence. Thus, women's football coaches can introduce scoring objects to boost tactical performance without compromising the primary purpose of possession games: keeping the ball.

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Conflicts of interest

The authors declare no conflict of interest.

References

Arias-Estero, J. L., Alonso, J. I., & Yuste, J. L. (2013). Psychometric properties and results of enjoyment and perceived competence scale in youth basketball. *Universitas Psychologica*, *12*(3), 945–956. https://doi.org/10.11144/Javeriana.UPSY12-3.ppra

Bastida-Castillo, A., Gómez-Carmona, C. D., De La Cruz Sánchez, E., & Pino-Ortega, J. (2019). Comparing accuracy between global positioning systems and ultra-wideband-based position tracking systems used for tactical analyses in soccer. *European Journal of Sport Science*, *19*(9), 1157–1165. https://doi.org/10.1080/17461391.2019.1584248

Castellano, J. (2008). Analysis of the possession ball in soccer: frequency, duration and transition. *Motricidad. European Journal of Human Movement*, *21*, 179–196.

Castellano, J., Casamichana, D., & Dellal, A. (2013). Influence of game format and number of players on heart rate responses and physical demands in small-sided soccer games. *Journal of Strength and Conditioning Research*, *27*(5), 1295–1303. https://doi.org/10.1519/JSC.0B013E318267A5D1

Clemente, F. M. (2025). The enjoyment of small-sided games: a narrative review. *Human Movement*, *26*(1), 1–14. https://doi.org/10.5114/hm/197230

Clemente, F. M., Praça, G. M., Bredt, S. D. G. T., Linden, C. M. I. V. Der, & Serra-Olivares, J. (2019). External load variations between medium- and large-sided soccer games: ball possession games vs regular games with small goals. *Journal of Human Kinetics*, *70*(1), 191–198. https://doi.org/10.2478/hukin-2019-0031

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Coito, N., Davids, K., Folgado, H., Bento, T., & Travassos, B. (2022). Capturing and quantifying tactical behaviors in small-sided and conditioned games in soccer: a systematic review. *Research Quarterly for Exercise and Sport*, *93*(1), 189–203. https://doi.org/10.1080/02701367.2020.1823307

Coutinho, D., Gonçalves, B., Kelly, A. L., Santos, S., Figueiredo, P., Soares, C., & Travassos, B. (2024). Exploring the impact of ball possession directionality on youth footballers' positioning, technical skills and physical abilities in small-sided games. *International Journal of Sports Science and Coaching*, *19*(6), 2438–2448. https://doi.org/10.1177/17479541241257016

de Dios-Álvarez, V., Lorenzo-Martínez, M., Padrón-Cabo, A., & Rey, E. (2022). Small-sided games in female soccer players: a systematic review. *The Journal of Sports Medicine and Physical Fitness*, *62*(11), 1474–1480. https://doi.org/10.23736/S0022-4707.21.12888-9

Emmonds, S., Dalton Barron, N., Myhill, N., Barrett, S., King, R., & Weaving, D. (2023). Locomotor and technical characteristics of female soccer players training: exploration of differences between competition standards. *Science and Medicine in Football*, *7*(3), 189–197. https://doi.org/10.1080/24733938.2022.2089723

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Folgado, H., Bravo, J., Pereira, P., & Sampaio, J. (2019). Towards the use of multidimensional performance indicators in football small-sided games: the effects of pitch orientation. *Journal of Sports Sciences*, *37*(9), 1064–1071. https://doi.org/10.1080/02640414.2018.1543834

Fonseca, S., Milho, J., Passos, P., Araújo, D., & Davids, K. (2012). Approximate entropy normalized measures for analyzing social neurobiological systems. *Journal of Motor Behavior*, *44*(3), 179–183. https://doi.org/10.1080/00222895.2012.668233

Gonzalez-Artetxe, A., Pino-Ortega, J., Rico-González, M., & Los Arcos, A. (2022). Training effects of artificial rules on youth soccer team tactical behavior. *Physical Education and Sport Pedagogy*, *27*(5), 467–482. https://doi.org/10.1080/17408989.2021.1903411

Gréhaigne, J. F., & Godbout, P. (1995). Tactical knowledge in team sports from a constructivist and cognitivist perspective. *Quest*, *47*(4), 490–505. https://doi.org/10.1080/00336297.1995.10484171

Harkness-Armstrong, A., Till, K., Datson, N., & Emmonds, S. (2022). Determining age-specific velocity thresholds for elite youth female soccer players. *Science and Medicine in Football*, *6*(5), 581–588. https://doi.org/10.1080/24733938.2021.1991585

Harkness-Armstrong, A., Till, K., Datson, N., & Emmonds, S. (2023). Influence of match status and possession status on the physical and technical characteristics of elite youth female soccer match-play. *Journal of Sports Sciences*, *41*(15), 1437–1449. https://doi.org/10.1080/02640414.2023.2273653

Los Arcos, A., Gonzalez-Artetxe, A., Bayer-Perez, U., & Folgado, H. (2025). Consequences of field obstacles on tactical, conditional, and emotional dimensions in young female soccer players during small-sided games. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, *239*(1), 70–77. https://doi.org/10.1177/17543371231191845

Los Arcos, A., Gonzalez-Artetxe, A., Lombardero, S., Esnal-Arrizabalaga, O., & Aginaga, J. (2025). Exploring the impact of social relationship modification on young female soccer players' performance in small-sided games. *Journal of Human Kinetics*, *95*, 227–241. https://doi.org/10.5114/jhk/189425

Low, B., Coutinho, D., Gonçalves, B., Rein, R., Memmert, D., & Sampaio, J. (2020). A systematic review of collective tactical behaviours in football using positional data. *Sports Medicine*, *50*, 343–385. https://doi.org/10.1007/s40279-019-01194-7

McKay, A. K. A., Stellingwerff, T., Smith, E. S., Martin, D. T., Mujika, I., Goosey-Tolfrey, V. L., Sheppard, J., & Burke, L. M. (2022). Defining training and performance caliber: a participant classification framework. *International Journal of Sports Physiology and Performance*, *17*(2), 317–331. https://doi.org/10.1123/IJSPP.2021-0451

Papaioannou, A., Bebetsos, E., Theodorakis, Y., Christodoulidis, T., & Kouli, O. (2006). Causal relationships of sport and exercise involvement with goal orientations, perceived competence and intrinsic motivation in physical education: A longitudinal study. *Journal of Sports Sciences*, *24*(4), 367–382. https://doi.org/10.1080/02640410400022060

Park, L. A. F., Scott, D., & Lovell, R. (2019). Velocity zone classification in elite women's football: where do we draw the lines? *Science and Medicine in Football*, *3*(1), 21–28. https://doi.org/10.1080/24733938.2018.1517947

Parlebas, P. (2013). Motor praxeology: a new scientific paradigm. In M. Vaczi (Ed.), *Playing fields: power, practice, and passion in sport* (pp. 127–144). Center for Basque Studies.

Roca, A., & Ford, P. R. (2020). Decision-making practice during coaching sessions in elite youth football across European countries. *Science and Medicine in Football*, *4*(4), 263–268. https://doi.org/10.1080/24733938.2020.1755051

Santos, F., Clemente, F. M., Sarmento, H., Ferreira, C., Figueiredo, T., Hernández-Beltrán, V., Gamonales, J. M., & Espada, M. (2024). External load of different format small-sided games in youth football players in relation to age. *International Journal of Sports Science and Coaching*, *19*(5), 2024–2034. https://doi.org/10.1177/17479541241231485

Soto-Fernández, A., Camerino, O., Iglesias, X., Anguera, M. T., & Castañer, M. (2022). LINCE PLUS software for systematic observational studies in sports and health. *Behavior Research Methods*, *54*(3), 1263–1271. https://doi.org/10.3758/S13428-021-01642-1

ORIGINAL SCIENTIFIC PAPER

Dance Movement Therapy as a Psychomotor Intervention for Children with Autism Spectrum Disorder

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Abstract

The aim of the present study was to investigate the effect of one-year dance therapy on psychomotor development in children with autism spectrum disorder (ASD). Fourteen male children (age = 10.29 ± 1.50 years) participated in this study. They were randomly assigned to an experimental group (n = 7, age = 10.29 ± 1.50 years), who were engaged in dance therapy training, or a control group (n = 7, age = 10.29 ± 1.50 years). General motor coordination, Draw-a-person, and the gesture imitation tests were used to assess subjective and objective scores, intelligence quotient (IQ), and the simple gestures of the hands and arms, respectively. Of note, both experimental and control groups were also subdivided according to their ASD degree: mild (n = 4) and moderate (n = 3) ASD. The findings revealed that dance therapy training significantly enhanced general motor coordination, namely objective scores, compared with the control group (p = 0.01). For the imitation of gestures, dance therapy was associated with higher simple gestures of the hands (p = 0.003) and arms (p < 0.001) scores compared to the control group. Conversely, the post-subjective scores of motor coordination and post-IQ values did not significantly differ between the overall experimental and control groups (p = 0.11 and p = 0.56, respectively). Moreover, a greater effect of dance therapy on subjective scores in children with mild ASD compared with those with moderate ASD (p = 0.03) was observed. The practice of dance therapy is an appropriate psychomotor therapy to develop visuo-spatial and motor execution in children with mild and moderate ASD, with a greater effect in children with mild ASD for subjective scores of motor coordination.

Keywords: *autism, therapy, coordination, imitation, intelligence quotient*

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Introduction

Sporting activities are considered a privileged way of learning at the sensorimotor, communication, and socialization levels for people with autism spectrum disorder (ASD) (Massion, 2006). Numerous studies have been conducted on this topic, including a study by Dugas and Moretton (2012) on the evolution of young people with ASD who have participated in various sporting activities, such as swimming, climbing, and basketball. This intervention has been proven effective; however, children with ASD face different degrees of constraint when participating in sporting activities, the most important of which is paying attention to the trainer or the educator, particularly when playing in teams (Vernazza-Martin et al., 2005). Additionally, children with ASD lack intrinsic or extrinsic motivation for performing any motor action (Schmitz et al., 2003).

With regard to these difficulties, it is recommended that instructors or caregivers of children with ASD follow a specific set of pedagogical procedures. These facilitate the integration of children with ASD into their environment and provide them with the required care. First, the trainer or the educator is invited to identify the particular needs of each child (Rogers et al., 2005). Children with ASD are often dependent during various periods. The trainer or the educator is encouraged to establish a trust-based relationship between the child with ASD and the people around them (Baron et al., 1998). Several studies have reported that sports in the social life of individuals with ASD can represent an overlapping area of intervention, with children suffering from the same problem to different degrees. To address this disorder, choosing a convenient sporting activity is vital for achieving the desired goals (Dugas and Moretton, 2012).

Dance movement therapy can be defined as “a psychotherapeutic use of the movement as a process to promote the physical, psychic and social integration of an individual” (Vaysse et al., 2003). It has been widely practiced in England, the USA, and Australia for 50 years. It harmonizes the physical and cognitive aspects of one’s personality and promotes self-expression. This form of therapy offers opportunities to establish connections among sensory perceptions, representations, and the child’s environment (Bartenieff and Lewis, 2013). According to Blos (1993), psychomotor development is organized as an integrative system with four levels (tonic, sensory, affective, and representative). Dance is a vehicle for leading all these movements in an adaptable and playful way. Moreover, dance engages the body in action as an entity to be felt, lived, and appropriated or reappropriated (Biotteau et al., 2015). The bodily movements of dance, as a practice, generally reflect the dimensions of time, structure, and organization. Undoubtedly, to dance is to put one's body into action for a certain duration by following a set of movements (Louppe, 2010).

Dance as a mediation is considered therapeutic only when it is part of a package of therapeutic interventions (Albaret, 2015). Referring to Larousse, "a package is a set of means implemented for a specific intervention". It is possible to distinguish some specific ways of dancing. The first way is related to the group parameter, by which situations or exercises allow the subject to interact with an individual or a group of individuals to test their relationships with oneself, the other, and the group. The second is the spatial parameter, which concerns the different spatial forms of use, specifically, the capacity of the circle, the frontality of the line, or the investment of the different levels of space. Notably, symbolization and creativity are other parameters embodied in mediating objects such as fabric, sticks, balloons, and music (Lesage, 2006).

Various experiments have highlighted the importance of dance therapy for children with ASD. A study of the effects of dancing was carried out with a group of nine children with ASD who pursued dance classes for 2 h every 15 days. They were accompanied by a dance teacher, an occupational therapist, and a psychologist. After one year of practice, children’s gestural and technical improvements could be observed, although researchers noted some difficulties at the levels of segmentation, coordination, and amplitude (Xia and Grant, 2009). In this respect, Peterson et al. (2015) reported that dancing helps foster the relational abilities of children with ASD through the involvement of various disorders that hinder their relationships with others. Another experiment, described by Seal and Bonvillian (1979), was performed in a sample of three teenagers with ASD. The goal was to evaluate the relationship between the dance teacher and the children after their participation in different dance sessions. This research reported a change in the interactions between the children with ASD and the dance teacher, as well as among the group members.

With respect to the beneficial effects of dance therapy for children with ASD in terms of the unification of body image, symbolization of gestures, and integration in group performance (Henze et al., 1998; Scharoun et al., 2014), the precise effects of dance therapy in children with different degrees of ASD still have to be thoroughly assessed. Moreover, the existing body of scholarly research highlights the benefits of dance movement-based therapies in ASD (Aithal et al., 2021; Chen et al., 2022; Cui & Wang, 2024; Takahashi et al., 2019), yet few studies systematically examine their impact on both motor and cognitive domains. Understanding these effects could provide evidence-based support for integrating dance therapy into therapeutic and educational programs, offering a non-pharmacological approach to improving functional outcomes in children with ASD. Therefore, the aim of the present research was to evaluate the effect of dance therapy on children with mild and moderate ASD and the degree-specific effects. We hypothesized that dance therapy would help develop motor coordination, intellectual maturity, and body schema compared to the control group, with greater improvements expected in children with mild ASD. This study was prompted by the need to understand the potential contributions of dance movement therapy to children with ASD, given their documented difficulties in perception, motor coordination, communication, and socialization. It examined whether participation in dance therapy had supported improvements in their ability to navigate social environments. The investigation also considered whether the intervention had enhanced bodily awareness and self-regulation, thereby enabling greater control in interactions with space and objects. Particular attention was paid to whether the therapeutic effects had differed between children with mild and moderate forms of ASD.

Methods

Participants

Fourteen male children (age = 10.29 ± 1.50 years) participated in this study. They were a representative sub-sample of patients of the Errahma Center of the Ibn Sina Association, Sfax, Tunisia. They were randomly assigned to an experimental group (n = 7, age = 10.29 ± 1.50 years) (Tables 1 and 2) or a control group (n = 7, age = 10.29 ± 1.50 years) using stratified randomization to ensure balance between groups based on

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ASD severity (mild = 4 vs. moderate = 3). Within each stratum (mild/moderate ASD), allocation to groups was determined by a computer-generated randomization sequence (blocked 1:1 ratio), ensuring equal distribution of subjects based on ASD severity. To prevent selection bias, allocation was concealed using sealed opaque envelopes, and an independent researcher managed the randomization process to maintain blinding (Figure 1). Participants were included if they met the following criteria: (a) suffering from mild and moderate ASD, (b) no history of chronic disease, (c) absence of interaction disorders and motor difficulties, and (d) abstinence from physical activities 48 h prior to the testing sessions. Participants not meeting these criteria were excluded from the study. The investigation adhered to the guidelines outlined in the Declaration of Helsinki. All participants were informed about the study's objectives and provided written, informed consent for their inclusion.

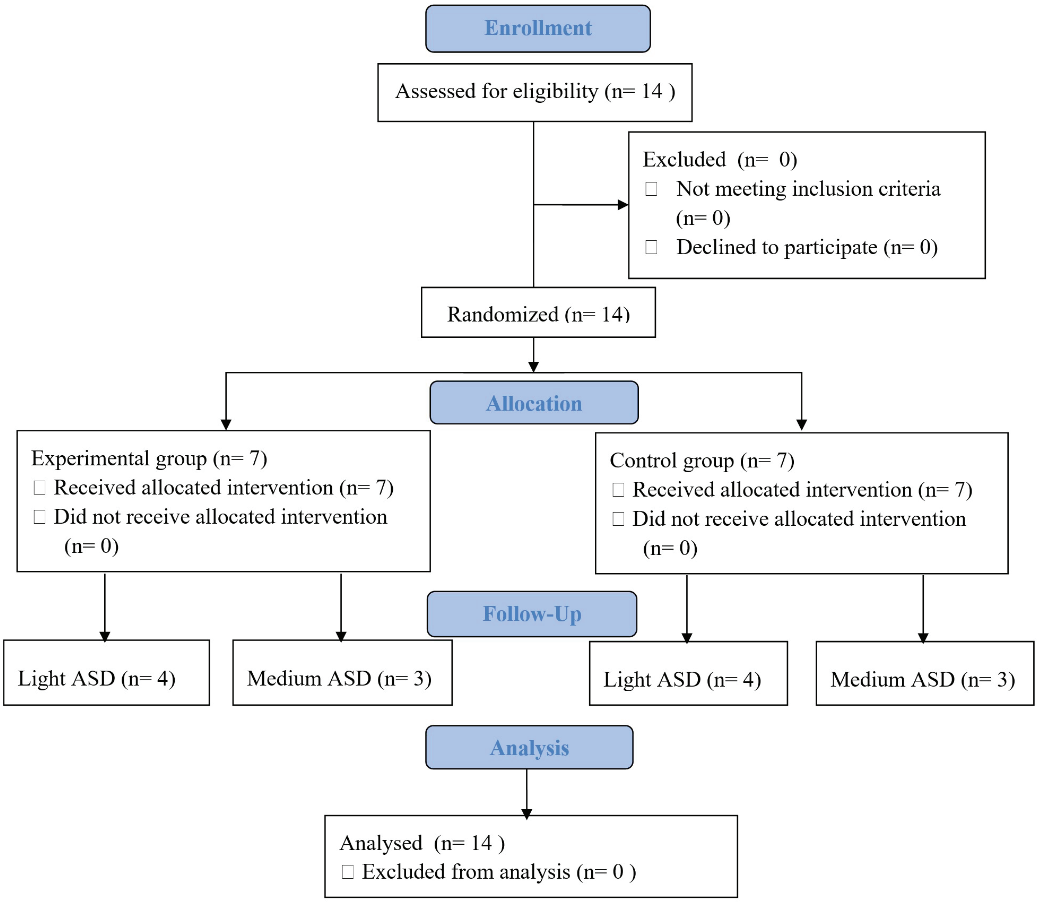

Figure 1. CONSORT diagram showing the flow of participants through each stage of a randomized trial.

Table 1. Characteristics of the experimental group suffering from moderate ASD.

Participant	Age (years)	Gender	Clinical Features
A	10	Boy	• Agitation • Absence of imitation in gestural communication • Fairly rigid movements
M	9	Boy	• Difficulties in movement due to obesity • Requires support to maintain balance (coordination disorder) • Hyperactivity
N	11	Boy	• Scarcity of facial expression • Absence of language

The study was conducted from December 2015 to November 2016 in the sports hall of the Errahma Center. Each Monday, a session from 11:00 to 12:00 was scheduled for the experimental "moderate" ASD and control groups. The second experimental group, categorized as "mild", participated in the session from 12:00 to 13:00. During the first visit, one week prior to the beginning of the experiment, all the subjects were invited to the laboratory to familiarize themselves with the procedure and tests involved to minimize their learning effects during the test. The reception of weekly information regarding the evolution and the characteristics of each child was guaranteed. This approach ensured that the children could adapt to the context of the experiment, thus facilitating their examination. Each child's scores were recorded on a grid, noting the capacities in question. Thereafter, participants were subjected to the same tests at the second and third visits, one day before and after one of the two

Table 2. Characteristics of the experimental group suffering from mild ASD.

Children (N = 4)	Age (years)	Gender	Clinical Features
D	12	Boy	• Leader of the group and a model for his friends • Understands verbal instructions (comprehension preserved) • Capable of outputting simple verbal exchanges (absence of interaction disorders)
F	12	Boy	• Capable of outputting simple verbal exchanges (absence of interaction disorders) • Prefers relaxation music • Slightly uncoordinated actions
H	10	Boy	• Laughs excessively (emotional regulation disorder) • No motor difficulties • Capable of outputting simple verbal exchanges (absence of interaction disorders)
B	8	Boy	• Agitated • Slack body posture

interventions (experimental or control group). The participants of the experimental groups engaged in dance therapy training, specifically the "opening ritual" and "therapeutic touch". The participants in the control group matched the dance therapy group in duration, frequency, and group size and performed various adapted physical activities, including conventional gross motor activities (e.g., obstacle courses, ball games, and balance exercises) and cooperative games (e.g., parachute activities), but were intentionally excluded from rhythmic movement, music-based interventions, and expressive dance components. Activities were adapted for autism-related needs using visual task cards, noise-reducing headphones, and consistent routines.

Psychomotor test evaluation

The development of children with ASD in different areas, namely, sensory and motor areas, usually occurs through individualized interventions by either specialists or psychomotor therapists (Feinberg and Beyer, 1998). In the present study, tests were used to assess children's abilities in areas of development in which an interest was noticed before and after each intervention.

The Charlop Atwell's motor coordination scale

This test measures general motor coordination both quantitatively and qualitatively (Schopler et al., 1995). The test lasts approximately 15 min. The six items are divided into four categories: the coordination between the upper limbs and the lower ones are grouped into the categories of "puppet" and "prehistoric animal". These two items also measure the ability to learn motor tasks quickly and accurately. The coordination of the two simultaneous actions with the "U-turn jump" and "whirling" as a dynamic balance is represented by "successive jumps on one foot and static equilibrium on tiptoes". This task was not originally standardized or validated for the age group of the children being tested. The children received an objective and a subjective score for each item (Charlop and Atwell, 1980), which are the sum of the six items. The objective score measured if the children performed the item as instructed and modeled by the individual administering the scale, and the subjective score measured how fluid or natural the children looked while performing the item (Charlop and Atwell, 1980).

The gesture imitation test

This test was used to evaluate the implementation of the children's body schema (Bergès and Lézine, 1963). Two sets of 10 simple and complex gestures involving the arms, hands, and fingers were proposed to the children without any verbal intervention (Bergès and Lézine, 1963). However, we used only simple gestures of arms (10 items) and hands (10 items) due to the difficulty of complex gestures in children with ASD. The test did not include any specific material except for illustrations of the gestures.

The test lasted approximately 10 minutes. In the original version, items were rated as 1 or 0, according to the success criteria (immediate, mirror, after trial, "piece to piece") or failure (global errors, incomplete answers, outliers) (Bergès and Lézine, 1963).

Draw-a-person test

This test was used to assess intellectual maturity (Goodenough, 1929). It allows the psychometrician to evaluate the idea that children possess a diagrammatic understanding of their body. Children were asked to draw themselves, a man, or a woman as best as they could. The raw score was assigned according to the number of drawing elements, with a maximum of 52 points. After that, each score was recorded and converted to the intelligence quotient (IQ) (Naglieri, 1988). Of note, Naglieri's DAP-IQ system represents a detailed and objective checklist to minimize subjective interpretation (Lichtenberger & Kaufman, 2013; Matto & Naglieri, 2005), with a high inter-rater reliability (0.84–0.88; Motta et al., 1993).

Dance therapy training program

The first part of the program was based on body awareness, self-awareness, and openness-to-space work (Lesage, 2006). At the beginning of each training session, ten minutes were spent listening to music while singing. This was called "the opening ritual". Each child learned to sing a few words and, in turn, attempted to repeat them. The same song was played frequently through the end of the year. After the opening ritual, relaxing music was chosen for the next exercise. The children with ASD lay on the ground. Light balloons were thrown over different parts of the children's bodies (first on the upper part and then the lower parts). In psychomotricity, this approach is termed "therapeutic touch" (Albaret, 2015). The children focused on their feelings. The touch-based demonstration of the exercise is important with such interventions because children with ASD cannot be guided verbally (Baron-Cohen et al., 1998). Subsequently, the light balloons were replaced with heavier ones. The same exercise was repeated while insisting that the children

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noticed the sensations moving from their center downward and upward (Lesage, 2006). The sessions encouraged the children to work on their own; each child picked up the balloon and tried to touch different parts of the partner's body (Butté, 2016). For the second group, the children were well rested. They could even close their eyes. In the second stage, fabrics were used to rub parts of their bodies (Biotteau et al., 2015). The children continued lying on the floor while the relaxing music was played. To make the session more dynamic, the children also participated on their own. The aim was to induce them to come into contact with their comrades (Morin et al., 2013). At first, it was difficult to combine these two actions simultaneously. For this reason, the work was split into two parts (Massion, 2006): The first part concerned how to hold the hoops by spreading the hands up, and the second part was based on how to close and then open the body from the bottom up. The children were amused by this process, and their pleasure was obvious, especially when the circle was opened and closed (Schopler, 1987). Motility games were proposed as a second part of the training program to promote the development of general motor skills.

Statistical analyses

Descriptive statistical analyses were performed by calculating the means and standard deviations for each parameter under study. The normality of the data distribution was assessed using the Shapiro–Wilk test, which was selected due to its suitability for small sample sizes, as utilized in this investigation. Depending on the normality of the data, two-way analysis of variance (ANOVA) was conducted. If the data violated normality assumptions, the Friedman test was applied as a non-parametric alternative, to determine differences (a) between pre- and post-test measurements and (b) among various groups. When necessary, p-values were adjusted for multiple comparisons using the Bonferroni correction method. Effect sizes (ES) were calculated based on partial eta squared values, with values <0.06 considered small, >0.14 large, and between 0.06 and 0.14 considered medium (Lovakov and Agadullina, 2021). The magnitude of the ES was interpreted using standard guidelines: values <0.06 were considered small, while values >0.14 were considered large. All statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS, version 24.0; IBM, Armonk, NY, USA). Results with p-values <0.05 were considered statistically significant.

Results

Measurement of general motor coordination: Charlop Atwell Scale

For objective scores, a significant main effect of time was observed ($F(1,12) = 33.57$, $p < 0.001$, ES = 0.73, 95% Confidence Interval [CI] = 3.92-8.64), as well as a significant main effect of intervention ($F(1,12) = 8.47$, $p = 0.013$, ES = 0.41, 95% CI = 1.22-8.49). Additionally, a significant time × intervention interaction effect was identified ($F(1,12) = 27.74$, $p < 0.001$, ES = 0.69). Post-hoc analysis revealed that post-objective scores were significantly higher in the experimental compared to the control groups ($p = 0.013$). Furthermore, objective scores in the mild ASD experimental group were significantly higher than in the moderate control group ($p = 0.031$) (Table 3).

For the subjective scores, no significant effects of intervention ($F(1,12) = 2.83$, $p = 0.11$, ES = 0.19, 95% CI = -1.25-9.82) could be found, while a significant effect of time ($F(1,12) = 73.83$, $p < 0.001$, ES = 0.86, 95% CI = 7.03-11.81) was observed, with higher subjective scores post-intervention compared to pre-intervention (Table 3). Additionally, a significant time × intervention interaction effect was reported ($F(1,12) = 37.44$, $p < 0.001$, ES = 0.75). Post-hoc comparisons revealed no significant differences between the experimental and control groups ($p = 0.11$). More in detail, subjective scores were higher in the mild ASD experimental group than the moderate ASD experimental group ($p = 0.03$) and moderate ASD control group ($p = 0.002$).

Imitation of gestures test

Regarding the imitation of gestures, analyses revealed a significant effect of intervention on the simple gesture of hands ($F(1,12) = 13.78$, $p = 0.003$, ES = 0.53, 95% CI = 1.09-4.19), with higher scores in the experimental group compared to the control group ($p = 0.003$). Additionally, the simple gestures of arms differed significantly between experimental and control groups ($F(1,12) = 22.38$, $p < 0.001$, ES = 0.65, 95% CI = 1.81-4.90). Furthermore, higher post-simple gesture of hands scores in the mild ASD experimental group than in the mild and moderate ASD control groups (both, $p = 0.02$) (Table 1). Imitation of the simple gesture of arms scores were lower in the mild ASD control groups compared with the mild and moderate ASD experimental groups ($p = 0.02$, $p = 0.03$, respectively) (Table 3).

Table 3. Values of general motor coordination and imitation of gestures broken down according to each group.

Variable			Experimental group (Mean ± SD)			Control group (Mean ± SD)			Statistical Significance (Time × Intervention)
			Overall	Mild ASD	Moderate ASD	Overall	Mild ASD	Moderate ASD	
General motor coordination	Objective scores	Before	4.00 ± 2.58	4.5 ± 3.00	3.33 ± 2.30	4.85 ± 1.57	5.5 ± 1.91	4.00 ± 0.00	p < 0.001
		After	16.00 ± 6.42	19.00 ± 6.63	12.00 ± 4.00	5.42 ± 2.22	6.50 ± 2.51	4.00 ± 0.00	
	Subjective scores	Before	4.57 ± 3.10	6.50 ± 1.73	2.00 ± 2.64	7.00 ± 3.31	9.25 ± 1.89	4.00 ± 2.00	p < 0.001
		After	20.71 ± 7.67	25.25 ± 3.86	14.66 ± 7.63	9.71 ± 5.28	13.50 ± 3.31	4.66 ± 0.57	
Imitation of gestures	Simples gesture of hands	Before	2.28 ± 1.70	3.00 ± 1.63	1.33 ± 1.52	2.14 ± 0.89	2.25 ± 0.95	2.00 ± 1.00	p < 0.001
		After	6.28 ± 1.97	7.00 ± 1.41	5.33 ± 2.51	1.14 ± 0.89	1.25 ± 0.95	1.00 ± 1.00	
	Simples gesture of arms	Before	2.71 ± 1.70	2.75 ± 1.70	2.66 ± 2.08	1.85 ± 0.89	1.75 ± 0.95	2.00 ± 1.00	p < 0.001
		After	7.85 ± 1.67	7.75 ± 1.89	8.00 ± 1.73	2.00 ± 1.73	1.75 ± 1.25	2.33 ± 2.51	

Abbreviations: ASD: Autism Spectrum Disorder; SD: Standard deviation

Draw-a-person test

For the IQ, no significant effects of time (F(1,12) = 0.36, p = 0.55, ES = 0.03, 95% CI = -1.96-3.47) and intervention (F(1,12) = 0.34, p = 0.56, ES = 0.02, 95% CI = -10.54-18.35) were reported. A significant time × intervention interaction effect was observed (F(1,12) = 8.13, p = 0.01, ES = 0.40). Post-hoc comparisons indicated that post-IQ values did not differ between the experimental and control groups (p = 0.56). Finally, no significant difference was found between both mild and moderate ASD experimental and control groups (p > 0.05) (Figure 2).

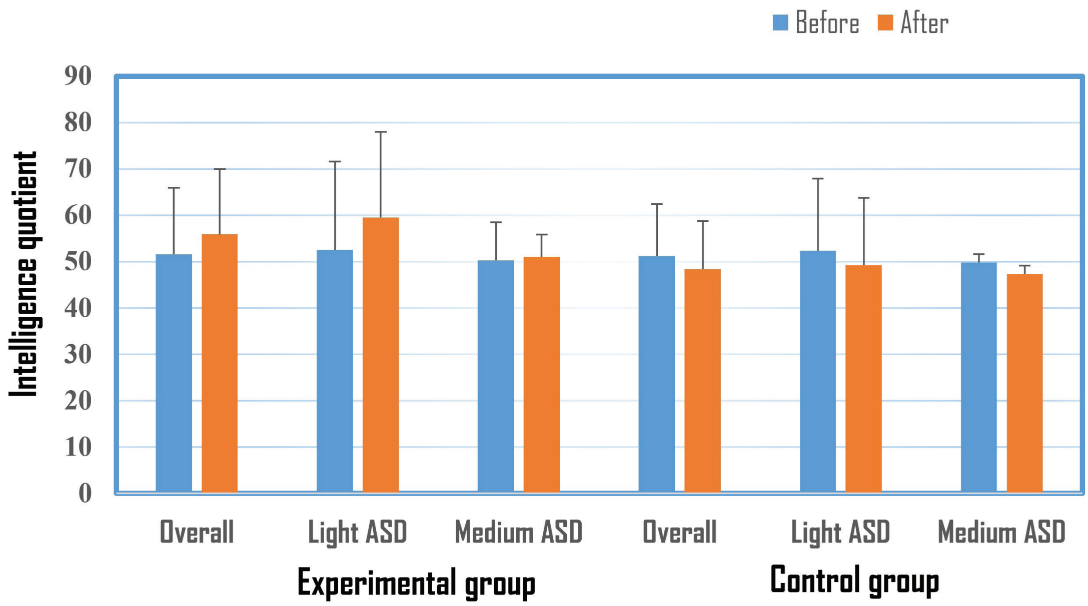

Figure 2. Intelligent quotient broken down according to the group.

Discussion

The objective of the present study was to evaluate the effects of dance therapy on motor coordination, intellectual maturity, and body schema in children with mild and moderate ASD and the difference between them. This research found that one year of dance movement therapy significantly enhanced motor coordination, body schema, and IQ in children with ASD compared with the control group. The results of the post-test revealed significant motor progress at both objective and subjective levels. Nevertheless, this progress was less significant for the subjective scores of motor coordination in the group diagnosed with more severe autism, namely moderate ASD. These findings agree with those of Dawson (1997), who emphasized the importance of sports in the development of motor skills and the general functional development of people with autism. The motor stimulation provoked by this activity makes it possible to create relationships with others, as Birnbrauer and Leach (1997) noted, in interventions within a therapeutic environment. They stated that "to get in motion is already the beginning of a life of relationship... with the other, being either with or against him". In addition, in terms of relationships, this progress was noticed in the sessions during which grouping and exchanging between peers were pursued. The findings were confirmed by the dance movement therapy experiments described by Lesage (2006), through which the contributions of the dancing activity were learned at the motor and relational levels. Generally, dance therapy eliminates the restricted images that always confine participants to the same register (Lesage, 2006). The majority of children had a positive experience (Lleixa et al., 2016), reflecting that "pleasure, and more particularly this relation of pleasure to the practice of physical and sporting activities, must be considered as the fundamental acquisition in physical education, conditioning all other acquisitions, their reinvestment, and, ultimately, their social utility".

From a neurodevelopmental standpoint, dance therapy leverages brain plasticity to strengthen neural pathways involved in motor planning, social cognition, and sensorimotor integration, which are often atypical in autism (Hildebrandt et al., 2016; Thaut et al., 2015). It also enhances cerebellar-prefrontal connectivity, which in turn improves coordination and balance (Hildebrandt et al., 2016). In addition, listening to music while dancing (e.g., rhythmic auditory cues) activates the basal ganglia, which supports motor timing and sequencing (Thaut et al., 2015). From a sensorimotor learning viewpoint, dance therapy provides multisensory input (auditory, kinesthetic, visual) to reinforce motor learning and body schema through embodied cognition. The dynamic systems theory posits that dance therapy promotes motor variability, enabling children to explore and adapt movements (Thelen & Smith, 1994), while proprioceptive feedback from dance steps further refines motor accuracy (Bhat et al., 2011).

The present data reported an evolution of children's imitative capacities after one year of dance movement therapy. The improvement of these capacities is necessary so that these children can manage and control their emotions and reactions, since they have problems with imitation and being imitated (Lainé et al., 2008). The games chosen in the current investigation promoted imitation (facing the mirror, a simple imitation). Schopler's system is helpful for achieving good results (Schopler, 1987). Nevertheless, these results were variable in accordance with the complexity of the test. This variability was demonstrated by the gesture imitation test results. The more complex the items were, the less improvement was achieved. This finding agrees with the findings of Vaivre-Douret et al. (2016), who mentioned that people with autism can imitate if they are offered simple tasks. They can also imitate if the execution of the movement is not too fast for them (Gepner and Mestre, 2002). Practitioners have affirmed that dance therapy is important for different parts of the body (Lesage, 2006). This step is essential for body coordination in children with ASD (Smolak, 2004). The current approach argues

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that different exercises, such as dance therapy, help children elaborate their body schema in a better way.

Dance therapy enhances body schema/imitation through multiple integrated mechanisms. Tactile cues in partner dance improve body boundary perception by addressing sensory integration deficits (Cascio et al., 2012), while slow, mindful approaches such as the Laban/Bartenieff movement foster interoceptive awareness (Mehling et al., 2018). The mirror neuron system (MNS) further contributes by synchronizing visual, proprioceptive, and tactile feedback during dance, strengthening body awareness (Koch et al., 2012). Collectively, these neurophysiological processes lead to measurable improvements in postural control and spatial orientation in children with autism (Scharoun et al., 2014), demonstrating dance's unique capacity to remodel body schema through multisensory integration and neural plasticity. In addition, predictable rhythmic patterns leverage predictive coding mechanisms to reduce cognitive load (Van der Kamp et al., 2008), permitting greater allocation of attentional resources to imitation. These effects are amplified through therapeutic social scaffolding, where modeled movements strengthen visuomotor coupling via MNS activation (Rizzolatti & Craighero, 2004), collectively establishing dance as a potent modality for addressing imitation impairments through synchronized bottom-up (sensorimotor) and top-down (cognitive) neural processes.

Children's different developments in intellectual maturity and body image were interpreted through a draw-a-person test performed by the subjects examined before and after the intervention. Specifically, dance movement therapy was more beneficial in children with ASD than in the control group. For example, participant "A" from the moderate ASD group performed differently in the pretest. A closed figure of his drawn man, termed "round or ovoid", was observed. At this stage, according to the explanations of Brechet et al. (2009) about the round man, "this child does not have the capacity to coordinate in parts or in all. During this stage of the drawn man test, it can be concluded that the child focused on its entirety but forgot the parts". In the posttest, the drawing moved from "ovoid" to a "tadpole man or a man in detached pieces" (tadpole in English and Kopfflüssler in German) (Brechet et al., 2009). This type of drawn man is usually composed of an "ovoid" shape containing facial elements around which radiating lines represent the limbs. For participant "D" of the second group, whose degree of autism was mild, there was a transition from a stage of sex differentiation (index: mustache) to the profile stage, or "the contour man" (participant draws what he sees). Notably, "the child began to draw starting from the contour; his drawing then resembles to the silhouette of a body" (Baldy, 2005). For the other children, a transition was also detected from one stage to another with associated changes in their IQ levels. According to Ajuriaguerra (1970), body image is based on tactile, kinesthetic, labyrinthine, and visual impressions. In this investigation, dance therapy, which included exercises such as body opening and closing, body awareness and openness to space, mobilized the internal experiences of the examined children. This experience provided the opportunity for the subjects to find themselves, share their emotions, and get in touch with the outside world. These results confirm those of Barnet-López's work (Benoit, 2006), which highlighted the importance of dance therapy in the construction of body image.

Dance therapy may enhance IQ and improve body image (assessed via the Draw-A-Person test) in children with ASD through neurodevelopmental and sensorimotor learning mechanisms. Neuroplastically, dance movement therapy strengthens white matter connectivity (Sihvonen et al., 2017), improves cerebellar function (Koziol et al., 2014), and activates MNS (Haboushaw et al., 2021), supporting cognitive gains in executive function and non-verbal IQ (Reinders et al., 2019). Sensorimotor frameworks suggest that dance therapy recalibrates proprioception (Mastrominico et al., 2018) and interoception (Shah et al., 2021), fostering body schema refinement, which may translate to more accurate/holistic human figure drawings (Koch et al., 2015; Priebe et al., 2022). Rhythmic entrainment (Thaut et al., 2015) and mirroring exercises (Behrends et al., 2012) further integrate motor and cognitive timing while enhancing self-other differentiation, collectively addressing core autism-related deficits in body awareness and IQ-linked skills (Berger et al., 2019).

Strengths and Limitations

This study provides valuable insights into the effects of adapted physical activity, namely dance therapy, on motor coordination and body schema in participants with ASD. One of the main strengths is the long training volume and the degree-specific effects. Additionally, the use of validated tools such as the Charlop Atwell Scale, Draw-a-person, and imitation of gestures tests enhances the reliability of the findings. However, this study is not without limitations. The small sample size (n = 14), unequal gender distribution, and limited demographic diversity in participants affect the generalizability of the results to larger populations and may reduce the statistical power and the ability to draw conclusions about gender-specific effects. Furthermore, the sample consisted solely of mild and moderate ASD children, making it challenging to extend the findings to individuals with other neurodevelopmental disorders. Finally, the lack of a direct neurophysiological assessment of cognitive function, such as electroencephalography (EEG) or functional magnetic resonance imaging (fMRI), restricts the ability to elucidate the underlying mechanisms of the observed changes. Future investigations including cognitive and neurobiological data are essential to improve the current body of scholarly knowledge and help understand the underlying mechanisms of the effectiveness of dance therapy in children with mild and moderate ASD.

Conclusion

In summary, motor and relational skills can be developed in children with differing degrees of ASD. The practice of dance therapy not only helps reduce inappropriate behavior but also leads to social and life access. The observed motor and relational changes seemed to intervene only in the case of the organization of materials and human resources for running various sessions in favorable conditions, such as group stability, learning duration, accompaniment by psychologists, and room availability, which were guaranteed for weekly work. Children with ASD are disrupted at the motor, relational, and communicative levels. However, they can develop via an adapted and reassuring framework as well as through the relevant choice of activities to promote later social integration. The aim of this research was not to teach these children these techniques nor to help them achieve better performance. It was merely to help them find themselves, share moments of pleasure, and encourage them to discover their own bodies. The goal was not to help these people live like others but to live with others.

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Conflict of interest information

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References

Ajuriaguerra, J. (1970). Manual of Child Psychiatry. Masson, Paris.

Albaret, J. M. (2015). Research methodology and effects evaluation of psychomotor therapy. De Boeck-Solal: 211-235.

Aithal, S., Moula, Z., Karkou, V., Karaminis, T., Powell, J., & Makris, S. (2021). A systematic review of the contribution of dance movement psychotherapy towards the well-being of children with autism spectrum disorders. Frontiers in psychology, 12, 719673.

Baldy R. (2005). Drawing and cognitive development. Childhoods, 57(1), 34-44.

Baron-Cohen, S., Ring, H. A., Wheelwright.S., Bullmore, E., Brammer, M. J., Simmons, A., & Williams S. C. (1898). Social intelligence in the normal and autistic brain: an fMRI study. European Journal of Neuroscience, 11(6).

Barnet-López, S., Pérez-Testor, S., Cabedo-Sanromà, J., Gozzoli, C., Oviedo, G. R., & Guerra-Balic, M. (2015). Developmental items of human figure drawing: dance/movement therapy for adults with intellectual disabilities. American Journal of Dance Therapy, 37(2), 135-149.

Bartenieff, I., & Lewis, D. (2013). Body movement: Coping with the environment. Routledge.

Behrends, A., Müller, S., & Dziobek, I. (2012). Moving in and out of synchrony: A concept for a new intervention fostering empathy through interactional movement and dance. The Arts in Psychotherapy, 39(2), 107–116.

Berger, J. M., Rohn, T. T., & Oxford, M. (2019). Autism: The movement sensing perspective. Frontiers in Integrative Neuroscience, 13, 44.

Bergès, J., & Lézine, I. (1963). Test d'imitation de gestes: Techniques d'exploration du schéma corporel et des praxies chez l'enfant de 3 à 6 ans. [Test of imitation of gestures: Methods for plotting body image and movements of children from 3 to 6 years of age]. Masson & Cie.

Bhat, A. N., Landa, R. J., & Galloway, J. C. (2011). Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. Physical Therapy, 91(7), 1116–1129.

Biotteau, M., Chaix, Y. & Albaret, J. M. (2015). Procedural learning and automatization process in children with developmental coordination disorder and/or developmental dyslexia. Human Movement Science, 43, 78-89.

Birnbrauer, J. S. & Leach, D. J. (1993). The Murdoch early intervention program after 2 years. Behavior Change, 10(2), 63-74.

Blos, J. r. P. (1993). The Trauma of Transgression: Psychotherapy of Incest Victims: Edited by Selma Kramer and Salman Akhtar. Northvale, New Jersey a. International Journal of Psycho-Analysis, 74, 425-428.

Bonnier, P. (1893). Le vertige. Paris: Rueff.

Brechet, C., Baldy, R., & Picard, D. (2009). How does Sam feel? Children's labelling and drawing of basic emotions. British Journal of Developmental Psychology, 27(3), 587-606.

Butté, C. (2016). Primitive expression and dance therapy: when dancing heals. 11(4):1-4.

Cascio, C. J., Foss-Feig, J. H., Burnette, C. P., Heacock, J. L., & Cosby, A. A. (2012). The rubber hand illusion in children with autism spectrum disorders: Delayed influence of combined tactile and visual input on proprioception. Autism, 16(4), 406–419.

Charlop, M. H., & Atwell, C. W. (1980). The Charlop-Atwell Scale of Motor Coordination: A quick and easy assessment of young children. Perceptual and Motor Skills, 50(3, Pt 2), 1291–1308.

Chen, T., Wen, R., Liu, H., Zhong, X., & Jiang, C. (2022). Dance intervention for negative symptoms in individuals with autism spectrum disorder: A systematic review and meta-analysis. Complementary Therapies in Clinical Practice, 47, 101565.

Cui, X., & Wang, S. (2024). Research on the Effect of Dance Therapy on Improving Social Communication Ability of Children with Autism. International Journal of Mental Health Promotion, 26(5).

Dawson, G. (1997). Early intervention in autism. The effectiveness of early intervention.

Dennis, W. (1996). Goodenough scores, art experience, and modernization. The Journal of Social Psychology, 68(2), 211-228.

Dugas,E. & Moretton, J. P. (2012). What is the choice from sports and physical activities within a learning perspective for youngsters with cognitive impairments or mental disorders? Alter: 6(1):39-56.

Feinberg, E. & Beyer, J. (1998). Creating public policy in a climate of clinical indeterminancy: Lovaas as the case example du jour. Infants and Young Children, 10(3), 54-66.

Gepner, B. & Mestre D.R. (2002). Brief report: postural reactivity to fast visual motion differentiates autistic from children with Asperger syndrome. Journal of Autism and Developmental disorders, 32(3), 231-238.

Goodenough, F. (1926). Measurement of intelligence by drawings. New York: World Book Co.

Haboushaw, A., Davidson, J. W., & Müllensiefen, D. (2021). The role of mirror neurons in dance therapy for autism spectrum disorder. Psychology of Music, 49(5), 1251–1267.

Henze, R., Lucas, T., & Scott, B. (1998). Dancing with the monster: Teachers discuss racism, power, and white privilege in education. The Urban Review, 30(3), 187-210.

Hildebrandt, M. K., Koch, S. C., & Fuchs, T. (2016). “We dance and find each other”: Effects of dance/movement therapy on negative symptoms in autism spectrum disorder. Behavioral Sciences, 6(4), 24.

Koch, S. C., Mehl, L., Sobanski, E., Sieber, M., & Fuchs, T. (2012). Fixing the mirrors: A feasibility study of the effects of dance movement therapy on young adults with autism spectrum disorder. The Arts in Psychotherapy, 39(3), 234–238.

Koch, S. C., Mehl, L., Sobanski, E., Sieber, M., & Fuchs, T. (2015). Fixing the mirrors: A feasibility study of the effects of dance movement therapy on young adults with autism spectrum disorder. Autism, 19(3), 338–350.

Koziol, L. F., Budding, D. E., & Chidekel, D. (2014). From movement to thought: Executive function, embodied cognition, and the cerebellum. The Cerebellum, 13(1), 151–177.

Lainé,F., Tardif, C., Rauzy, S., & Gepner, B. (2008). Perception and Imitation of Biological Motion in Autism: A Matter of Time. 2(60), 140-157.

Lesage, B. (2006). The concept of space. Psychology Childhoods, 33(4), 113-123.

Lichtenberger, E. O., & Kaufman, A. S. (2013). Essentials of WPPSI-IV assessment. John Wiley & Sons. ISBN: 978-1-118-37342-2.

Lleixa, T., Gonzalez-Arevalo, C., & Braz-Vieira, M. (2016). Integrating key competences in school physical education programs. European Physical Education Review, 22(4), 506-525.

Louppe, L. (2010). Poetics of Contemporary Dance, trans. Sally Gardner. Alton, UK: Dance Books.

Lovakov A., & Agadullina E. R. (2021), Empirically derived guidelines for effect size interpretation in social psychology, "European Journal of Social Psychology", vol. 51, no. 3, pp. 485-504.

Massion, J. (2006). Sport and autism. Science & sport, 21(4), 243-248.

Mastrominico, A., Fuchs, T., Manders, E., Steffinger, L., Hirjak, D., Sieber, M., ... & Koch, S. C. (2018). Effects of dance movement therapy on adult patients with autism spectrum disorder: A randomized controlled trial. Behavioral Sciences, 8(7), 61.

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2018). The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2). PLOS ONE, 13(12), e0208034.

Morin, D., Rivard, M., Crocker, A.G., Boursier, C.P., & Caron, J. (2013). Public attitudes towards intellectual disability: A multidimensional perspective. Journal of Intellectual Disability Research, 57(3), 279-292.

Motta, R. W., Little, S. G., & Tobin, M. I. (1993). The Draw-a-Person Test: An indicator of children's cognitive and emotional adaptation? Journal of Clinical Psychology, 49(3), 399–405.

Matto, H. C., & Naglieri, J. A. (2005). "Race and Ethnic Differences on the Draw-a-Person Screening Procedure for Emotional Disturbance." Psychology in the Schools, 42(4), 375–381.

Naglieri, J. A. (1988). Draw-a-person a quantitative scoring system manual. San Antonio, TX: The Psychological Corporation.

Peterson, C.C., Slaughter, V., & Brownell, C. (2015). Children with autism spectrum disorder are skilled at reading emotion body language. Journal of Experimental Child Psychology, 139, 35-50.

Priebe, J. A., Hassett, A., & Geuter, S. (2022). Understanding body perception and mental imagery in autism spectrum disorder through dance movement therapy. Frontiers in Psychology, 13, 902637.

Reinders, N. R., Willemsen, T. M., Veling, W., & Boonstra, N. (2019). Dance therapy improves executive function and non-verbal IQ in children with autism spectrum disorder. Journal of Autism and Developmental Disorders, 49(7), 2941–2952.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. Annual Review of Neuroscience, 27, 169–192.

Rogers, S.J. (1998). Empirically supported comprehensive treatments for young children with autism. Journal of Clinical Child Psychology, 27(2):168-179.

Scharoun, S. M., Reinders, N. J., Bryden, P. J., & Fletcher, P. C. (2014). Dance/movement therapy as an intervention for children with autism spectrum disorders. American Journal of Dance Therapy, 36(2), 209–228.

Shah, P., Catmur, C., & Bird, G. (2021). Emotional decision-making in autism spectrum disorder: The roles of interoception and alexithymia. Molecular Autism, 12(1), 1–15. Scharoun, S. M, Reinders, N. J, Bryden, P. J, & Fletcher, P. C. (2014). Dance/movement therapy as an intervention for children with autism spectrum disorders. American Journal of Dance Therapy, 36(2), 209-228.

Schmitz, C., Martineau, J., Barthélémy,C., & Assaiante, C. (2003). Motor control and children with autism: deficit of anticipatory function? Neuroscience Letters, 348(1), 17-20.

Schopler, E., Mesibov, G.B, Hearsey, K. & Boston, M.A. (1995). Structured teaching in the TEACCH system. In Learning and cognition in autism Springer: 243-268.

Schopler, E. (1987). Specific and nonspecific factors in the effectiveness of a treatment system. American Psychologist, 142(4), 376.

Seal, B. C. & Bonvillian, J. D. (1997). Sign language and motor functioning in students with autistic disorder. Journal of Autism and Developmental Disorders, 27(4), 437-466.

Sihvonen, A. J., Särkämö, T., Leo, V., Tervaniemi, M., Altenmüller, E., & Soinila, S. (2017). Music-based interventions in neurological rehabilitation. The Lancet Neurology, 16(8),

Smolak, L. (2004). Body image in children and adolescents: where do we go from here? Body Image, 1(1), 15-28.

Takahashi, H., Matsushima, K., & Kato, T. (2019). The effectiveness of dance/movement therapy interventions for autism spectrum disorder: A systematic review. American Journal of Dance Therapy, 41(1), 55-74.

Thaut, M. H., McIntosh, G. C., & Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: Rhythmic entrainment and the motor system. Frontiers in Psychology, 5, 1185.

Thaut, M. H., Hoemberg, V. (Eds.). (2015). Handbook of neurologic music therapy. Oxford University Press.

Thelen, E., & Smith, L. B. (1994). A dynamic systems approach to the development of cognition and action. MIT Press.

Vaivre-Douret, L., Lalanne, C., & Golse, B. (2016). Developmental coordination disorder, an umbrella term for motor impairments in children: nature and co-morbid disorders. Frontiers in Psychology, 7, 502.

Van der Kamp, J., Oudejans, R., & Savelsbergh, G. (2008). The development and learning of the visual control of movement: An ecological perspective. Infant Behavior and Development, 31(2), 181–191.

Vernazza-Martin, S., Martin, N., Vernazza, A., Lepellec-Muller, A, Rufo, M., Massion, J., & Assaiante, C. (2005). Goal directed locomotion and balance control in autistic children. Journal of Autism and Developmental Disorders, 35(1), 91-102.

Vaysse, J. & Boinon D. (2003). Specificity and efficiency of a creative psychotherapy: from space organization to psychic organization. Annales Medico Psychologics, 161, 766-773.

Xia, J. & Grant, T. J. (2009). Dance therapy for people with schizophrenia. Schizophrenia Bulletin, 35(4), 675.

ORIGINAL SCIENTIFIC PAPER

A New Table Tennis Match Stroke Forecasting Method Using Transformer-Based Deep Neural Networks

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Abstract

This paper proposes a novel approach for forecasting stroke outcomes in table tennis matches using a transformer-based deep neural network architecture. Table tennis rallies' highly dynamic and fast-paced nature makes trajectory and stroke prediction a particularly challenging. Our model employs dual encoder-decoder structures to extract contextual features from rally sequences and individual players separately, addressing this issue. The model uses attention mechanisms to evaluate the relative importance of stroke techniques and landing positions. Key game-specific attributes, including the ball speed and spin, are incorporated to enhance strategic insight and prediction accuracy. We further introduce a stroke-level event stream representation to convert raw match records into a structured and consistent format, significantly improving interpretability and enabling more efficient analysis. A feature fusion network is employed to integrate rally dynamics and player-specific traits, allowing the model to accurately forecast the type and landing zone of the next stroke. The "Intellectual Tactical System in Competitive Table Tennis" system database provided the table tennis match data collected in this study. This database collects the data of Lin Yun-Ju's matches against male opponents (23 matches, 121 games, 2,225 rallies, totaling 10,517 hits, an average of 4.7 hits per rally). Experimental results show that the proposed architecture significantly improves prediction performance. On the dataset, it achieved top-1 accuracies of 57.2% for stroke type and 42.8% for landing zone (spot), with top-5 accuracies of 98.2% and 91.8%, respectively. Furthermore, we visualize prediction outcomes alongside known stroke data, providing a novel perspective for tactical analysis. This visualization facilitates intuitive understanding for coaches and players, offering a valuable tool for performance evaluation and strategic development in professional table tennis.

Keywords: *Table Tennis, Deep learning, Attention Mechanism, Stroke forecasting, Technical and tactical analysis*

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Introduction

With the rapid development of innovative sports technologies, data collection has become an integral aspect of ball games. Through comprehensive analysis of match data, game strategies are no longer solely reliant on intuitive experience; instead, they are grounded in concrete data evidence, enhancing the accuracy and effectiveness of tactical decision-making. In the highly competitive sport of table tennis, analyzing an opponent's match data enables players to understand their opponent's behavioral patterns better, allowing them to target weaknesses during matches. Players can gain a deeper understanding of their opponents' stroke patterns, tactical approaches, and technical characteristics by systematically collecting and analyzing various types of match data. This facilitates a more comprehensive understanding of the game situation, improving the precision and flexibility of tactical decision-making.

In table tennis, the variability of stroke patterns presents a significant challenge in predicting stroke trajectories. The factors influencing stroke trajectories in table tennis are highly complex, including variables such as stroke speed and spin angle, which can affect the ball's trajectory. Traditional methods for predicting stroke trajectories predominantly rely on observation and subjective judgment. Players and coaches often spend extensive time analyzing match footage frame by frame to anticipate the opponent's next move. These methods are not only time-consuming and labor-intensive, but they are also prone to errors and inconsistencies. However, implementing a stroke trajectory prediction system enables effective extraction and integration of key information from the complex features of players for analysis. This significantly enhances the speed of predictions, providing players with timely data support during the early stages of matches and actual gameplay. Such systems enable players to adjust their tactics quickly in response to their opponent's changes.

Recent research in table tennis has primarily focused on identifying stroke-related information from video footage or quantifying stroke performance through match records. In previous image analysis studies (Kulkarni & Shenoy, 2021), human pose estimation techniques have been utilized to recognize strokes and predict ball landing points by analyzing the positions of various human joint points in images. However, due to the high similarity in stroke actions among players, it is often difficult for computers to distinguish between them accurately. Furthermore, image recognition is susceptible to factors such as image quality and environmental conditions, resulting in poor recognition results, particularly when scene changes occur. Therefore, using human pose estimation methods for stroke prediction in table tennis videos may not be the ideal approach.

To enhance the accuracy of match predictions, many studies have employed the analysis of match records (Chiang & Denes, 2023; Liu et al., 2024,2025; Tsai et al., 2023), often utilizing machine learning or neural network techniques. However, current comprehensive table tennis datasets primarily focus on recording landing points, scores, and events. As a result, much of the existing research has concentrated on using statistical data to predict winning probabilities (Huang et al., 2021), overlooking the significance of other critical information, such as stroke types, in technical and tactical analysis. Thus, to accurately predict future stroke types and landing points, it is essential to consider the four fundamental elements of table tennis tactics: landing point, technique, speed, and spin (Liu et al., 2024). Given the high variability of the sport, variations in these elements - beyond the ball's landing point - must be considered. By effectively leveraging these features, we can gain a more objective understanding of different stroke characteristics, which, in turn, will aid in predicting stroke types and devising strategic approaches for competitive table tennis.

This study formulates stroke prediction as a sequence prediction task to address the challenges and limitations present in existing table tennis analysis applications. This constitutes the core research objective, wherein we employ sequence-to-sequence models to extract match features from input sequences and use an encoder to generate predictive outcomes. Since table tennis rallies consist of alternating strokes between two players, the prediction task is inherently turn-based rather than a conventional single-target sequence prediction problem. Furthermore, a player's overall playing style and rally dynamics may vary depending on the opponent, necessitating a model architecture that can account for such variability. To this end, the sequence-to-sequence model is divided into two distinct components, enabling the learning of player-specific and rally-specific features.

This study builds upon ShuttleNet (Wang et al., 2022a), a stroke prediction method designed to learn stroke techniques and landing points. ShuttleNet employs dual encoders and decoders to model rally progression and player style, effectively capturing stylistic differences between players. It then integrates these features via a fusion network to predict the technique and landing point of the next stroke. To improve the accuracy and comprehensiveness of technical and tactical predictions in table tennis, we convert match records into an event-stream representation focused on stroke sequences. This representation facilitates more efficient and precise analysis. Moreover, we incorporate critical attributes, including the spin and speed, into the rally and player extractors, allowing for more nuanced judgments of stroke techniques and ball landing points.

Related Works

Despite the growing interest in landing point prediction for technical and tactical analysis in table tennis, comprehensive literature remains on full-scale stroke prediction in the sport. This session explores prior studies on landing point prediction in table tennis, discusses the application of sequence prediction methods in sports trajectory forecasting, and further examines stroke forecasting within turn-based sports.

Zhang et al. (2010) proposed a high-speed stereo vision system for table tennis. This system utilizes two smart cameras with a distributed parallel processing architecture based on local networks to track the ball. It computes the ball's trajectory and landing point by analyzing the coordinates obtained from the cameras using mathematical methods. The study primarily employs traditional image processing techniques, such as adjacent frame difference, to detect moving objects and contour analysis to identify the ball's position. The center of the ball is then accurately calculated using the growth of sampled points method. The system derives the ball's 3D position through stereo vision and integrates these equations to predict the ball's flight path, hitting point, and landing point.

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While this method effectively predicts landing and hitting points, providing a comprehensive system for practical application, its image processing technique requires a stable environment. Variations in lighting, background, or player movements can reduce accuracy. The system relies on pre-designed mathematical models and requires extensive manual parameter adjustments to adapt to different scenarios, making it time-consuming and less adaptable to environmental changes. The system's complex hardware and software architecture also require high equipment standards, which increases implementation difficulty and cost.

The researchers (Wu & Koike, 2020) proposed a landing point prediction system for table tennis based on deep learning techniques. This system employs a single camera to capture the player's serving motion, and the video data is processed using the lightweight residual convolutional neural network ResNet50, which performs well in real-time human pose estimation. The network accurately estimates the player's 2D joint positions, extracting motion features before the stroke. These pose data are then input into a long short-term memory (LSTM) network, effectively capturing dependencies in the sequence of stroke actions, leading to accurate landing point predictions. Finally, the results are projected onto the table to provide real-time feedback during training.

Although this system enables real-time prediction of landing points without requiring model parameter adjustments, it mainly relies on the player's current hitting posture for prediction, which overlooks essential factors such as hitting techniques and spin. Consequently, the prediction is less effective in complex situations involving spin strokes. Additionally, like the previously mentioned image processing methods, the system is susceptible to environmental factors that affect image recognition accuracy. Precise camera calibration is necessary to ensure correct image angles, which is a cumbersome process susceptible to interference, presenting operational challenges and increasing maintenance costs.

In recent years, the application of transformers in deep learning has become increasingly widespread, particularly excelling in natural language processing and other sequence modeling tasks. Giuliari et al. (2021) introduced a transformer network based on an attention mechanism to predict future pedestrian trajectories. The model's input consists of an individual's current and past positions; its output is the predicted future positions. The input positions are initially combined with time encoding to assign a unique marker to each time point. The encoder then captures feature relationships within the observed sequences, primarily utilizing the attention mechanism to determine which parts of the sequence to focus on to learn features more effectively. The decoder then autoregressively predicts future positions.

Unlike traditional LSTM networks, transformers can process input data in parallel, resulting in faster training speeds and improved performance, particularly in capturing global relationships for long-term predictions. Their flexibility and scalability enable them to be applied to tasks beyond natural language processing, including image processing and time-series data analysis. This versatility makes transformers well-suited for sequence prediction and feature extraction tasks. However, conventional sequence prediction methods typically only consider the sequential relationship of data to generate subsequent predictions. In turn-based sports like table tennis, it is crucial to consider the sequence of strokes and the stylistic differences between players. Predicting based solely on stroke sequences may reduce accuracy. Thus, transformers require further refinement to effectively apply to table tennis stroke prediction, thereby achieving the desired results.

The researchers (Wang et al., 2022a) proposed a sequence prediction model, ShuttleNet, for predicting badminton strokes, marking the first research effort to address stroke prediction in this context. This model emphasizes rally progression and player style as key features, effectively integrating them to understand match dynamics and player characteristics comprehensively. The model utilizes a transformer-based rally extractor to capture overall rally features from sequential data and incorporates a multi-head attention mechanism (Vaswani et al., 2017) to capture global relationships better. Additionally, a transformer-based player extractor splits the sequential data into two subsequences, using encoder-decoder structures to extract feature information for each player. A position-aware fusion network integrates player and rally information from different transformers to predict future stroke techniques and landing points.

While this method is based on past match records for predictions, providing relatively reliable results by capturing players' stroke characteristics, it was initially designed for badminton, considering only landing points and techniques as key features. However, table tennis must also consider additional critical factors such as speed and spin. These elements are vital for accurate stroke prediction in table tennis, and relying solely on landing points and technique features may not fully capture the complexity of table tennis dynamics. Therefore, when applying ShuttleNet to table tennis stroke forecasting, adjustments are necessary to integrate more table tennis-specific features, including speed and spin, to enhance the model's predictive capability.

A review of the literature on table tennis stroke prediction reveals that while Wu and Koinke (2020) have explored landing point prediction using deep learning methods, primarily through LSTM networks for temporal prediction in human pose estimation, and Wang et al. (2022a) used transformers for badminton stroke forecasting, predicting stroke techniques in table tennis remains largely underexplored. Previous studies on table tennis prediction have primarily focused on landing points and trajectories, with image analysis methods requiring high environmental and equipment standards, which present challenges for practical implementation.

This study aims to accurately predict table tennis techniques and stroke placements. To achieve this, we convert match records into an event-stream representation based on individual strokes, enhancing data consistency and readability, facilitating more efficient and accurate analysis and prediction. We propose a deep learning approach based on ShuttleNet for the stroke prediction framework. The main contributions of this study include incorporating key factors specific to table tennis - namely ball speed and spin, and modifying the model's loss function better to suit the analysis of table tennis tactics and strategies. Additionally, to provide more diverse perspectives in tactical analysis, we employ a moving window approach to capture short-term rally patterns within matches, enabling in-depth analysis of localized tactical scenarios and yielding more precise predictive outcomes.

Methodology

This study proposes a deep learning-based method for predicting table tennis strokes to analyze players' stroke strategies during matches. By forecasting players' potential stroke techniques and placements throughout a match and presenting these predictions graphically, we investigate the relationship between different players' techniques and tactical approaches. In the following, we first outline the preprocessing steps used to convert raw match data into sequential formats suitable for deep learning. The proposed stroke prediction model architecture is then described, which employs two transformer modules to extract features from rally dynamics and player styles, integrating them through a gated multimodal network. Finally, we present the methods used for predicting stroke techniques and placements, along with the associated loss functions.

Data Preprocessing

In sports data analysis, data is typically annotated manually by experts. Experts review match footage and convert the content into a standardized format. For example, in football match analysis, SPADL (Soccer Player Action Description Language) (Decroos et al., 2018) consolidates existing football match data and represents continuous movements in an event stream format, thereby enhancing data analysis and interpretation. In this study, we utilize table tennis match records as our dataset (Liu et al., 2024), which detail the players, stroke techniques, placements, and other information for each rally, providing rich material for analysis.

Due to manual annotation, data inconsistencies and missing values can occur. Additionally, existing representations are based on rallies, which involve recording multiple consecutive strokes, making it difficult to discern individual stroke information quickly. To address these issues, we refer to the BLSR (Badminton Language for Shot Rally) (Wang et al., 2022b) used in badminton, designing a preprocessing method to convert match records into an event stream representation based on individual strokes, thereby improving data consistency and readability, and enhancing the efficiency and accuracy of subsequent analysis and prediction tasks. The representation methods are shown in Table 1, which references the BLSR format and combines the match record's description of table tennis with a stroke-based representation unit.

In a match, there are multiple games, each subdivided into rallies, and each rally consists of various strokes. Each stroke involves interactions between two players. This structure is similar to a corpus in natural language, so we treat each stroke as a word and each rally as a sentence based on the relationships in natural language corpora, sentences, and words. Each rally $R^{(i)}$ can be seen as a stroke sequence $\{s_1^{(i)}, s_2^{(i)}, \ldots, s_{N(i)}^{(i)}\}$, where each stroke $s_n^{(i)}$ contains the following six types of information:

(a) Player: The player who performed the stroke.
(b) Technique: The technique used for the stroke.
(c) Forehand/Backhand: Hit the ball with forehand or backhand technique.
(d) Spin: The type of spin is applied to the ball.
(e) Speed: The speed of the stroke.
(f) Spot: The location where the ball lands on the table.

Information for each rally $R^{(i)}$ can be described as follows:

(a) Player A Score: The score of the player who strikes first in the rally.
(b) Player B Score: The score of the player who strikes second in the rally.
(c) Get-point Player: The player who won the rally.
(d) End Reason: The reason the rally ended, such as out of bounds or net.

Deep Neural Network for Stroke Forecasting in Table Tennis

Each rally in table tennis matches consists of multiple strokes, with two players alternating hits. Thus, stroke prediction in table tennis is defined as a turn-based prediction problem (Wang et al., 2023). We first simulate future player behavior based on known rally information and player styles. Thus, we utilize two feature extractors to separately extract rally information and player styles and then predict the technique and landing point of the next stroke, as shown in Figure 1.

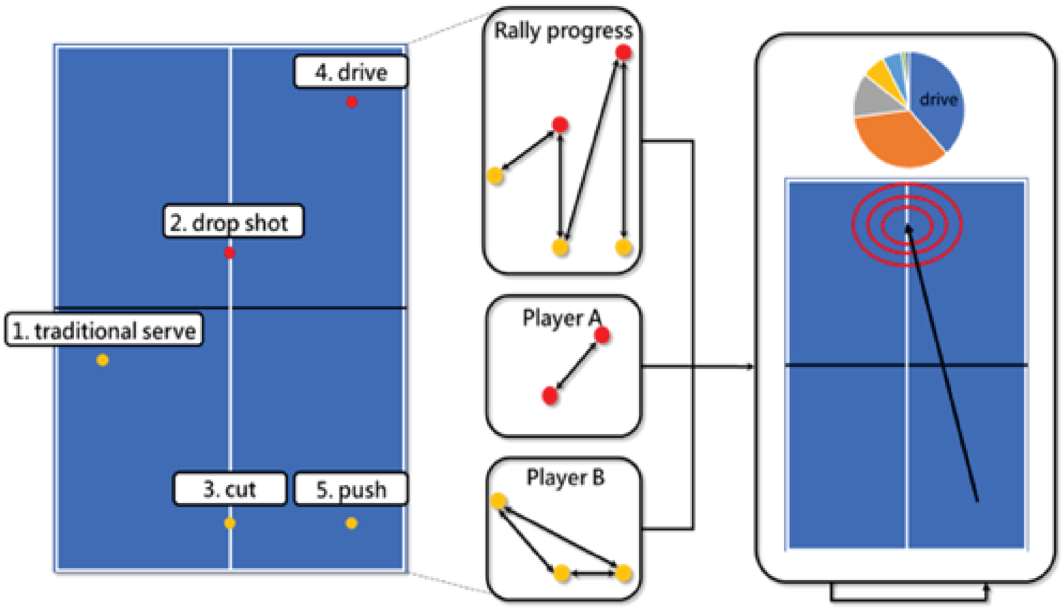

Figure 1. Diagram of a turn-based table tennis stroke forecasting prediction method

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We designed a deep learning-based table tennis stroke prediction model, primarily utilizing the ShuttleNet (Wang et al., 2022a) architecture. The aim is to objectively forecast stroke techniques and landing points in table tennis matches. This framework includes two extractors for extracting rally progress and player styles, consisting mainly of transformers' encoders and decoders. The model replaces the self-attention mechanism with a type-area attention mechanism to better integrate the stroke technique and the landing point. A transformer-based rally extractor generates the rally context, while a transformer-based player extractor obtains the contexts of the two players. A position-aware gated fusion network further fuses these contexts to predict the technique and landing point of the next stroke.

Firstly, a rally in a table tennis match is represented as $R=\{S_1,S_2,\ldots,S_n\}$, composed of multiple strokes, which represent the known information for that rally. The i-th stroke is performed by a player and is denoted as $S_i=\langle p_i,t_i,a_1,r_i,s_i\rangle$, where it includes five key pieces of information: p_i represents the player who performed the stroke, t_i represents the stroke technique, a_i represents the ball's landing points, r_i represents the type of spin applied to the stroke, and s_i represents the speed of the stroke. The stroke prediction problem is defined as forecasting stroke techniques and landing points, given the known information for the previous τ strokes $\{\langle t_i,a_1\rangle\}_{(i=1)}^{\tau}$ combined with player, speed, and spin information, to predict the technique and landing point for the next *n* strokes $\{\langle t_i,a_1\rangle\}_{(i=\tau+1)}^{(\tau+n)}$.

The model can effectively capture complex strategy patterns in table tennis matches and accurately predict future stroke techniques and landing points with this structure. This enhances stroke prediction accuracy and provides robust support for subsequent tactical analysis and match strategy.

Embeddings Layer

In table tennis matches, each stroke includes technique, landing point, spin, speed, and player information. Before inputting this data into the model, it needs to be converted into vector representations so that the model can understand and process the input information. Therefore, we utilize word embedding techniques to effectively capture the relationships between input data, generating dense, low-dimensional vector representations that improve model processing efficiency and prediction accuracy.

Word embedding aims to convert a given input sequence into a representation that is model-readable. A standard method uses One-Hot Encoding, which converts input words into sequence vectors. The length of the vector corresponds to the number of input categories, with only one position being 1 and the rest being 0, where the 1 position corresponds to the index of the word in the vocabulary. However, this method produces large, sparse vectors, which leads to the curse of dimensionality and negatively impacts model performance. Additionally, one-hot Encoding does not capture the semantic relationships between words. Therefore, we utilize word embedding as a representation method, treating it as a lookup table where the input vectors are multiplied by a weight matrix to map into a lower-dimensional vector space, thereby capturing dependencies between words and providing contextual information.

To effectively utilize player information in technique and placement, we add speed, spin, and player information to the technique and landing point vectors, thereby better reflecting the importance of speed and spin in table tennis tactics. For the *i*-th stroke, the embedding layer e^i is calculated as follows:

$$e_i = \langle e_i^t, e_i^a \rangle = \langle t_i' + r_i' + s_i' + p_i', a_i' + r_i' + s_i' + p_i' \rangle \quad (1)$$

where t_i' is the technique vector obtained by projecting t_i' using $M_t \in R^{(N_t \times d)}$, N_t being the number of stroke technique categories; r_i' is the spinvector obtained by projecting r_i using $M_r \in R^{(N_r \times d)}$, N_r being the number of spin categories; s_i' is the speed vector obtained by projecting s_i using $M_s \in R^{(N_s \times d)}$, N_s being the number of speed categories; p_i' is the player vector obtained by projecting a_i using $M_p \in R^{(N_p \times d)}$, N_p being the number of player categories; and a_i' is the placement vector obtained by projecting a_i using $M_a \in R^{(N_a \times d)}$, N_a being the number of placement categories.

Although word embeddings provide rich semantic information for input sequences, transformers process all strokes in parallel and cannot capture the positional information of each stroke in the sequence. Therefore, position encoding is introduced to provide the relative position of each stroke within the sequence. According to the original paper (Wang et al., 2022), strokes that are closer together have more similar position encoding vectors. We can effectively learn the relative positions between strokes by adding the position encoding vectors to each stroke's word embedding vectors. The position encoding vectors are determined based on the order of strokes in the input sequence. This allows the model to retain the sequence order and learn the sequential relationships between strokes. The calculations for position encoding are shown in Equations (2) and (3):

$$pe_{(pos,2i)} = \sin\left(\frac{pos}{10000^{\frac{2i}{d}}}\right) \quad (2)$$

$$pe_{(pos,2i+1)} = \cos\left(\frac{pos}{10000^{\frac{2i}{d}}}\right) \quad (3)$$

where pos represents the position of the stroke in the sequence, d is the dimensionality of the word vectors, 2i represents the even dimensions, and 2i + 1 represents the odd dimensions. This encoding method ensures that different positions are not encoded as identical values across all dimensions, thereby giving each position a unique encoding.

Rally Progress Extractor

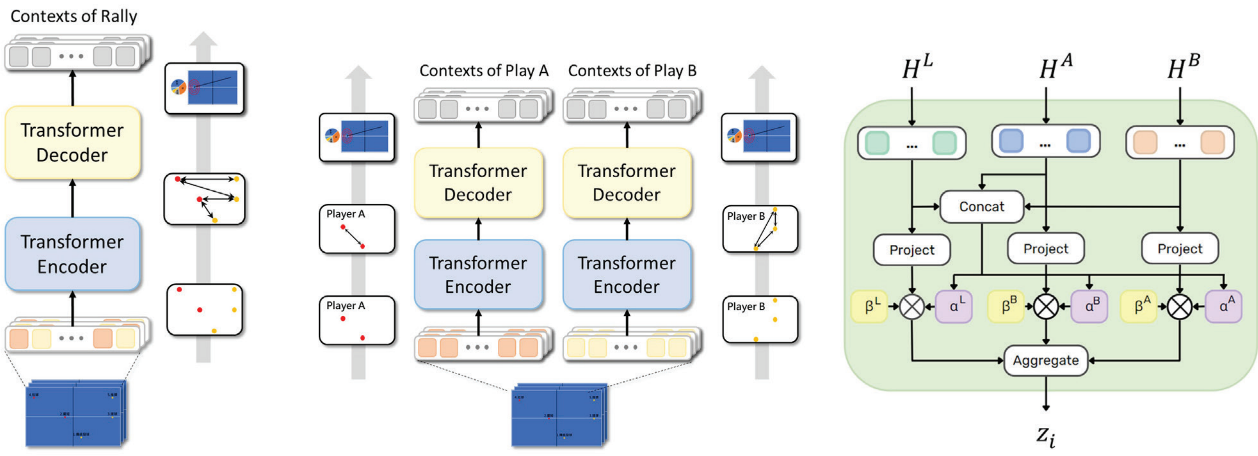
During a rally, players develop strategies to counter their opponents based on the current state of the game. We simulate this process using a rally extractor, as shown in Figure 2(a). The known match records are converted into sequence information, and the input to the rally encoder is represented as:

$$E_R=(\langle e_1^t + pe_1, e_1^a + pe_1\rangle, \langle e_2^t + pe_2, e_2^a + pe_2\rangle, \ldots) \quad (4)$$

where pe_i is the stroke embedding vector with added position encoding. The encoder in the transformer extracts features from each stroke, enabling the model to effectively learn the relationships between strokes and reflect the dynamic state of the game. The rally extractor primarily reflects the current state of the rally, identifying whether a player is currently in an offensive or defensive position. The decoder then uses the extracted rally information to generate contextual information for the rally, as shown in Equation (5):

$$H^R = (h_{(\tau+1)}^R, h^{(\tau+2)R}, \ldots) \quad (5)$$

where $h_i^R \in R^d$ represents the contextual information generated by the encoder for the *i*-th stroke. The generated information is then input into the feature fusion network to infer the possible strategy for the next stroke.



(a) (b) (c)

Figure 2. Diagram of the network architecture. (a) rally progress extractor; (b) player style extractor (c) position-aware gated fusion network.

Player Style Extractor

In table tennis matches, players must devise strategies based on the information from previous strokes and aim to minimize their opponents' advantages while maximizing their own. Therefore, we utilize a player style extractor, as shown in Figure 2(b), to capture each player's playing style and consider their stroke preferences, which enables us to predict the next stroke more accurately for different players. The input sequence data is divided into two sub-sequences according to the players, as represented by Equations (6) and (7):

$$E_A=(e_1,e_3,\dots) \quad (6)$$

$$E_B=(e_2,e_4,\dots) \quad (7)$$

where E_A is the sequence for Player A and E_B is the sequence for Player B. The two sequences are first added with position encoding. Two separate encoders extract the stroke style for each player, and two decoders generate contextual information for both players, as shown in Equations (8) and (9):

$$H_A=(h_{(\tau+1)}^A, h_{(\tau+1)}^A, h_{(\tau+2)}^A, h_{(\tau+2)}^A,\dots) \quad (8)$$

$$H_B=(0, h_{(\tau+1)}^B, h_{(\tau+1)}^B, h_{(\tau+2)}^B, h_{\tau+2)}^B,\dots) \quad (9)$$

where $h_i^A \in R^d$ represents the context generated by the encoder for the *i*-th stroke of the serving player, while $h_i^B \in R^d$ represents the context for the receiving player. Since the serving player performs the first stroke and odd-numbered strokes, the receiving player's sequence has the first stroke filled with zeros and the odd-numbered strokes filled with the contexts of the previous stroke.

The rally progress and player style extractor used in this study employs a transformer as the backbone network to extract features, primarily consisting of an encoder and a decoder. Initially, the encoder transforms the input vectors of each stroke into a set of high-dimensional feature vectors. Subsequently, the decoder generates feature vectors predicting outcomes based on these vectors and uses the prediction results of the previous stroke as input into the decoder.

The encoder is the main component within the transformer, primarily converting input sequences into high-dimensional vector representations. It achieves this by learning the semantic and structural information of the input data, providing rich contextual information for the subsequent operations of the decoder. The encoder comprises six identical sub-layer stacks, each consisting of two main modules: the multi-head self-attention mechanism and a feed-forward network.

The input sequence first undergoes the multi-head self-attention mechanism, which captures global relationships by calculating attention weights between each position in the sequence and every other. This information is then subjected to a nonlinear transformation through a feed-forward network to extract features further, allowing for better learning of complex features and semantic information. Each sub-layer includes residual connections and layer normalization, which help alleviate the vanishing gradient problem and enhance model training efficiency. After processing through multiple encoder layers, the enriched information extracted from the input sequence is represented as high-dimensional vectors, which are then passed to the decoder to generate the final output sequence.

Attention modules (Vaswani et al., 2017) have achieved significant success in deep learning, particularly within the Transformer, which is widely used due to the powerful performance of its self-attention mechanism. The main goal is to calculate the similarity between each element in the input sequence and reweight the results of other elements based on these similarities. The multi-head self-attention, as the technological core of the Transformer, can dynamically learn the semantic features. Typically, it computes attention weights through query, key, and value vectors to determine which features the model should focus on. Attention scores are normalized using activation functions and ultimately used to generate the output of the attention module.

However, in the stroke strategies in table tennis matches, the technique of each stroke mainly depends on the player's previous stroke, while the landing point is determined based on the opponent's past playing habits. Since traditional self-attention mechanisms can only focus on the same position, the model tends to focus on a single position when predicting stroke types and landing points, which is insufficient for fully capturing complex contextual information. To address this issue, Wang et al. (2022a) proposed the Type-Area Attention Layer (TAA), which separately calculates the importance of stroke technique and landing point, then combines them to generate the final attention scores.

Feedforward neural networks play a critical role in enhancing the feature vector representation capabilities and task performance of query indices. Each encoder layer follows the multi-head self-attention mechanism. It consists of two fully connected layers that enable independent feature transformations at each position. This network can be combined with the global context captured by the self-attention mechanism, allowing the encoder to possess stronger learning capabilities when processing sequential data. Additionally, nonlinear activation functions are employed between layers to capture more complex features and patterns. By processing input data from different positions independently in a consistent manner, the network ensures uniformity in feature extraction from the input sequence, as shown in Equation (10):

$$FFN(x)=max(0,xW_1+b_1)W_2+b_2 \quad (10)$$

where x represents the output from the self-attention mechanism, W_1 and W_2 are the trainable weight matrices of the first and second layers, respectively, and b_1 and b_2 are bias vectors. The first fully connected layer maps the input dimension from $d_{model} = 512$ to a higher dimension $d_{ff} = 2048$. After applying the ReLU activation function, the second fully connected layer projects the dimension back to d_{model}. Feedforward neural networks effectively enhance the model's feature representation capabilities through local nonlinear transformations. Combined with the self-attention mechanism, this significantly improves the performance of the transformer model in handling stroke sequence processing tasks.

The decoder's primary function is to generate new output sequences step-by-step based on the previously generated output sequences. Similar to the encoder, the input sequence is first added with positional encoding to retain the order information of each position in the sequence. The input vectors are then passed through multiple decoder layers, primarily including three modules: the Masked Multi-Head Attention Layer, the Multi-Head Attention Layer, and the feedforward neural network.

The masked multi-head attention Layer (Vaswani et al., 2017) introduces a masked mechanism to prevent the model from attending to future positions in the sequence during the generation process, ensuring that each step's prediction is based solely on the parts that have already been generated. The Multi-Head Attention Layer facilitates interactive learning between the decoder's current known output information and the encoder's output. It calculates the similarity between the input sequence and the current sequence context by using the output from the previous layer as the query matrix, and the encoder's output as the key and value matrices, thereby improving the accuracy of predictions. The feedforward neural network consists of two fully connected layers and utilizes nonlinear activation functions for transformation, further extracting features and generating the final predicted vector representations. Additionally, each sub-layer is followed by residual connections and layer normalization, which help mitigate the vanishing gradient problem and enhance training efficiency. Through these modules, the decoder can fully leverage the contextual information provided by the encoder while generating the output sequence step-by-step, thereby improving understanding and prediction accuracy of the input sequence and significantly enhancing the performance and flexibility in stroke sequence prediction tasks.

The Masked Multi-Head Attention Mechanism (Vaswani et al., 2017) is primarily used within the self-attention mechanism of the decoder to prevent the model from focusing on positions in the output sequence that have not yet been generated during the inference process. When calculating attention scores, the masked multi-head attention mechanism adds a mask to obscure the attention values between the current and subsequent non-generated positions. This ensures that each step's output can only be predicted based on the sequence generated up to that point, thus avoiding interference from future information.

The attention mechanism first computes the dot product of the query, key, and value matrices. Then, it applies the masking matrix to the output, setting the attention weights of the future sequence (upper right part of the matrix) to zero. This ensures that the model can only attend to the input of the current and previous steps at each generation step.

The cross-attention mechanism in the decoder is based on the masked multi-head self-attention module. Its primary function is to attend to both the encoder's output and the output from the previous multi-head self-attention module of the decoder when generating each output. This approach effectively leverages the feature information learned by the encoder to better capture the relationship between the input sequence and the output being generated at the current step of the decoder. The decoder first computes a query matrix based on its input, then utilizes the encoder's output to create the key and value matrices. Using the cross-attention mechanism, the decoder acquires contextual information enriched with features learned from the encoder. This enables the model to consider the relationship between the input and the generated sequence at each step, resulting in more accurate predictions.

Position-aware gated fusion network

In the transformer model, the decoder maps the generated high-dimensional feature matrix to a vector of the same length as the number of prediction classes through a linear layer, used for the final prediction. However, players predict the next stroke strategy in a table tennis match based on their opponent's stroke strategy and the current state of the rally. Therefore, it is necessary to process the player and rally information individually and consider the importance of this information comprehensively. A traditional linear layer alone may transform this information into a high-dimensional feature matrix. Still, it does not sufficiently account for the varying importance of this information across different rallies.

To address this issue, we employed a position-aware gated fusion network (Wang et al. 2022a), which aims to more effectively fuse information from different sources while considering their importance in each rally. The Position-Aware Gated Fusion Network utilizes Gated Multimodal Units (Arevalo et al., 2017), enabling the model to dynamically adjust the weight of each information source during the fusion process, accurately reflecting the relative importance of each piece of information in the current context, as shown in Figure 2(c). Firstly, the rally context h_i^R output from the rally progress extractor and the context of both players h_i^A and h_i^B output from the player style extractor are mapped to the hidden vector space, as shown in Equations (11)-(13):

$$\tilde{h}_i^A = \delta_t\left(h_i^A W^A\right) \quad (11)$$

$$\tilde{h}_i^B = \delta_t\left(h_i^B W^B\right) \quad (12)$$

$$\tilde{h}_i^L = \delta_t\left(h_i^L W^L\right) \quad (13)$$

Here, $\delta_t(\cdot)$ represents the tanh activation function, and W^A, W^B and W^R are learnable matrices. Next, the weight of each context is calculated to convey its importance in the current rally, as shown in Equations (14)–(16):

$$\alpha^A = \delta_s\Big([\,\tilde{h}_i^A,\, \tilde{h}_i^B,\, \tilde{h}_i^L\,]W^A\Big) \tag{14}$$

$$\alpha^B = \delta_s\Big([\,\tilde{h}_i^A,\, \tilde{h}_i^B,\, \tilde{h}_i^L\,]W^B\Big) \tag{15}$$

$$\alpha^R = \delta_s\Big([\,\tilde{h}_i^A,\, \tilde{h}_i^B,\, \tilde{h}_i^L\,]W^R\Big) \tag{16}$$

Here, $\delta_s(\cdot)$ the sigmoid activation function is denoted, and $W^{\tilde{A}}$, $W^{\tilde{B}}$ and $W^{\tilde{R}}$ are learnable weight matrices. Finally, the projected vectors, information weights, and position weights are multiplied elementwise and summed up to obtain the final fused output, as shown in Equation (17):

$$z_i=\delta_s\,(\beta_i^A \otimes \alpha^A \otimes \tilde{h}_i^A+\beta_i^B \otimes \alpha^B \otimes \tilde{h}_i^B+\beta_i^R \otimes \alpha^R \otimes \tilde{h}_i^R) \tag{17}$$

In this equation, $\otimes$denotes element–wise multiplication, and β_i^A,β_i^B and β_i^R represent the learned position information weights. This method dynamically adjusts the strategy for fusing information between rallies and players. It introduces complex nonlinear transformations to enhance the prediction accuracy of the following stroke type and landing point. It offers significant advantages in multi-source information fusion. improving prediction accuracy.

Technique and Spot Prediction

In transformer models, the final layer is usually a fully connected layer for classification or generation tasks. The activation function of its output is softmax, which mainly converts the model output into a probability distribution for classification. In the table tennis stroke prediction model, the embedded vector p_i of the player hitting the *i*-th ball is combined with the result z_i from the fusion network. The softmax function then converts each vector element into a probability value between [0,1]. The class with the highest probability is the model's prediction for the technique and landing point of the following stroke in the sequence, as shown in Equations (18)-(19):

$$\hat{t}_{i+1}=\text{softmax}((z_i+p_{i+1})W^t) \tag{18}$$

$$\hat{a}_{i+1}=\text{softmax}((z_i+p_{i+1})W^a) \tag{19}$$

Here, $\hat{t}_{i+1}$ represents the predicted probability distribution of the stroke technique for the next hit, and $\hat{a}_{i+1}$ denotes the predicted probability distribution of the landing point for the next hit. W^t and W^a are learnable matrices.

In deep learning models, an appropriate loss function is selected according to the task requirements to evaluate the model's learning effectiveness and establish measurement standards to quantify the difference between the ground truth and the predicted results. In the task of stroke forecasting in table tennis, the model mainly has two outputs: technique and spot, both of which are multi-class outputs. Cross-entropy loss, commonly used in deep learning for classification tasks, enables the comparison of the predicted probability distribution with the actual labels, accurately reflecting the prediction results, especially in multi-class classification problems.

When predicting the type of the next stroke, multi-class cross-entropy loss is used to measure the difference between the predicted stroke probability and the actual stroke type, which effectively handles classification problems with multiple categories, as shown in Equations (20)–(21):

$$L_{type}=-\sum_{r=1}^{|R|} \sum_{i=r+1}^{|S_r|} t_i \log_{(\hat{t}_i)} \tag{20}$$

$$L_{area}=-\sum_{r=1}^{|R|} \sum_{i=r+1}^{|S_r|} a_i \log_{(\hat{a}_i)} \tag{21}$$

The total loss function consists of two parts: L_{type}, which is the loss for stroke technique prediction, and L_{area}, which is the loss for landing point prediction. Here, S_r represents the input stroke sequence, and R represents all the rally sequences. The total loss value is obtained by summing these two losses, as shown in Equation (22):

$$L=L_{type}+L_{area} \tag{22}$$

Using this loss function, the model can simultaneously optimize the prediction for stroke type and landing point, improving its performance and accuracy in table tennis stroke prediction tasks. This approach effectively handles the complex dynamics in table tennis matches and helps us better understand and simulate player behavior patterns.

Experimental Results and Discussion

Experimental Environment

Due to the high computational demand of training and inference for deep learning networks, the experiment used a GPU to accelerate processing. The hardware setup consisted of an Intel(R) Core(TM) i9-11900K CPU @ at 3.50GHz, an NVIDIA GeForce RTX 4060 GPU, 64GB of memory, and the Windows 10 operating system. The development was mainly performed using Python and the PyTorch framework.

Datasets

The table tennis match data collected in this study were provided by the "Intellectual Tactical System in Competitive Table Tennis" system database (Liu et al., 2024). We selected matches between world-ranked table tennis player Lin Yun-Ju and his opponents as a case analysis, using a dataset comprising 23 matches, totaling 121 games, 2,225 rallies, and 10,517 shots, with an average of 4.7 shots per rally. In the shot prediction task, 80% of the rallies in each match were used as training data, while the remaining 20% were used for inference.

In table tennis, there are 18 stroke techniques. Fourteen of them are categorized as rally strokes: drive, counter-drive, smash, twist, fast drive, fast push, flick, pimple's long push, pimple's fast push, long push, drop shot, chop, block, and lob. The remaining four—traditional serve, hook serve, reverse pendulum serve, and squat serve—are classified as serve techniques. The table tennis table is divided into two halves by a net, with each side further segmented into nine landing zones: forehand short (1), middle short (2), backhand short (3), forehand mid-long (4), middle mid-long (5), backhand mid-long (6), forehand long (7), middle long (8), and backhand long (9). Stroke speed is categorized as slow, medium and fast, and spin types include topspin, backspin, no spin, sidespin-top, and sidespin-back. Hitting type is classified into forehand and backhand.

Evaluation Metrics

Accuracy typically refers to the ratio of correctly predicted samples to the total number of samples. However, in trajectory prediction, where multiple valid tactical options exist, simple accuracy may be too stringent a criterion for evaluation. Thus, we adopted Top-k Accuracy as the evaluation metric, as shown in Equation (23).

$$\text{Acc@}k = \frac{1}{N}\sum_{i=1}^{N} I\Big(y_i \in \hat{y}_i^{(k)}\Big) \tag{23}$$

Top-k Accuracy is commonly used in multi-class classification tasks, measuring whether the actual class appears in the model's top k predictions. This metric accommodates the

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tactical variability of table tennis and provides a more comprehensive assessment of model performance under various scenarios.

Comparisons

We applied the proposed prediction method to table tennis trajectories, enhancing ShuttleNet (Wang et al., 2022a) by incorporating speed and spin—two critical elements in the game of table tennis. These features significantly influence ball trajectories. We evaluated our model on datasets from one world-ranked Taiwanese player, Lin Yun-Ju.

Table 1 shows the results of Lin Yun-Ju's dataset comparing models with and without speed and spin. 'Spot' refers to landing prediction, and 'Technique' to stroke type prediction. Acc@1, Acc@3, and Acc@5 represent Top-1, Top-3, and Top-5 accuracy, respectively. ShuttleNet (Ori) refers to our baseline without speed/spin; ShuttleNet (Adv) includes them. Results show improved accuracy with speed/spin included. For landing prediction, improvements were minimal due to aggressive strategies favoring long strokes. Stroke prediction accuracy improved by about 5.4%.

We conducted experiments with observed sequence lengths τ = 2, 3, and 4 to investigate how the known stroke sequence length affects performance. Table 2 shows that with Lin Yun-Ju's dataset, Acc@1 was highest for τ = 2. Accuracy dropped for τ = 4, likely due to fewer long rallies in the dataset.

Table 1. Evaluation Comparison of the Lin Yun-Ju Dataset

	Landing Area (Spot)			Stroke Type (Technique)		
Methods	Acc@1	Acc@3	Acc@5	Acc@1	Acc@3	Acc@5
ShuttleNet (Ori)	41.3%	94.4%	98.1%	51.4%	77.2%	91.8%
ShuttleNet (Adv)	41.4%	94.5%	98.2%	56.8%	77.3%	94.9%

Table 2. Sequence Length Evaluation Comparison of the Lin Yun-Ju Dataset

Model	Observed Strokes(τ)	Landing Area			Stroke Type		
		Acc@1	Acc@3	Acc@5	Acc@1	Acc@3	Acc@5
ShuttleNet (adv)	2	42.8%	93.4%	97.6%	57.2%	76.6%	88.9%
	3	41.4%	94.5%	98.2%	56.8%	77.3%	91.8%
	4	40.9%	94.8%	98.1%	35.7%	77.9%	90.9%

According to a study by Hung et al. (2020), the adoption of the 40+ABS plastic ball in table tennis since 2017 has once again impacted the development ecosystem of the sport. The advantage of determining the outcome through serve and attack within the first three strokes has gradually diminished, while rally exchanges have increased. Therefore, enhancing the ability to predict tactical and technical performance in prolonged rallies would better align with the actual competitive scenarios of modern table tennis matches. From the data results of this elite player mentioned above, it can be observed that the optimal prediction stroke count for Lin is 2 strokes; his accuracy begins to decline from the fourth stroke onward. Upon review, this may be due to the relatively fewer data points for rallies extending beyond 4 strokes. This suggests that, although the study collected data from 23 matches for the player, it is still insufficient. To more accurately predict the patterns of prolonged rallies, future research should continue to track and expand the match data of players, thereby bringing greater value to the tactical applications of players.

We also examined sliding window sizes (k = 2, 3, 4) to predict the next stroke. Table 3 shows that for Lin Yun-Ju, stroke prediction was best at k = 2, while landing prediction peaked at k = 4. This may be due to his consistent rear-court play, where larger windows better capture player tendencies.

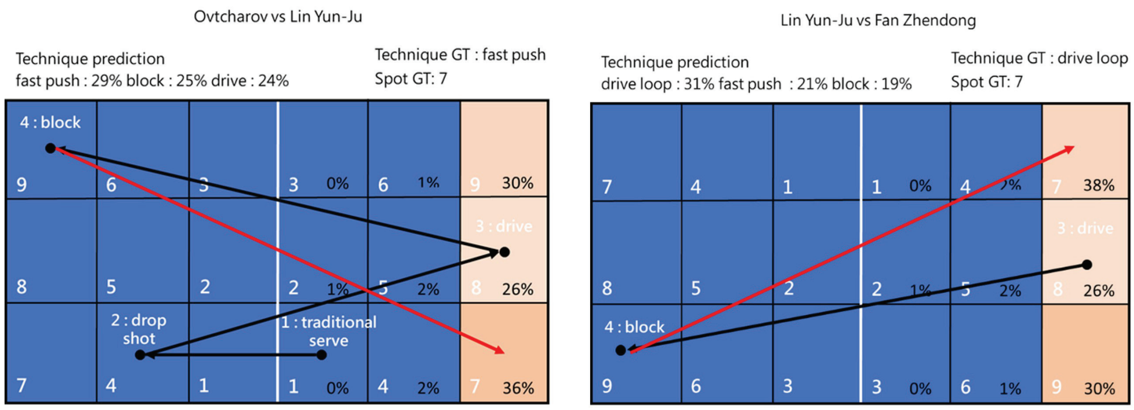
Table 3. Window Size Evaluation Comparison of the Lin Yun-Ju Dataset

	Window (k)	Landing Area			Stroke Type		
		Acc@1	Acc@3	Acc@5	Acc@1	Acc@3	Acc@5
ShuttleNet (adv)	2	40.9%	90.8%	97.4%	59.1%	91.0%	97.9%
	3	43.1%	92.5%	97.9%	58.4%	90.4%	96.4%
	4	45.0%	92.7%	97.7%	51.0%	87.3%	95.0%

The results of this study are also quite in line with actual competition scenarios. Regarding match tactics, elite players typically focus on short or mid-long serves, intending first to control the receiver, making it difficult for them to employ aggressive attack techniques. For the receiver, they might respond with drop shot, push, or back twist attacks. However, after the third stroke, both sides gradually reduce the use of control-focused techniques, leading to what is known as dynamic back-and-forth offensive exchanges. The hitting points for this style of play often occur in the rear court. From this phenomenon, we can generally infer that dynamic offensive exchanges begin by the third stroke in matches between top players.

Prediction Results

Our trained model predicts both the stroke type and landing zone based on a sequence of preceding strokes and visualizes the top three most probable outcomes. Figure 3 shows the prediction result of the proposed method. Figure 3(a) is used as a representative example. It illustrates a rally in which Ovtcharov serves to the "forehand short" area (zone 1), followed by a "drop shot" to zone 4 from Lin Yun-Ju, a "drive loop" to zone 8 by Ovtcharov, and a "block" to zone 9 by Lin Yun-Ju. The model predicted the next stroke as a"fast push" (red line) to zone 7 by Ovtcharov, which corresponded with the actual outcome. Figure 3 (b) shows the predictions for the fifth stroke, based on the data from the third and fourth strokes. In Figure 3 (b) (Lin Yun-Ju vs. Fan Zhendong), the predicted drive loop to zone 7 matched the real result



(a) (b)

Figure 3. Prediction result of the proposed method. (a) the match between Ovtcharov and Lin Yun-Ju in the 5th stroke; (b) the match between Fan Zhendong and Lin Yun-Ju in the 5th stroke

From the above, we learned from the accuracy of predictions regarding the player Lin in the 5th stroke that our proposed method can almost accurately predict the techniques and landing positions they are likely to execute in the next shot. To ensure the reasonableness of the prediction results actual competition scenarios, after interpretation by two national-level table tennis coaches, it was noted that the predicted ball trajectory aligns well with the competition's offensive and defensive strategies, thereby proving the effectiveness of our proposed method. This outcome aligns with the findings of Wang et al. (2022), which suggest that players' stroke selection strategies are influenced by both their overall playing style and the current rally situation. In real match scenarios, when two offensive players face each other, if one initiates an aggressive technique (e.g., a drive), the other may respond with a high-difficulty counterattack (e.g., a counter-drive) if they are confident. However, if the player's strategy leans more conservative, the likelihood of responding with a defensive block increases significantly.

Moreover, previous studies have indicated that the first five strokes are a crucial factor in determining the outcome of a match (Tsai et al., 2023). In this study, we found that Lin Yun-Ju's average number of strokes in the match was 4.7 strokes, corresponding to approximately five strokes per point. This result aligns closely with the rhythm of offensive players, making it significant to predict the trajectory of the fifth stroke. However, unlike previous prediction models, here we attempt to use only the player's preceding two strokes (i.e., the 3rd and 4th strokes) as predictive information for the trajectory of the fifth stroke. The aim is to effectively predict the player's subsequent tactical execution with minimal intelligence-gathering effort, thereby saving considerable data collection time to enhance intelligence-gathering and analysis efficiency. The results revealed that our model achieved excellent predictive performance even with only the preceding two strokes as input. For example, the system's top-ranked prediction that Lin Yun-Ju would hit a "drive loop" to Fan Zhendong's zone 7 on the fifth stroke was entirely accurate.

Conclusion

This paper employs a transformer-based architecture to propose a novel approach for predicting stroke techniques and landing points in table tennis. Converting match data into a stroke-level event stream improves input consistency and interpretability, facilitating more effective learning. The proposed dual-encoder-decoder framework captures rich contextual features from rallies and player profiles, while incorporating critical factors including the ball speed and spin, to model strategic behavior accurately. Landing point prediction is formulated as a classification task, and a sliding window mechanism is employed to capture short-term trajectory patterns, enabling fine-grained analysis of local tactical scenarios. Prediction results are visualized to assist coaches and players in strategic decision-making.

Although the current model is trained on a specific dataset, future work will enhance its generalizability by integrating vision-based technologies, such as pose estimation and ball tracking, to automate the annotation of technical actions. This will support the collection of more diverse and representative datasets, improving the model's applicability across a broader range of players and match contexts. Ultimately, this research advances intelligent sports analytics in table tennis, providing practical tools for performance evaluation and tactical planning.

References

Arevalo, J., Solorio, T., Montes-y-Gomez, M., & Gonzalez, F.A. (2017). Gated multimodal units for information fusion. *arXiv preprint*, arXiv:1702.01992.

Chiang, S., & Denes, G. (2023). Supervised learning for table tennis match prediction. *arXiv preprint* arXiv:2303.16776. https://doi.org/10.48550/arXiv.2303.16776

Decroos, T., Van Haaren, J., & Davis, J. (2018). Automatic discovery of tactics in spatio-temporal soccer match data. In *Proceedings of the 24th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, pp. 223-232. (London, August 19-23, 2018). https://doi.

 DOI 10.26773/mjssm.260306

org/10.1145/3219819.3219832

Giuliari, F., Hasan, I., Cristani, M., & Galasso, F. (2021). Transformer networks for trajectory forecasting. In *2020 25th International Conference on Pattern Recognition (ICPR)*, Milan, Italy, 2021, pp. 10335-10342, doi: 10.1109/ICPR48806.2021.9412190.

Huang, W., Lu, M., Zeng, Y., Hu, M., & Xiao, Y. (2021). Technical and tactical diagnosis model of table tennis matches based on BP neural network. *BMC Sports Science, Medicine and Rehabilitation, 13*(1), 54. https://doi.org/10.1186/s13102-021-00281-y

Hung, C. C., Chou, T. C., & Hsu, M. H. (2020). The impact of 40+ competitive table tennis connecting techniques on the tactics of high-level athletes. *Quarterly of Chinese Physical Education Society of Physical Education, 34*(4), 273-286. DOI: 10.6223/qcpe.202012_34(4).0006

Kulkarni, K. M., & Shenoy, S. (2021). Table tennis stroke recognition using two-dimensional human pose estimation. In *2021 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*, Nashville, TN, USA, 2021, pp. 4571-4579, doi: 10.1109/CVPRW53098.2021.00515

Liu, J.-W., Hsu, M. H., Lai, C. L., & Wu, S. K. (2024). Using video analysis and artificial neural network to explore association rules and influence scenarios in elite table tennis matches. *The Journal of Supercomputing*, 80(4), 5472–5489. https://doi.org/10.1007/s11227-023-05399-6

Liu, J. W., Hsu, M. H., Lai, C. L., Wu, S. K. (2025). A novel framework for table tennis match analysis: combining 3S theory, video analysis, and big data analytics. *Journal of Mechanics in Medicine and Biology, 25*(5), 2540045. https://doi.org/10.1142/S0219519425400457

Tsai, A. L., Hsu, M. H., & Chiu, C.H. (2023). Analyzing the Impact of the Competitive Performance of Olympic Medal-Winning Table Tennis Players from the Perspective of Victory and Defeat. *Sports Coaching Science,71*, 35-50. DOI:10.6194/SCS.202309(71).0004

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A.N., Kaiser, Ł., & Polosukhin, I. (2017). Attention is all you need. In I. Guyon, U. Von Luxburg, S. Bengio, H. Wallach, R. Fergus, S. Vishwanathan and R. Garnett *Proceedings of the 31st International Conference on Neural Information Processing Systems*, 6000-6010.

Wang, W.-Y., Shuai, H.-H., Chang, K.-S., & Peng, W.-C. (2022a). Shuttlenet: Position-aware fusion of rally progress and player styles for stroke forecasting in badminton. In *Proceedings of the AAAI Conference on Artificial Intelligence, 36*(4), 4219-4227. https://doi.org/10.1609/aaai.v36i4.20341

Wang, W.-Y., Chan, T.-F., Peng, W.-C., Yang, H.-K., Wang, C.-C., &Fan, Y.-C. (2022b). How is the stroke? Inferring shot influence in badminton matches via long short-term dependencies. *ACM Transactions on Intelligent Systems and Technology, 14*(1), 1–22. https://doi.org/10.1145/3545311

Wang, W.-Y., Peng, W.-C., Wang, W., & Yu, P.S. (2023). ShuttleSHAP: A turn-based feature attribution approach for analyzing forecasting models in badminton. *arXiv preprint*, arXiv:2312.10942.

Wu, E., & Koike, H. (2020). Futurepong: Real-time table tennis trajectory forecasting using pose prediction network. In *Proceedings of the Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, Honolulu, HI, USA, 25–30 April 2020; pp. 1–8. https://doi.org/10.1145/3334480.3382853

Zhang, Z., Xu, D., & Tan, M. (2010). Visual measurement and prediction of ball trajectory for table tennis robot. *IEEE Transactions on Instrumentation and Measurement, 59*(12), 3195–3205. https://doi.org/10.1109/TIM.2010.2061450

ORIGINAL SCIENTIFIC PAPER

Normative Values for the Growth and Development of Morphological Characteristics in Students Aged 12, 13, 14, and 15 in Kosovo

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Abstract

Monitoring adolescent growth is important for understanding public health trends, especially in the regions and countries where national reference data are still missing, such as Kosovo. The aim of this study was to establish age- and sex-specific reference values for height, weight, and body mass index (BMI) among school-aged students in the Republic of Kosovo and to compare these values with World Health Organization (WHO) growth standards. The study included 1,950 students (997 boys and 953 girls), aged 12 to 15 years, selected from a nationally representative sample. Standard anthropometric methods were used, and BMI was categorized based on WHO criteria. Descriptive statistics, t-tests, and percentile calculations (P1–P99) were performed. The results showed a linear increase in height, weight, and BMI across all age groups. No significant gender differences were found at ages 12 and 13, but from age 14, boys were significantly taller and heavier. Compared to WHO references, height values were mostly similar, except for slightly lower height in 13-year-old boys, while BMI values were consistently higher in both sexes from ages 12 to 14. A high percentage of students, especially boys, were categorized as overweight or obese. Further research is needed to determine whether the higher BMI reflects increased fat mass or lean body mass.

Keywords: *Adolescent Growth and Development; Anthropometry; Body Mass Index; Overweight; Reference Standards*

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Introduction

From an early age, children require not only regular medical care, but also strong emotional and cognitive support in order to grow and develop properly (Moisiu et al., 2005). These early influences are important because they form the base for a child's future physical and mental health. Therefore, monitoring the healthy growth and development of school-aged children is very important, especially for those who are already in the education system. It supports their physical, emotional, and mental development during a period that is full of changes. In addition, growth monitoring allows teachers, doctors, and parents to identify any delays or

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problems that may need attention. It also helps governments and institutions to design better policies and practical programs in the areas of health, education, and social services (Institute of Medicine & National Research Council, 2015). Among many available health indicators, anthropometric characteristics like height, weight, and body mass index (BMI) are considered reliable and simple to measure. These indicators are commonly used to assess physical growth and general health status in children and adolescents. They are also used in public health research to study population-level trends over time.

Adolescent growth is not only a biological process, but also strongly influenced by social and environmental conditions, including daily lifestyle habits. Teenagers do not grow in isolation; their development is shaped by many factors inside and outside the home. For example, the education level and financial situation of the parents can affect how children eat, how active they are, and whether they have regular access to medical and health services (Mollborn et al., 2014). Children from families with lower income may have fewer opportunities for sports or healthy meals, which can directly affect their physical development. On the other hand, improvements in living conditions and the fast spread of digital technology have brought both benefits and problems. While digital tools help with learning and communication, they have also increased screen time and reduced movement, especially among students who spend many hours on computers or mobile devices (Panjeti-Madan et al., 2023). Today, physical inactivity in youth has become a well-known issue and is considered a serious public health concern (Opstoel et al., 2015; WHO, 2019; Halilaj & Gallopeni, 2022). Although it is true that genetic factors play a strong role in how a child grows (Jelenkovic et al., 2011), environmental influences must also be carefully studied and included when evaluating child development (Lilic et al. 2024). Therefore, it is widely accepted that both nature and lifestyle work together to shape the growth of young people.

The World Health Organization (WHO) developed international growth standards in 2006, based on a large multicenter study that collected data from six different countries: Brazil, Ghana, India, Norway, Oman, and the United States. These countries were selected because they represented a range of ethnic and geographical backgrounds, and the children included were raised in environments that provided optimal health, nutrition, and care (Stein et al., 2009; Yang et al., 2015). The goal of the WHO was to create a set of global reference standards that could be used to monitor child growth in any country, regardless of location or income level. These growth charts became widely used in medical and educational systems around the world. By 2011, about 125 countries had already adopted the WHO growth standards, and another 25 were still in the process of evaluating them. Around 30 countries had not adopted them at that time (de Onis et al., 2012; Yang et al., 2015). Even though the WHO growth charts are widely accepted and useful for international comparison, they may not fully match the genetic and environmental conditions of every population. For this reason, some countries have started to develop their own national growth references to better reflect their local population and health realities.

It is of utmost importance for each country to develop its own national norms of growth in children. These norms help to detect any delays in development and to respond early with proper support (Shonkoff & Phillips, 2000; American Psychological Association, 2019). When growth is evaluated using data from the same country and context, the results are more realistic and useful. Such reference norms are used in schools, health centers, and even in sports. Kosovo is a young country and still faces many challenges in the public health system. It still does not have national reference values for growth in adolescents. Due to lack of resources and limited research, many professionals rely on WHO norms, which may not always match the genetic and environmental situation of Kosovo. The aim of this study was to develop local growth references for students aged 12 to 15 in Kosovo and compare them with WHO standards.

Materials and Methods

Participants

This study included 1,950 students (997 boys and 953 girls) from lower secondary schools in Kosovo. All participants were aged between 12 and 15 years. According to official records of the Ministry of Education, there were 94,024 students in this age group in the 2022/2023 school year. Based on this number, the minimum sample for 95% confidence level was 1,071 participants, so the sample of this study can be considered as statistically representative.

Before starting the measurements, the research team explained the aim and procedure to the students, school directors, and parents, and consents were obtained. Students with known health conditions were not included. Only students with signed parental consent forms were measured. The study was approved by the University of Pristina's governing council (Protocol no. 2/963, dated 15.11.2023) and followed the Declaration of Helsinki (WMA, 2001).

Variables, Measurement, and Protocol

The main variables in this study were age, sex, body height, body weight, and BMI. Age and sex were taken from school records. Body weight was measured using a digital scale (accuracy: 100 g), and height was measured using a vertical anthropometer (accuracy: 0.5 cm). Students were lightly clothed, and the clothing weight was subtracted. BMI was calculated using the standard formula (kg/m^2) and compared using WHO reference values (WHO, 2006). All tools were produced by RossCraft Innovation and were calibrated before each measurement. Trained staff collected all data, which was divided by sex and age for analysis.

Statistics

The data were analyzed using basic descriptive statistics, including mean, standard deviation, and frequency. Independent t-tests were used to compare boys and girls in height, weight, and BMI. The BMI values were categorized as underweight, normal, overweight, and obese based on WHO criteria. Normality of data was checked using the Shapiro–Wilk test. If data was not normally distributed, Box–Cox transformation was applied (Oyhenart et al., 2014). Percentiles from P1 to P99 were calculated and compared with WHO reference percentiles (De Onis et al., 2007).

Results

Table 1 shows the normality test using the Shapiro–Wilk method. Only the height values of girls aged 12, 13, and 14

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years, and boys aged 12 years showed normal distribution. All other measured variables had statistically significant deviation from normality, so transformation was needed before analysis.

Table 1. Normality test according to the Shapiro Wilk test method

YEARS	GENDER	VARIABLE	SHAPIRO-WILK		
			STATISTIC	DF	P
12	GIRLS	HEIGHT	.993	209	.454
		WEIGHT	.951	209	<.001
		BMI	.929	209	<.001
	BOYS	HEIGHT	.995	240	.584
		WEIGHT	.940	240	<.001
		BMI	.929	240	<.001
13	GIRLS	HEIGHT	.995	261	.557
		WEIGHT	.931	261	<.001
		BMI	.931	261	<.001
	BOYS	HEIGHT	.986	255	.012
		WEIGHT	.951	255	<.001
		BMI	.931	255	<.001
14	GIRLS	HEIGHT	.993	210	.409
		WEIGHT	.943	210	<.001
		BMI	.875	210	<.001
	BOYS	HEIGHT	.982	246	.003
		WEIGHT	.940	246	<.001
		BMI	.904	246	<.001
15	GIRLS	HEIGHT	.983	258	.003
		WEIGHT	.972	258	<.001
		BMI	.947	258	<.001
	BOYS	HEIGHT	.984	256	.006
		WEIGHT	.936	256	<.001
		BMI	.881	256	<.001

Note. Statistic: Statistic; DF: the degrees of freedom; P: the two-tailed significance or p-value

After transformation using the Box–Cox method, data became more normally distributed. Table 2 shows the basic descriptive statistics and differences between boys and girls for height, weight, and BMI. At ages 12 and 13, there were no significant differences between sexes. Starting from age 14, boys were taller (t = -6.90; p < 0.001) and heavier (t = -3.20; p = 0.01), but BMI was not significantly different. At age 15, boys continued to be taller (t = -13.52; p < 0.001) and heavier (t = -4.38; p < 0.001), and still no difference in BMI.

Table 2. Descriptive Statistics and discriminative T-test of anthropometric, height, weight and BMI parameters (girls & boys)

			HEIGHT				WEIGHT				BMI			
YEARS	GENDER	N	MEAN	SD	T	P	MEAN	SD	T	P	MEAN	SD	T	P
12	GIRLS	209	152.80	8.00	1.31	0.19	46.57	15.19	-0.04	0.97	19.84	5.06	-0.66	0.51
	BOYS	240	151.83	7.66			46.62	14.49			20.14	4.65		
13	GIRLS	261	157.82	6.42	0.14	0.885	51.98	12.10	0.30	0.75	20.76	4.14	0.71	0.47
	BOYS	255	157.73	8.07			51.63	14.14			20.48	4.69		
14	GIRLS	210	160.64	6.36	-6.90	<0.001	54.24	11.09	-3.20	0.01	20.91	3.85	-0.20	0.84
	BOYS	246	165.73	9.28			58.13	14.31			20.99	4.30		
15	GIRLS	258	162.55	5.53	-13.52	<0.00	58.18	9.53	-4.38	<0.001	22.02	3.40	1.86	0.06
	BOYS	256	170.55	7.68			62.44	12.35			21.42	3.97		

Note. N: number of participants; SD: standard deviation; T: T-test; P: P-value or significance

Table 3 shows the frequency and percentage of students according to BMI categories. For 12-year-old girls, 7.7% were underweight, 62.7% normal, 18.7% overweight, and 11% obese. For boys, 2.9% were underweight, 60% normal, 18.8% overweight, and 18.3% obese. Similar trends continue in other ages, with boys showing higher percentages in overweight and obesity.

Table 3. Categorization in percentage and frequencies according to body mass index data (girls & boys)

AGE	GENDER	F&%	UNDERWEIGHT	NORMAL WEIGHT	OVERWEIGHT	OBESE	N
12	GIRLS	F	16	131	39	23	209
		%	7.7	62.7	18.7	11.0	100
	BOYS	F	7	144	45	44	240
		%	2.9	60.0	18.8	18.3	100
13	GIRLS	F	5	191	40	25	261
		%	1.9	73.2	15.3	9.6	100
	BOYS	F	17	153	47	38	255
		%	6.7	60.0	18.4	14.9	100
14	GIRLS	F	6	164	26	14	210
		%	2.9	78.1	12.4	6.7	100
	BOYS	F	14	170	33	29	246
		%	5.7	69.1	13.4	11.8	100
15	GIRLS	F	4	197	44	13	258
		%	1.6	76.4	17.1	5.0	100
	BOYS	F	18	181	29	28	256
		%	7.0	70.7	11.3	10.9	100

Note. F: Frequencies; %: percentage; N: number of participants

Table 4 compares the results from Kosovo with WHO norms for height and BMI. No significant difference was found in height, except for 13-year-old boys, where WHO students were taller ($p < 0.001$). But in BMI, Kosovar students had higher values in both sexes from age 12 to 14 ($p < 0.001$).

Table 4. Differences between Kosovo and WHO student according to height and BMI (girls & boys)

		HEIGHT				BMI			
YEARS	GENDER	KOSOVO	WHO	MEAN DIFF	P	KOSOVO	WHO	MEAN DIFF	P
12	GIRLS	152.80	153.7	-0.90	-0.10	19.84	18.36	1.47	<0.001
	BOYS	151.83	152.18	-0.35	0.47	20.14	17.84	2.29	<0.001
13	GIRLS	157.82	158.08	-0.25	0.51	20.76	19.16	1.60	<0.001
	BOYS	157.73	159.35	-1.62	<0.001	20.48	18.58	1.90	<0.001
14	GIRLS	160.64	160.7	-0.05	0.90	20.91	19.83	1.08	<0.001
	BOYS	165.73	165.97	-0.23	0.69	20.99	19.35	1.64	<0.001
15	GIRLS	162.55	162.13	0.42	0.22	22.02	20.45	1.57	<0.001
	BOYS	170.55	170.91	-0.35	0.45	21.42	20.10	1.32	<0.001

Note. P: P-value or significance

Table 5. Normative values for girls - height, body weight, body mass index

AGE	VARIABLE	N	Percentiles										
		VALID	1	3	5	15	25	50	75	85	95	97	99
12	HEIGHT	209	133.18	136.77	138.92	144.23	147.63	153.18	157.61	160.64	166.01	169.02	171.09
	WEIGHT	209	12.4	18.35	21.39	31.06	36.68	46.27	56.22	63.14	72.36	76.73	83.39
	BMI	209	8.51	9.99	10.97	14.81	16.82	19.85	23.37	24.70	28.39	29.54	31.25
13	HEIGHT	261	140.25	145.56	147.03	151.63	153.96	157.88	162.19	164.35	167.81	169.48	173.34
	WEIGHT	261	23.48	30.44	33.47	40.75	44.28	51.08	59.01	64.32	75.44	77.54	81.39
	BMI	261	11.88	13.48	14.41	16.29	17.57	20.80	23.54	25.05	27.76	28.49	30.69
14	HEIGHT	210	143.91	147.11	149.40	153.81	156.75	161.41	165.12	166.94	170.24	171.08	174.37
	WEIGHT	210	28.94	34.29	35.77	43.48	46.62	53.87	60.29	65.66	72.59	76.84	85.14
	BMI	210	11.36	14.12	15.32	17.42	18.57	20.62	23.20	24.82	27.59	28.97	32.08
15	HEIGHT	257	148.92	151.06	152.52	156.75	159.28	162.70	166.25	167.99	171.43	172.39	176.08
	WEIGHT	258	39.14	40.97	43.14	47.84	51.39	57.51	65.05	68.34	74.03	76.53	79.11
	BMI	258	14.71	16.09	16.52	18.37	19.64	22.15	24.40	25.49	27.70	28.27	30.02

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Table 5 gives the normative values for girls. There is a clear increase in height, weight, and BMI from age 12 to 15, which shows regular growth.

Table 6 shows the same data for boys. Linear growth is seen here too. The biggest increase in height happened between ages 13 and 14.

Table 6. Normative values for boys - height, body weight, body mass index

AGE	VARIABLE	N	Percentiles										
		VALID	1	3	5	15	25	50	75	85	95	97	99
12	HEIGHT	240	133.26	136.84	138.75	144.13	146.46	152.23	157.13	159.68	164.76	166.44	168.47
	WEIGHT	240	16.03	22.09	25.47	31.98	36.14	44.90	57.68	61.97	73.62	76.63	81.42
	BMI	240	10.60	12.49	13.05	15.30	16.30	19.92	23.69	25.33	27.90	29.02	29.78
13	HEIGHT	255	140.75	143.56	144.77	148.72	151.90	157.82	162.63	166.47	172.40	174.02	175.05
	WEIGHT	255	26.59	28.05	30.62	36.21	39.10	51.06	62.02	67.00	75.39	78.50	82.22
	BMI	255	11.57	12.11	12.76	15.20	16.98	20.47	24.37	25.62	27.73	28.13	30.31
14	HEIGHT	246	142.90	147.46	149.25	155.16	159.87	166.71	172.48	175.02	179.07	181.89	184.78
	WEIGHT	246	23.59	28.62	34.22	43.76	48.54	58.35	67.10	70.89	83.23	85.75	93.37
	BMI	246	8.97	12.80	14.19	16.94	18.55	21.07	23.44	25.10	28.62	29.42	31.97
15	HEIGHT	255	150.04	153.28	155.51	163.71	166.76	170.77	175.48	178.05	182.26	184.24	188.41
	WEIGHT	255	33.12	39.11	43.33	50.24	54.24	61.87	70.73	75.28	84.02	86.29	92.34
	BMI	255	12.93	13.93	14.66	17.65	18.54	21.20	23.90	25.79	28.37	29.23	31.64

Discussion

This study was carried out to create national reference values for height, body weight, and BMI in school-aged students in Kosovo. It included students aged 12 to 15 years and used a representative sample from different regions. The results were also compared with WHO international growth standards to observe how Kosovar children grow compared to global patterns. There are several most important results. First, students' height increased steadily across ages in both sexes, while BMI values appeared higher than the WHO standards. However, many students, especially boys, were found in the overweight and obese categories. These observations offer information about how adolescents in Kosovo are growing in recent years.

Results showed that students' body height increased every year in both boys and girls. Girls had the highest increase in height between ages 12 and 13, while boys experienced this change between 13 and 14 years. After that, the growth slowed down. This kind of development difference between sexes is commonly reported in the literature, where girls enter puberty earlier. Body weight and BMI also increased each year as expected during adolescence. The general trend of the variables followed similar results from previous studies (Sweeting & West, 2002; Madhu, 2022). These results describe the basic physical growth in adolescents from Kosovo.

At ages 12 and 13, there were no significant differences in anthropometric measures between boys and girls. At age 14 and especially 15, boys were significantly taller and heavier than girls, while BMI did not show a clear difference between sexes. This can be explained by the fact that weight and height increased at similar rates in boys, keeping BMI relatively stable. On the other hand, it is also possible that muscle mass increased more than fat mass, especially in boys, which may not be reflected in BMI. Previous studies have also shown that BMI is not always accurate to describe body composition, especially during puberty, while other measurements like body fat percentage, and/or analyses of lean body mass might provide better understanding of BMI trends, and should be definitively considered in future studies.

When the data from Kosovo were compared with WHO standards, height values were mostly similar. An exception was seen in boys aged 13, where WHO values were higher. For BMI, differences were more visible, with Kosovar students showing higher values across most age groups, especially from 12 to 14 years. This was the case for both boys and girls, and almost certainly is at least partially associated with previously specified difference in body height between Kosovar students and WHO-reported data. Many factors could explain this, such as diet, lifestyle, or physical activity. The difference may also be related to environmental or social changes in the country, which are different from the populations used to develop WHO standards (Lopes et al., 2012). Irrespective of the background, these comparisons give a perspective about where Kosovo stands in terms of growth indicators.

The BMI category analysis showed that many Kosovar students, were classified as overweight or obese. This is particularly evident for boys. Most specifically, at age 12, this was 37.1% for boys and 29.7% for girls being classified as overweight/obese. The numbers were still high at older ages, although evidently lower. However, in all age groups, the percentage of overweight and obese students remained above one-fifth of the population. These numbers were higher than authors of the study expected, but in general followed a similar direction as global studies showing increasing weight problems in young people (Hedayetullah et al., 2023).

It is interesting to note that global results show that body weight issues are present already in early adolescence and affect both sexes, but a a deeper look into recent literature suggests that body weight concerns may, in fact, are more prevalent or more intense among females during early adolescence. For instance, a review by Martini et al. (2022) found that the prevalence of weight dissatisfaction ranged widely (from 10.8% to 82.5% among boys and from 19.2% to 83.8% among girls), indicating a consistently higher concern among females, while Mäkinen et al. (2012) confirmed that body dissatisfaction often begins in early adolescence, with girls reporting lower satisfaction with their bodies compared to boys. Other studies also supported these findings, showing that 78.1% of adolescent females and 60.1% of males experienced weight-related concerns (Neumark-Sztainer et al. 2018). These studies suggest that while both sexes are affected by weight issues during adolescence, the psychological burden and body image dissatisfaction tend to be more pronounced in females.

Higher BMI in students may be the result of various lifestyle changes in recent years. Children and teenagers are now spending more time sitting indoors, using technology, and eating foods that are rich in calories but poor in nutritional value. These habits can contribute to excessive weight gain. (Barnett, et al., 2018). In countries that are still developing their health education systems, these problems may appear faster. The situation in schools may also affect growth, especially if physical activity is not promoted or if access to healthy food is limited. Some of these issues may be more common in urban areas than rural ones, but this was not analyzed in the present study. Including such variables in future research could help to understand the influence of daily habits and environment.

At the same time, we can specifically determine if the higher BMI values found in this study are caused mainly by fat accumulation or by increases in lean body mass, especially if we take into account differences between sexes (please see previously for discussion). Specifically, during puberty, boys in particular may gain more muscle, which also increases body weight and BMI (McCabe, et al., 2002). Without using direct methods to measure fat and muscle, such as skinfold tests or bioimpedance, it is difficult to interpret the health meaning of higher BMI. Future studies should include such tools to give a more complete picture of adolescent growth.

Strengths and limitations

One strength of this study is the use of a large and nationally representative sample, which included students from different regions of Kosovo. This makes the data more reliable for describing the growth patterns of adolescents in the country. Another strength is the use of standard anthropometric protocols and trained staff for measurements, which helped to reduce possible errors. The comparison with WHO growth standards also made it possible to see how students in Kosovo are developing compared to international data.

However, there were some limitations. The study only included basic anthropometric variables and did not measure physical activity, food intake, or detailed body composition. These factors may have an effect on BMI and could help explain the results more clearly. Also, information about socioeconomic status or rural and urban differences was not collected. These variables might influence the growth of children and should be considered in future research. The study was cross-sectional, so it shows a snapshot in time, and does not follow students over many years.

Conclusion

This study created the first reference values for height, weight, and BMI among students aged 12 to 15 years in Kosovo. The findings showed that growth in height was similar to WHO standards in most age groups, while BMI values were often higher. The results also showed that many students, especially boys, were in the overweight and obese categories.

At the moment, it is not known whether the high BMI values are a result of increased fat mass or increased lean body mass. BMI alone cannot make this difference, especially during adolescence, when boys often gain more muscle. Because of this, the results should be interpreted carefully. Future studies should include more detailed indicators of body composition to better understand if the increased BMI represents a health risk or a normal part of physical development.

The use of national reference data makes it easier for teachers, doctors, and researchers to evaluate physical development of students in Kosovo. These findings may help in the future when planning health education programs or improving physical activity in schools. More research is needed to explore lifestyle factors, family background, and other influences on adolescent growth.

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Conflict of interest

The authors declare no conflict of interest.

All authors read and approved the final version of the manuscript.

References

American Psychological Association. (2019, December 12). Digital guidelines: Promoting healthy technology use for children. https://www.apa.org/topics/social-media-internet/technology-use-children

Barnett, T. A., Kelly, A. S., Young, D. R., Perry, C. K., Pratt, C. A., Edwards, N. M., ... & American Heart Association Obesity Committee of the Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular Disease in the Young; and Stroke Council. (2018). Sedentary behaviors in today's youth: approaches to the prevention and management of childhood obesity: a scientific statement from the American Heart Association. Circulation, 138(11), e142-e159. https://doi.org/10.1161/CIR.0000000000000591

de Onis, M., Onyango, A., Borghi, E., Siyam, A., Blössner, M., & Lutter, C. (2012). Worldwide implementation of the WHO Child Growth Standards. Public Health Nutrition, 15(9), 1603–1610. doi:10.1017/S136898001200105X

de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization, 85(9), 660–667. https://doi.org/10.2471/blt.07.043497

Giuriato M, Lovecchio N, Carnevale Pellino V, Mieszkowski J, Kawczyński A, Nevill A, Biino V. 2022. Gross motor coordination and their relationship with body mass and physical activity level during growth in Children aged 8–11 years old: a longitudinal and allometric approach. PeerJ 10:e13483 https://doi.org/10.7717/peerj.13483

Hedayetullah, S., Sagar, V., Singh, S. B., Minz, P., Kujur, A., Kashyap, V., Haque, M. S., Kumar, D., Sahu, S., & Wasnik, A. (2023). Prevalence of Overweight and Obesity among Students of Government and Private High Schools in an

DOI 10.26773/mjssm.260307

Indian State With Significant Tribal Population: A Cross-Sectional Analytical Study. Cureus, 15(8), e43105. https://doi.org/10.7759/cureus.43105

Halilaj B, Gallopeni F. (2022) Impact of physical activities in mental health of physical education and sports students during pandemic COVID-19. Gazz Med Ital - Arch Sci Med 2022;181:455-60. DOI: 10.23736/S0393-3660.21.04758-6

Institute of Medicine and National Research Council. 2015. Transforming the Workforce for Children Birth Through Age 8: A Unifying Foundation. Washington, DC: The National Academies Press. https://doi.org/10.17226/19401.

Jelenkovic, A., Ortega-Alonso, A., Rose, R. J., Kaprio, J., Rebato, E., & Silventoinen, K. (2011). Genetic and environmental influences on growth from late childhood to adulthood: a longitudinal study of two Finnish twin cohorts. American journal of human biology: the official journal of the Human Biology Council, 23(6), 764–773. https://doi.org/10.1002/ajhb.21208

Lilic, A. S., Vuletic, P. R., Pehar, M., Uzicanin, E., Zovko, I. C., Bujakovic, B., & Zenic, N. (2024). Analyzing the Associations between Physical Literacy, Physical Activity Levels, and Sedentary Behavior: Cross-sectional Study in Preadolescent Children. Sport Mont, 22(2). https://doi.org/10.26773/smj.240708

Lopes, V. P., Stodden, D. F., Bianchi, M. M., Maia, J. A., & Rodrigues, L. P. (2012). Correlation between BMI and motor coordination in children. Journal of science and medicine in sport, 15(1), 38–43. https://doi.org/10.1016/j.jsams.2011.07.005

Łuszczki, E., Bartosiewicz, A., Bobula, G., Kuchciak, M., Jagielski, P., Oleksy, Ł., ... & Dereń, K. (2021). New media development, sleep and lifestyle in children and adolescents. Sustainability, 13(4), 2248.

Martini, M. C. S., Assumpção, D. D., Barros, M. B. D. A., Mattei, J., & Barros Filho, A. D. A. (2022). Prevalence of body weight dissatisfaction among adolescents: a systematic review. Revista Paulista de Pediatria, 41, e2021204. https://doi.org/10.1590/1984-0462/2023/41/2021204

McCabe, M. P., Ricciardelli, L. A., & Finemore, J. (2002). The role of puberty, media and popularity with peers on strategies to increase weight, decrease weight and increase muscle tone among adolescent boys and girls. Journal of psychosomatic research, 52(3), 145-153. https://doi.org/10.1016/S0022-3999(01)00272-0

Mäkinen, M., Puukko-Viertomies, L. R., Lindberg, N., Siimes, M. A., & Aalberg, V. (2012). Body dissatisfaction and body mass in girls and boys transitioning from early to mid-adolescence: additional role of self-esteem and eating habits. BMC psychiatry, 12(1), 35. https://doi.org/10.1186/1471-244X-12-35

Moisiu, P., Tushe, E., Naqi, D., Ceka, N., Spahiu, L., & Ceka, N. (2005). Arti i rritjes së fëmijëve. Tiranë: © UNICEF DHE MINISTRIA E SHËNDETËSISË SHTËPIA BOTUESE & SHTYPSHKRONJA PEGI. ISBN 99943-729-3-9

Mollborn, S., James-Hawkins, L., Lawrence, E., & Fomby, P. (2014). Health lifestyles in early childhood. Journal of health and social behavior, 55(4), 386–402. https://doi.org/10.1177/0022146514555981

Ministry of Education, Science, Technology and Innovation. Kosovo education statistics 2022-2023 https://masht.rks-gov.net/statistikat-e-arsimitne-kosove-2022-2023/

Medically reviewed by: (Madhu Desiraju, MD 2022). Your Child's Growth. Date reviewed: June 2022. Nemours Children's Health.

National Research Council (US) and Institute of Medicine (US) Committee on Integrating the Science of Early Childhood Development, Shonkoff, J. P., & Phillips, D. A. (Eds.). (2000). From Neurons to Neighborhoods: The Science of Early Childhood Development. National Academies Press (US).

Neumark-Sztainer, Dianne, Melanie M. Wall, Chen Chen, Nicole I. Larson, Mary J. Christoph, and Nancy E. Sherwood. "Eating, activity, and weight-related problems from adolescence to adulthood." American journal of preventive medicine 55, no. 2 (2018): 133-141. https://doi.org/10.1016/j.amepre.2018.04.032

Opstoel, K., Pion, J., Elferink-Gemser, M., Hartman, E., Willemse, B., Philippaerts, R., Visscher, C., & Lenoir, M. (2015). Anthropometric characteristics, physical fitness and motor coordination of 9 to 11year old children participating in a wide range of sports. PloS one, 10(5), e0126282. https://doi.org/10.1371/journal.pone.0126282

Oyhenart, E. E., Lomaglio, D. B., Dahinten, S. L. V., Bejarano, I. F., Herráez, Á., Cesani, M. F., … Marrodán, M. D. (2015). Weight and height percentiles calculated by the LMS method in Argentinean schoolchildren. A comparative references study. Annals of Human Biology, 42(5), 439–446. https://doi.org/10.3109/03014460.2014.968207

Panjeti-Madan, Vaishnavi N., and Prakash Ranganathan. 2023. "Impact of Screen Time on Children's Development: Cognitive, Language, Physical, and Social and Emotional Domains" Multimodal Technologies and Interaction 7, no. 5: 52. https://doi.org/10.3390/mti7050052

Stein, A. D., Rundle, A., Wada, N., Goldbohm, R. A., & Lumey, L. H. (2009). Associations of gestational exposure to famine with energy balance and macronutrient density of the diet at age 58 years differ according to the reference population used. The Journal of nutrition, 139(8), 1555–1561. https://doi.org/10.3945/jn.109.105536

Sweeting, H., & West, P. (2002). Gender differences in weight related concerns in early to late adolescence. Journal of Epidemiology & Community Health 2002;56:700-701. https://doi.org/10.1136/jech.56.9.700

WHO Multicentre Growth Reference Study Group (2006). WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development. Geneva: World Health Organization; pp 312.

World Health Organization. (2019). Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. World Health Organization. https://iris.who.int/handle/10665/311664. License: CC BY-NC-SA 3.0 IGO

Weiner JS, Lourie JA, editors. 1981. Practical human biology. London: Academic Press.

WMA. World Medical Association. 2001. Declaration of Helsinki. Ethical principles for medical research involving human subjects. Bull World Health Organ 79:373–374.

Yang, Z., Duan, Y., Ma, G., Yang, X., & Yin, S. (2015). Comparison of the China growth charts with the WHO growth standards in assessing malnutrition of children. BMJ open, 5(2), e006107. https://doi.org/10.1136/bmjopen-2014-006107

ORIGINAL SCIENTIFIC PAPER

Influence of sleep quality and patterns on different sports events of collegiate athletes in Bangladesh: Insights from the Pittsburgh Sleep Quality Index

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Abstract

Poor sleep quality and insufficient sleep can adversely affect cognitive and physical health, potentially impairing athletic performance and overall well-being. This study investigates sleep quality, duration and daytime sleepiness among collegiate athletes from Bangladesh. A cross-sectional, questionnaire-based study was conducted across 18 universities in Bangladesh, involving 258 athletes from 9 different sports. Participants provided data on demographics, diet, sports activity, academic performance and self-reported health. Sleep quality was assessed using the validated Modified Bangla Pittsburgh Sleep Quality Index (PSQI), a 19-item tool measuring seven sleep components with a total score range of 0 to 21, where scores above 5 indicate poor sleep quality. The athletes had an average PSQI score of 5.52±2.75 reflecting a high prevalence of poor sleep quality, particularly among cricket, football players and male athletics athletes. The average duration of nocturnal sleep on campus was 6.66 ± 1.04 hours. A significant positive association was found between PSQI scores (β = 0.140, 95% CI: 0.036 to 0.395, p = 0.019) and the duration of time it takes to fall asleep after dinner (β = 0.140, 95% CI: 0.080 to 0.872, p = 0.019) with BMI after adjustment for age and sex using linear regression analysis. Gender was significantly associated with napping patterns with weekly nap frequency (p<0.0001) and nap duration (p<0.05). This study emphasizes the prevalence of poor sleep quality among collegiate athletes in Bangladesh, its association with greater BMI and the importance of specific strategies to enhance sleep, sport performance and overall well-being.

Keywords: *Sleep patterns, PSQI assessment, Sleep restriction, Sports, Student-athlete*

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Introduction

Sleep is a fundamental component of overall health and well-being, playing a key role in numerous physiological functions, including learning, memory, cognition, metabolism, immune response, and cardiovascular regulation (Baranwal et al., 2023; Besedovsky et al., 2019). Quality sleep is essential for maintaining these processes, with most adults requiring between 7 and 9 hours per night (Hirshkowitz et al., 2015). Health guidelines recommend a minimum of 7 hours with at least 85% sleep efficiency meaning at least 85% of time in bed is spent asleep—for optimal health benefits (Ohayon et al., 2017). Insufficient or poor-quality sleep has been linked to heightened risks of cardiovascular diseases, obesity, diabetes, impaired cognitive performance, and depression (Li et al., 2022).

For athletes, sleep quality and duration are particularly critical, directly influencing training effectiveness, recovery, mood, and performance (H. H. K. Fullagar et al., 2015). Adequate, high-quality sleep aids both physical and mental recovery, reduces injury risk, and helps athletes maintain peak concentration and performance during competitions (Hossain et al., 2024; Kirschen et al., 2020). Recognizing this, elite athletes and coaches emphasize sleep as an essential element of preparation and recovery, critical to managing the physical and psychological stresses of training and competition (Bonnar et al., 2018). Variations in the body's natural 24-hour rhythms, such as the sleep-wake cycle and hormonal fluctuations, also play a role in an athlete's ability to perform, highlighting the need for structured rest (Fullagar et al., 2023).

However, understanding of sleep health among athletes across different sports in real-world settings remains limited (Mah et al., 2018). Real-life demands, such as intensive training, travel, jet lag, and pre-competition stress, can impact sleep quality and duration, often leading to reduced rest before events (Juliff et al., 2015a; Sargent et al., 2014). These sleep disruptions have become a growing area of concern in sports science, where optimizing sleep hygiene is seen as a means to improve both health and athletic outcomes (Gupta et al., 2017a).

The Pittsburgh Sleep Quality Index (PSQI) is widely used to assess sleep quality across clinical and non-clinical populations. This tool evaluates seven key components of sleep, providing a global score from 0 to 21, where higher scores indicate poorer sleep quality (Al Musharrafi et al., 2023). Evaluating components such as sleep latency, disturbances, and daytime dysfunction offers insights into common sleep issues, such as prolonged sleep onset and frequent awakenings (Bertolazi et al., 2011). Studies show that a PSQI score above 5 effectively distinguishes between good and poor sleepers, including in older populations (Zitser et al., 2022).

Global and South Asian Evidence on Sleep Quality Among Collegiate Athletes

Studies from Western countries show that a substantial proportion of collegiate athletes report suboptimal sleep often driven by academic workload, evening training, and competition stress with reported prevalence estimates frequently in the range of 40–60% for short sleep or poor sleep quality (Fullagar et al., 2015; Juliff et al., 2015a). East Asian studies report similar concerns, frequently attributing short sleep to academic pressures and cultural norms (Gupta et al., 2017a). Research from South Asia is comparatively sparse: a handful of studies from India and Pakistan report inadequate sleep duration, irregular sleep-wake patterns, and poor sleep hygiene among university athletes, but these studies generally do not stratify results by sport type or examine environmental contributors such as dormitory conditions and training schedules. Notably, there are no published, systematic investigations using standardized tools like the PSQI among collegiate athletes in Bangladesh.

Sleep disturbances are common in competitive settings and are often linked to poorer physical health and mood (Biggins et al., 2021). Athletes in some sports, such as swimming, may face increased vulnerability to sleep disturbances before competitions. Comprehensive assessments of sleep, fatigue, and overall health are essential to developing recovery strategies that enhance both performance and well-being (Costa et al., 2022). Olympic-level athletes, for instance, have shown poorer sleep quality than non-athletes, underscoring the need for targeted interventions.

The demands of different sports can also influence athletes' sleep needs (Erlacher et al., 2011; Juliff et al., 2015a; Leeder et al., 2012). For example, nighttime competitions can elevate cortisol levels, reducing sleep quality and duration (O'Donnell et al., 2018).Research on collegiate athletes has shown that increasing sleep duration from less than 7 to more than 8 hours per night can improve mood, alertness, and physical performance (Mah et al., 2011).

Although several studies have explored sleep among athletes, important gaps remain. Many investigations do not differentiate sleep quality across different sport types, despite evidence that endurance, team, and skill-based sports may influence sleep demands differently. Likewise, limited attention has been given to contextual factors such as sleeping environment, dormitory conditions, training schedules, and psychosocial stressors variables particularly relevant in low- and middle-income countries. Importantly, no prior study from Bangladesh has evaluated sleep quality among collegiate athletes using standardized tools, leaving a critical gap in understanding the sleep-health needs of this population.

Therefore, the present study aims to answer the research question: What is the overall sleep quality, duration, and daytime functioning of collegiate athletes in Bangladesh, and what factors contribute to poor sleep within this population?.

Study objectives and hypothesis

Estimate the prevalence of poor sleep quality (PSQI >5) among collegiate athletes in Bangladesh. Compare sleep quality and key PSQI component scores across sport types (team, individual, endurance/skill). Identify training, scheduling, and environment factors associated with poor sleep (e.g., evening training, shared dormitory, academic load).

Primary hypothesis: We hypothesise that a substantial proportion (>40%) of Bangladeshi collegiate athletes will report poor sleep quality (PSQI >5), with higher prevalence among athletes in sports with evening training/competition and among those living in shared or noisy accommodation.

Methods

Participants

The data collection took place between June 16 and July 20, 2024. A sample of athletes was recruited from an elite

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cohort of athletes from Bangladesh who engage in both national and interuniversity sports across various institutions (18 universities) using a systematic random process. The individual being assessed was positioned on the platform of the portable stadiometer (SECA Stadiometer 213 Japan). The height (in centimeters) and weight (in kilograms) of each selected individual were measured using a standard procedure, and the BMI of each subject was computed. Measurement with a high-quality stadiometer, which has a precision of 0.1 cm (equivalent to ⅛th of an inch), was utilized. The stadiometer is stable and equipped with a horizontal headpiece that may touch the topmost part of the head (Azim et al., 2024). Data collection from subjects during the research was conducted through face-to-face and survey-based methods. Informants were specifically selected to obtain relevant data and knowledge on the study topics.

Participant Selection

To provide a representative sample of collegiate athletes from Bangladesh, a systematic random sampling procedure was used. The selecting procedure included the following steps:

Inclusion Criteria:

Athletes were eligible if they were actively involved in university-level sports and had undergone consistent training and competition for a minimum of 6 months before the study. Only those who provided voluntary consent for participation were deemed eligible for inclusion in the study.

Exclusion Criteria:

Athletes who have sleep disorders, those on pharmacological treatment impacting sleep, or individuals with chronic health issues that could substantially alter sleep patterns were eliminated. This was implemented to eliminate biases that could distort the study's findings.

Sampling Process:

A rigorous random sampling method had been used to choose participants. A comprehensive list of all qualified athletes from the 18 participating universities was prepared. Athletes were subsequently chosen at random from these lists, guaranteeing diverse representation from various universities. A random number generator was utilized to choose athletes from the pool, thereby minimizing bias and ensuring unpredictability in the selection process.

Gender Balance Strategy:

Equal representation of all genders in the sample was attempted to be achieved. Their participation in each sport at the collegiate level was reflected in the number of male and female athletes chosen. In order to ensure that both male and female athletes were fairly represented in the study, the gender distribution of athletes within each sport served as a reference for participant selection.

Sport Diversity:

Participants were chosen from nine different sports, including both team and individual sports, ensuring diversity in sport representation. To make sure that every sport has sufficient representation for cross-sport comparisons, the selection process was stratified by sport type. Meaningful comparisons between various sports (e.g., team sports, individual sports, and endurance sports) were made possible by the stratification process.

Attrition and Participant Approach:

The initial pool included 310 athletes from the 18 universities. Of these, 52 declined to participate or were excluded based on the exclusion criteria.

Questionnaire

We designed a comprehensive questionnaire for individuals that inquired about their family status, dietary habits, specific sports participation, academic information, and health issues (Tabassum & Azim, 2024).

The PSQI stands as a widely utilized self-reported tool designed to evaluate sleep quality. Comprising 19 questions, including seven components such as subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, use of sleep medication, and daytime dysfunction, the PSQI assesses various aspects of sleep quality experienced over the preceding month (Buysse et al., 1989a). Each component is equally weighted on a scale from 0 to 3. The global PSQI score, indicative of overall sleep quality, is derived by summing the scores of the seven components, resulting in a range from 0 to 21. A higher score signifies poorer sleep quality, while a lower score indicates better sleep quality (Buysse et al., 1989a). In this study, the validated Bangla version of the PSQI was employed to evaluate sleep quality, consistent with previous research conducted in Bangladesh(Mondal et al., 2018). A PSQI score exceeding 5 served as the threshold for identifying poor sleep quality (Islam et al., 2021a).

For data collecting, we considered the following issues: a) Taking any medications, sleeping pills, or supplements. b) Addiction to drugs or beverages. a) Serious illness or disease. f) Sleep quality and disruptions (such as insomnia or sleep apnea). g) Routines and habits leading up to sleep, as well as sleep patterns. j) Sleep-related dietary intake (for example, coffee and late-night eating). h) The frequency of late-night training or competition.

Questionnaire Validation and Administration

The study's questionnaire was designed to evaluate the quality of sleep, taking into account variables like sleep length, disruptions, and sleep-related behaviors. Expert evaluation, in which experts in sports medicine and sleep science assessed the questions' comprehensiveness, relevance, and clarity, verified the questionnaire's content validity. The association between questionnaire responses and the Pittsburgh Sleep Quality Index (PSQI), a reliable indicator of sleep quality, provided evidence for construct validity. (Buysse et al., 1989b).

Face-to-face interviews were conducted to administer the questionnaire instead of self-administered surveys for the following reasons. clarification of questions, greater response rate, and oversight of environmental variables

Reliability of the PSQI

The reliability of the Bangla version of the Pittsburgh Sleep Quality Index (PSQI) was assessed using Cronbach's alpha, an indicator of internal consistency among the seven components of the PSQI. This study revealed a Cronbach's alpha value of 0.383, signifying a modest degree of internal consistency. Despite this score being below the commonly accepted criterion of 0.7, which is generally regarded as indicative of good reliability (Cronbach, 1951), it indicates that a few components of the PSQI may exhibit weaker correlations among this particular population of collegiate athletes. This moderate dependability may be affected by the distinct characteristics of this population. Future research should further assess the tool's dependability in other cohorts and potentially refine it to improve internal consistency across distinct groups.

Ethical standard

All procedures were approved by the Ethical Committee of the Institute of Biological Sciences at Rajshahi University, Bangladesh (Approval No: 72(22)/320/IAMEBBC/IBSc, Serial Number: #00019). The study was conducted in accordance with the World Medical Association's Declaration of Helsinki for human research (Islam et al., 2021b).

Statistical analysis

Statistical analyses were conducted using SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). The data are reported as mean ± (SD) and percentage for both male athletes, female athletes in following variable like PSQI, sleep rate on campus, time of going to sleep after dinner, disturbances of sleep, aids of sleep, napping habits of athlete's, poor sleep and good sleep. The differences in categorical variables (sex and sports events) and continuous variables (age, height, weight and BMI) of the participants were analyzed by a chi-square test and an independent sample t-test, respectively. The data's normality has been assessed using the Kolmogorov-Smirnov test. With the exception of the total BMI among females ($D = 0.124$, $p = 0.115$), which was normally distributed, the test revealed that the majority of variables did not follow a normal distribution ($p < 0.05$). In view of these findings, variables who met the normality assumptions had been put to parametric testing, whilst those that did not were taken to non-parametric tests. Linear regression was employed to assess the associations between Pittsburg sleep quality index and after dinner going to sleep with Body mass index of the participants before and after adjusting for age and sex. Results were reported using adjusted odds ratios, 95% confidence intervals and P values below 0.05 were considered statistically significant.

Results

Socio-demographic characteristics of participants

The study examined 258 athletes who participated in various sporting activities. Most of the sample is male (84.1%) with an age range between 19 and 27 years old. Male athletes were the predominant group across all age categories, especially at ages 22 (35, 13.6%) and 24 (47, 18.2%). On the other hand, women were less represented, with their largest participation occurring at ages 20 and 25 years (each 8, 3.1%). The athletes' mean height was 167.36 ± 8.39 cm and there was a significant ($p<0.001$) correlation between the heights of male and female athletes. Male athletes differ considerably ($p<0.05$) from female athletes in terms of weight. Both groups of male and female athletes had a BMI within the normal range (18.5-24.9 kg/m2), with male athletes having an average BMI of 22.55 ± 4.21 kg/m² and female athletes having an average BMI of 22.38 ± 4.42 kg/m².

Table 1. Participant demographics characteristics

	Total n (%)	Men n (%)	Women n (%)
Age (years)			
19	23 (8.9)	22 (8.5)	1(0.4)
20	20 (7.8)	12 (4.7)	8 (3.1)
21	24 (9.3)	20 (7.8)	4 (1.6)
22	38 (14.7)	35 (13.6)	3 (1.2)
23	32 (12.4)	26 (10.1)	6 (2.3)
24	51 (19.8)	47 (18.2)	4 (1.6)
25	36 (14)	28 (10.9)	8 (3.1)
26	17 (6.6)	16 (6.2)	1 (0.4)
27	17(6.6)	11 (4.3)	6 (2.3)
Total athletes	258 (100)	217 (84.1)	41 (15.9)
Height (m)	167.36± 8.39	168.45± 7.81	161.59± 9.10*
Weight(kg)	62.75± 10.53	63.51± 9.55	58.71± 14.14**
BMI(kg/m²)	22.52± 4.24	22.55± 4.21	22.38± 4.42

Values are presented as mean ± standard deviation (SD) for continuous variables and as frequencies (n) and percentages (%) for categorical variables. BMI = Body Mass Index. p values were from the independent sample t-test and chi-square test, respectively (* $p<0.05$; ** $p<0.01$).

Sleep quality and daytime sleepiness assessments

Table 2 shows the assessments of sleep quality and daytime drowsiness among male and female athletes. All participants had an overall PSQI score of 5.52±2.75; males scored somewhat higher (5.58±2.79) than women (5.24±2.52). On campus, the sleep score was similar for men average 6.65±1.07 and women averaging 6.54±0.90. Men took 2.63±1.25 hours and women took 2.45±1.00 hours, the average time spent falling asleep following dinner.

Evaluating by varsity team, male athletics had a PSQI of 6.52±2.84 while female athletics had a PSQI of 4.10±2.13 with significant ($P = 0.01$). Men in basketball had a PSQI of 5.94±3.05, while the female player had a PSQI of 6.25±2.05. Men's cricket had a PSQI of 5.16±3.08; women's cricket had a PSQI of 5.33±2.78. Other activities like hockey, martial arts and badminton showed various PSQI scores, typically reflecting a trend of good sleep quality (PSQI < 0.05). Especially, every athlete mentioned good quality and length of sleep, which emphasizes the frequency of adequate sleep in this population.

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Table 2. Sleep quality and daytime sleepiness assessments (n=258)

	Total n (%)	PSQI Mean (SD)	Sleep rating On campus Mean (SD)	Time of going to sleep after dinner
Range	----	0.0-14.0	4.0-12.0	0.1-7.0
All participants	258 (100)	5.52± 2.75	6.63± 1.04	2.60± 1.21
Sex				
Men	217 (84.1)	5.58± 2.79	6.65± 1.07	2.63±1.25
Women	41 (15.9)	5.24±2.52	6.54±0.90	2.45±1.00
P-value		0.47	0.52	0.39
Varsity team				
Men Athletics	31 (75.6)	6.52± 2.84	6.58± 0.81	2.52± 0.85
Women Athletics	10 (24.4)	4.10± 2.13	6.50± 0.85	2.00± 0.82
P-value		.01	0.78	0.10
Men Cricket	55 (85.9)	5.16± 3.08	6.69± 1.06	2.45± 1.27
Women Cricket	9 (14.1)	5.33± 2.78	6.78± 0.83	2.67± 0.71
P-value		0.87	0.81	0.61
Men Badminton	8 (100)	4.50± 1.77	6.50± 1.20	2.88± 1.89
Men Volleyball	13 (59.1)	5.85±2.12	6.46±2.13	3.48±1.48
Women Volleyball	9 (40.9)	5.33±3.28	6.56±0.88	2.00±0.71
P-value		0.65	0.83	0.006
Men Handball	8 (61.5)	6.13± 2.42	6.25± 1.28	2.37± 0.92
Women Handball	5 (38.5)	5.60± 1.82	6.20± 1.30	3.00± 1.00
P-value		0.68	0.94	0.27
Men Basketball	17 (68)	5.94± 3.05	6.29± 0.92	3.35± 1.32
Women Basketball	8 (32)	6.25±2.05	6.50±.93	2.94±1.42
P-value		0.79	0.60	.48
Men Martial arts	15 (100)	4.20±2.78	7.13±0.74	2.27±0.96
Men Football	41 (93.2)	6.59± 2.63	6.44± 1.03	3.12± 1.12
Men Hockey	29 (100)	4.45± 2.06	7.19± 1.33	1.55± 0.71

Sleep quality, sleep latency after dinner, sleep rating on campus, and daytime sleepiness among male and female collegiate athletes. PSQI = Pittsburgh Sleep Quality Index. A PSQI global score > 5 indicates poor sleep quality. "Sleep rating on campus" refers to the athletes' self-reported sleep satisfaction while residing in university dormitories (higher scores indicate better sleep).

Sleep environment factors and aids to help sleep

Table 3 displays statistics regarding sleep-disrupting causes and sleep aids among male and female athletes. The prevalence of sound as a sleep disturbance was highest among athletes, affecting 27.1% of the whole population (27.6% of males and 24.4% of females). The temperature was the second most prevalent component, affecting 24.0% of the entire sample (23.5% of males and 26.8% of females). Additional significant disruptions were observed in the form of roommates (12.4% overall; 13.4% males and 7.3% females), bathroom demands (7.4% overall; 6.9% males and 9.8% females), exposure to sunlight (7.8% overall; 7.4% males and 9.8% females), relationship tension (7.0% overall; 7.4% males and 4.9% females) and other unspecified factors (14.3% overall; 13.8% males and 17.1% females). The most commonly used sleep aid among athletes was a fan, which was effective for 42.6% of participants (44.7% of males and 31.7% of females). Additional forms of assistance included the utilization of music (15.5% overall; 16.1% among males and 12.2% among females) the implementation of unidentified methods (31.4% overall; 29.0% among males and 43.9% among females), the use of white noise (4.7% overall; 5.1% among males and 2.4% among females) and the application of eye masks (5.8% overall; 5.1% among males and 9.8% among females). Female athletes had a much larger proportion (43.9%) of utilizing different methods to enhance sleep compared to male athletes (29.0%).

Napping habits of athletes

Table 4 displays data regarding the sleep patterns also Chi-square test results to examine the association between gender and the frequency of napping habits among athletes, including categories such as, nap time, never, everyday etc. When it comes to how often athletes take naps, 39.1% of them stated that they never nap. Among those who never nap, a larger proportion of males (42.4%) than females (22.0%) were included. Among athletes, 24.0% reported napping daily, with 26.3% of males and 12.2% of females engaging in this habit. However, napping twice a week was more prevalent among females (61.0%) than males (20.3%). The amount of time of naps shown variation, with 39.1% of athletes avoiding from napping entirely (42.9% males and 19.5% females) There is a strong significant relationship between gender with napping habit (p<0.0001). The most prevalent duration for naps was between 10 and 30 minutes, accounting for 34.9% of the total. Both males and females had similar proportions, with 34.6%

Table 3. Chi-Square analysis of sleep environment factors and aids to help sleep by gender (n=258)

	Total n (%)	Male n (%)	Female n (%)	Chi-Square Value	Degrees of Freedom (df)	p-value
Disturb during sleep						
Bathroom	19(7.4)	15(6.9)	4(9.8)			
Roommates	32(12.4)	29(13.4)	3(7.3)			
Sound	70(27.1)	60(27.6)	10(24.4)			
Sunlight	20(7.8)	16(7.4)	4(9.8)	2.503	6	0.86
Temperature	62(24.0)	51(23.5)	11(26.8)			
Tension	18(7.0)	16(7.4)	2(4.9)			
Others	37(14.3)	30(13.8)	7(17.1)			
Thing that helps to sleep						
White noise	12(4.7)	11(5.1)	1(2.4)			
Eye mask	15(5.8)	11(5.1)	4(9.8)	5.954	4	0.20
Fan	110(42.6)	97(44.7)	13(31.7)			
Music	40(15.5)	35(16.1)	5(12.2)			
Others	81(31.4)	63(29.0)	18(43.9)			

Environmental sleep-disrupting factors and sleep aids used by athletes, presented by gender. Sleep disturbances include noise, temperature, roommates, sunlight exposure, relationship stress, and other factors. Sleep aids include fans, music, white noise, eye masks, and other methods. Values represent frequencies (n) and percentages (%). Statistical comparisons were performed using chi-square tests.

and 36.6% respectively. 15.9% of athletes (13.4% males and 29.3% females) reported taking longer naps of 30-60 minutes, while 9.3% (8.3% males and 14.6% females) napped for 1-2 hours. However, there is also a significant relation build up in between gender and length of sleep ($p<0.05$). Prior to important competitions, 45% of athletes engaged in a period of rest, with a greater proportion of females (58.5%) as opposed to males (42.4%). The duration of pre-game naps dif-

Table 4. Chi-Square Analysis of Napping Habits of Athletes by Gender (n=258)

	Total n (%)	Male n (%)	Female n (%)	Chi-Square Value	Degrees of Freedom (df)	p-value
How often do you nap?						
Never	101(39.1)	92(42.4)	9(22.0)			
Every day	62(24.0)	57(26.3)	5(12.2)			
Once in a week	3(1.2)	1(0.5)	2(4.9)	38.01	4	0.0001
Twice in a week	69(26.7)	44(20.3)	25(61.0)			
Once a month	23(8.9)	23(10.6)	0(0.0)			
Length of naps						
Don't nap	101(39.1)	93(42.9)	8(19.5)			
Less than 10 min	1(0.4)	1(0.5)	0(0.0)			
10-30 min	90(34.9)	75(34.6)	15(36.6)	12.20	5	0.03
30-60 min	41(15.9)	29(13.4)	12(29.3)			
1-2h	24(9.3)	18(8.3)	6(14.6)			
2+h	1(0.4)	1(0.5)	0(0.0)			
Do you nap before big game?						
Yes	116(45)	92(42.4)	24(58.5)	3.63	1	0.056
No	142(55)	125(57.6)	17(41.5)			
Length of naps before big games						
Don't nap	142(55)	125(57.6)	17(41.5)			
Less than 10 min	6(2.3)	4(1.8)	2(4.9)			
10-30 min	37(14.3)	30(13.8)	7(17.1)	4.495	5	0.405
30-60 min	42(16.3)	33(15.2)	9(22.0)			
1-2h	26(10.1)	21(9.7)	5(12.2)			
2+h	5(1.9)	4(1.8)	1(2.4)			

Distribution of napping habits among athletes, including frequency of naps, nap duration, and pre-competition napping behaviour, stratified by gender. Values represent frequencies (n) and percentages (%). Chi-square tests were used to assess associations between gender and napping patterns.

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fered across athletes. Specifically, 55% of athletes did not nap at all, with 57.6% of males and 41.5% of females abstaining from napping. Additionally, 16.3% of athletes napped for 30-60 minutes, with 15.2% of males and 22.0% of females falling into this category. Finally, 14.3% of athletes napped for 10-30 minutes, with 13.8% of males and 17.1% of females in this group. 10.1% of athletes, consisting of 9.7% males and 12.2% females, took longer pre-game naps lasting 1-2 hours.

Associations between Pittsburg sleep quality index and after dinner going to sleep with Body mass index

Table 5 indicates the associations between the PSQI and the duration of time it takes to go to sleep after dinner, in relation to BMI, among male and female athletes. Before the adjustment, the PSQI demonstrated a notable positive correlation with BMI (β = 0.142, 95% CI: 0.033 to 0.406, p = 0.021), suggesting that lower sleep quality is linked to increased BMI. The association remained statistically significant even after adjusting for other factors (β = 0.140, 95% CI: 0.036 to 0.395, p = 0.019). Similarly, sleeping after dinner was found to be positively correlated with BMI before adjustment (β = 0.136, 95% CI: 0.050 to 0.875, p = 0.028) and this correlation remained significant after adjustment (β = 0.140, 95% CI: 0.080 to 0.872, p = 0.019). These findings suggest that athletes who go to sleep later after dinner tend to have higher BMI.

Table 5. Associations between Pittsburg sleep quality index and after dinner going to sleep with Body mass index.

	Before adjustment		After adjustment	
Variables	BMI β (95% CI)	p-value	BMI β (95% CI)	p-value*
Total (PSQI)	0.142 (0.033,0.406)	0.021	0.140 (0.036,0.395)	0.019
After dinner going to sleep	0.136 (0.050,0.875)	0.028	0.140 (0.080,0.872)	0.019

Linear regression models examining associations between sleep quality (PSQI global score), time to fall asleep after dinner, and BMI among athletes. Results are shown as beta coefficients (β), 95% confidence intervals (CI), and p-values. Adjusted models account for age and sex. Higher PSQI scores reflect poorer sleep quality. *p<0.05; β is adjusted for age and sex (male used as a referent group)

The study of sleep quality ratios across different sports events indicates major trends. In the area of sports, participants in Hockey showed the highest percentage of poor sleep at 62.1%, whereas those engaged in Martial Arts reported the lowest percentage at 25%. In contrast, Martial Arts display the highest percentage of good sleep at 75%, with Volleyball following at 68.2%. Other sports events, including Basketball, Cricket, and Football, demonstrated little variations, with poor sleep percentages ranging from 43.9% in Athletics to 50% in Football. Correspondingly, good sleep percentages varied, with 56.1% in Athletics and 50% in Football. Badminton showed an equal distribution of sleep quality, with 50% classified as poor sleep and 50% as good sleep. Participants in handball demonstrated a greater incidence of poor sleep (53.8%) relative to good sleep (46.2%).

The data indicates that individuals involved with, hockey and handball are likely to experience poorer sleep quality, while those participating in martial arts and volleyball tend to have better sleep quality.

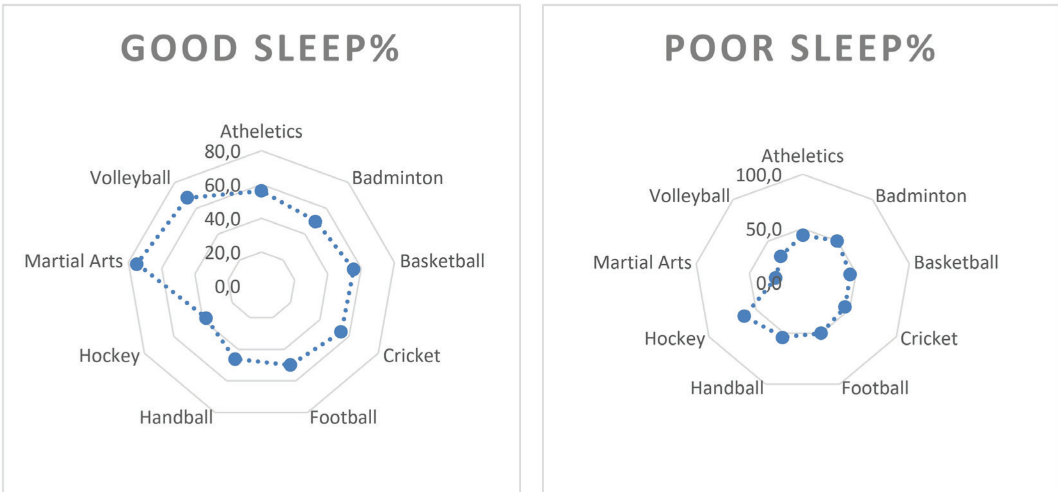

Figure 1. Distribution of Pittsburgh Sleep Quality Index (PSQI) categories across sport modalities among collegiate athletes. The figure illustrates the proportion of athletes classified as having good sleep quality (PSQI ≤ 5) and poor sleep quality (PSQI > 5) across nine sport modalities. PSQI = Pittsburgh Sleep Quality Index.

Discussion

The current study assessed the sleep patterns, quality, and duration of collegiate athletes in Bangladesh across both individual and team sports. It also explored factors such as the time athletes go to bed after dinner and the environment in which they sleep.

The primary findings reveal that male and female athletes in Bangladesh generally suffer from poor sleep quality, as evidenced by their PSQI scores. Males exhibited higher PSQI scores than females, indicating poorer sleep quality. Notably, a significant association was found between sleep quality and BMI, with a higher BMI correlating with lower sleep quality. Moreover, a longer time to fall asleep after dinner was linked to higher BMI, suggesting that athletes who go to bed later tend to have higher BMI levels. These results highlight the widespread occurrence of sleep disturbances among collegiate athletes in Bangladesh and the urgent need for tailored interventions aimed at improving sleep quality, which could enhance both athletic performance and general well-being. Sleep patterns among athletes are often influenced by stress, anxiety, mood disorders, and inadequate social support, all of which can contribute to poor sleep quality (Leduc et al., 2020). Future studies should explore the underlying factors contributing to sleep deprivation and investigate effective strategies to address these challenges.

This study included 258 athletes from 18 universities across Bangladesh, representing 9 sport modalities. The participants reported subpar sleep quality, with an average PSQI score of 5.52 ± 2.75. The athletes in this study, particularly those living in campus accommodations, experienced poor sleep quality and tended to go to bed late after dinner. This study is among the most comprehensive to examine sleep quality across a broad range of sports, providing valuable insights into the sleep patterns of collegiate athletes. The findings align with previous research, such as a study involving 628 athletes from 29 sports, which found a similar average PSQI score of 5.38 ± 2.45, indicating poor sleep quality (Mah et al., 2018). Furthermore, another study examining athletes in 20 Olympic sports found that 52% of athletes had a global PSQI score greater than 5, suggesting poor sleep quality (Halson et al., 2022).

Several factors can contribute to the lack of adequate sleep in athletes. The physical demands of their sports, psychological stress, competition-related tension, and intensive training schedules often disrupt normal sleep patterns (Cook & Charest, 2023). Additionally, balancing academics and athletics can further exacerbate sleep deprivation, as athletes struggle to maintain regular sleep patterns (Copenhaver & Diamond, 2017). Environmental factors, such as the quality of sleep accommodations in dormitories and disruptions caused by travel, also negatively affect sleep quality (Mao et al., 2018). Environmental factors, such as the quality of sleep accommodations in dormitories and disruptions caused by travel, also negatively affect sleep quality (Silva et al., 2022). These challenges create an environment where athletes struggle to achieve adequate and restorative sleep.

Despite these challenges, many athletes reported sleep disturbances due to noise, roommates, temperature, and stress. To mitigate these disruptions, some athletes have turned to sleep aids such as white noise machines, eye masks, fans, and relaxing sounds to improve their sleep quality. This highlights the need for practical solutions to help athletes optimize their sleep environment and address the specific causes of their sleep disturbances.

Research conducted on Australian athletes supports the findings of this study, further emphasizing the prevalence of inadequate sleep among athletes. In that study, 64.0% of participants reported experiencing a decline in sleep quality at least once in the evenings leading up to a major competition. The most common sleep issue was insomnia (82.1%), particularly difficulties with sleep initiation. Contributing factors included pre-competition cognitive rumination (83.5%) and anxiety (43.8%). Notably, team sport athletes were less likely to adopt sleep management strategies (59.1%) compared to individual sport athletes (32.7%) (Juliff et al., 2015b).

In this study, 60.9% of athletes reported taking naps at least once a week, with a third of them napping for 10-30 minutes. Additionally, 45% of athletes took a pre-game nap, with 14.3% napping for 10-30 minutes and 16.3% napping for 30-60 minutes. Napping, when done properly, can have beneficial effects on athletic performance. A brief 15-20 minute nap in the early to mid-afternoon is shown to improve cognitive performance, reduce stress, and enhance mood, which are essential for sports performance(George et al., 2024). A pre-game nap can also have significant advantages, such as improving sprint performance, response times, and endurance (Romdhani et al., 2020). Furthermore, naps can help alleviate pre-game anxiety and provide mental relaxation, promoting focus and calmness before competition. The optimal length of a pre-game nap is generally considered to be 20-30 minutes (Lastella et al., 2021).

In our study, a positive correlation was found between PSQI scores and both post-dinner sleep duration and BMI. Specifically, athletes with lower sleep quality tended to have higher BMI scores, with this association remaining significant even after adjusting for age and sex. Additionally, the time it took athletes to fall asleep after dinner was positively correlated with BMI. These results suggest that poor sleep habits, such as going to bed late after dinner, may contribute to higher BMI levels. This underscores the importance of improving sleep quality for athletes, not only to enhance their health but also to optimize their athletic performance.

Various factors contribute to the link between sleep quality and BMI. Sleep deprivation negatively impacts metabolic functions, leading to reduced energy expenditure and increased fat storage. Hormonal imbalances caused by poor sleep can disrupt appetite-regulating hormones such as leptin and ghrelin, leading to increased hunger and overeating (Markwald et al., 2013). Moreover, lifestyle behaviors such as reduced physical activity and late-night eating can further contribute to higher caloric intake and poorer dietary choices, ultimately raising BMI (Günal, 2023).

The examination of the Pittsburgh Sleep Quality Index (PSQI) findings disclosed major differences in sleep quality across athletes participating in different sports. Table tennis, swimming, and handball had the largest proportion of athletes who reported having good sleep quality, as indicated by a PSQI score of less than 5. In contrast, cricket players, football players, and hockey players had a significant prevalence of poor sleep quality (PSQI > 5), underscoring the necessity for focused interventions aimed at enhancing sleep quality among these populations.

The analysis of PSQI scores revealed notable differences in sleep quality across athletes from different sports. Athletes in sports such as table tennis, swimming, and handball reported better sleep quality (PSQI scores < 5), while those in cricket, football, and hockey experienced poorer sleep quality (PSQI scores > 5). This emphasizes the need for targeted interventions aimed at improving sleep among athletes in these sports. The type of sport may influence sleep quality, with athletes in team sports generally reporting worse sleep quality compared to those in individual sports. Factors such as competition scheduling, travel commitments, and training intensity all play a role in disrupting sleep (Gupta et al., 2017b; Roberts et al., 2019). Sports such as rugby and cricket, with their physically demanding schedules and unpredictable timings, may further exacerbate sleep problems (Swinbourne et al., 2016). Tailored interventions are essential to address these challenges and improve sleep quality, which will, in turn, enhance athletic performance.

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Our study suggests that athletes, coaches, and sports managers should familiarize themselves with the various components of the PSQI, including sleep latency, sleep duration, sleep disturbance, daytime dysfunction due to sleepiness, and overall sleep quality. Understanding these components can help in comprehensively assessing an athlete's sleep patterns and identifying factors that may impair their performance. This research provides valuable insights into the sleep habits of Bangladeshi collegiate athletes and emphasizes the importance of optimizing sleep to improve both health and athletic outcomes.

Limitations, strengths, and future directions

The current study utilized self-reported assessments to gauge sleep quality and duration. It's noteworthy that these self-reports may deviate from objective sleep measures, with self-reported sleep duration potentially being overestimated. Furthermore, the study was conducted during late winter to pre- monsoon, spanning both in-season and off-season periods for collegiate teams, potentially yielding varying sleep outcomes across these phases. Moreover, the PSQI used in the study may have limited alignment with clinical assessments of sleep quality, and it only inquired about weekday sleep duration for the global score, omitting weekend sleep patterns. Another potential weakness of this study is recollection bias, which may impair the accuracy of participants' self-reported data on sleep quality and behaviors. Because the Pittsburgh Sleep Quality Index (PSQI) is retroactive, participants must recollect their sleep patterns from the previous month, which may result in reporting inaccuracies due to memory lapses or subjective interpretation of their sleep experiences.

Despite these limitations, it is important to highlight some strengths. This study encompasses athletes from 18 universities in Bangladesh. The comprehensive analysis of sleep quality and duration among athletes provides valuable insights into the sleep patterns of this population. Additionally, the use of self-reported assessments offers a practical and accessible method for collecting data on sleep-related parameters. Furthermore, the inclusion of athletes from various sports disciplines in the study enhances its relevance and applicability to a diverse athletic population.

Future research could explore several avenues for enhancement. Integrating objective sleep measures alongside self-reported assessments could offer a more comprehensive understanding of sleep patterns among collegiate athletes. Longitudinal studies across multiple seasons could elucidate how sleep outcomes evolve over time in response to varying training and competitive schedules. Additionally, investigating the association between sleep quality and performance metrics could shed light on the impact of sleep on overall athletic performance and well-being, guiding evidence-based recommendations for optimizing performance through sleep management strategies.

Conclusions

This study offers valuable insights into the sleep quality, duration, and daytime functioning of collegiate athletes in Bangladesh, emphasizing the importance of sleep for overall health and athletic performance. The findings indicate that both male and female athletes experience poor sleep quality, with males showing worse outcomes as evidenced by their higher PSQI scores. The study also identifies common sleep disturbances such as noise and temperature, with fans emerging as the most commonly used sleep aid among athletes. Interestingly, female athletes tend to use more methods to improve sleep quality compared to their male counterparts.

Napping habits of athletes reveal that a significant portion avoids naps altogether, while those who do nap generally prefer shorter durations. Pre-competition rest patterns highlight the importance of adequate rest for performance, particularly among female athletes. The study also uncovers a significant correlation between sleep quality and BMI, suggesting that athletes with poorer sleep quality tend to have a higher BMI, a relationship that persists even after adjusting for age, sex, and other variables. Additionally, the time taken to fall asleep after dinner is positively correlated with BMI, with athletes who sleep later tending to have higher BMI.

Our study suggests that athletes, coaches, and sports managers should familiarize themselves with the various components of the PSQI, including sleep latency, sleep duration, sleep disturbance, daytime dysfunction due to sleepiness, and overall sleep quality. Understanding these components can help in comprehensively assessing an athlete's sleep patterns and identifying factors that may impair their performance. This research provides valuable insights into the sleep habits of Bangladeshi collegiate athletes and emphasizes the importance of optimizing sleep to improve both health and athletic outcomes.

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Institutional Review Board Statement

All procedures were approved by the Ethical Committee of the Institute of Biological Sciences at Rajshahi University, Bangladesh (Approval No: 72(22)/320/IAMEBBC/IBSc, Serial Number: #00019). The study was conducted in accordance with the World Medical Association's Declaration of Helsinki for human research.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data analyzed here will be shared on reasonable request to the corresponding authors.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

Al Musharrafi, S. A. S., Muthukrishnan, A., Tayyib, N. A., Lathamangeswari, C., Lindsay, G. M., Pandurangan, H., Asfour, H. I., Ahmed, E. E., Khamis, H. M., & Nomani, I. (2023). PITTSBURGH SLEEP QUALITY INDEX: EXPLORING QUALITY OF SLEEP AMONG OMANI OLDER ADULTS. *JP Journal of Biostatistics*, *23*(2), 107–123.

Azim, A., Hossain, J., Mauwa, J., Hanif, K., & Lobo, J. (2024).

Impact of the COVID-19 Pandemic on Weight, Height and BMI Percentiles in Urban School Girls: A Case Study Using US Centers for Disease Control and Prevention Growth Charts. *1*, 28–37. https://doi.org/10.5281/zenodo.12593233

Baranwal, N., Phoebe, K. Y., & Siegel, N. S. (2023). Sleep physiology, pathophysiology, and sleep hygiene. *Progress in Cardiovascular Diseases*, *77*, 59–69.

Bertolazi, A. N., Fagondes, S. C., Hoff, L. S., Dartora, E. G., da Silva Miozzo, I. C., de Barba, M. E. F., & Barreto, S. S. M. (2011). Validation of the Brazilian Portuguese version of the Pittsburgh sleep quality index. *Sleep Medicine*, *12*(1), 70–75.

Besedovsky, L., Lange, T., & Haack, M. (2019). The Sleep-Immune Crosstalk in Health and Disease. *Physiological Reviews*, *99*(3), 1325–1380. https://doi.org/10.1152/physrev.00010.2018

Biggins, M., Purtill, H., Fowler, P., Bender, A., Sullivan, K. O., Samuels, C., & Cahalan, R. (2021). Sleep, health, and well-being in elite athletes from different sports, before, during, and after international competition. *The Physician and Sportsmedicine*, *49*(4), 429–437. https://doi.org/10.1080/00913847.2020.1850149

Bonnar, D., Bartel, K., Kakoschke, N., & Lang, C. (2018). Sleep Interventions Designed to Improve Athletic Performance and Recovery: A Systematic Review of Current Approaches. *Sports Medicine*, *48*(3), 683–703. https://doi.org/10.1007/s40279-017-0832-x

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989a). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Cook, J. D., & Charest, J. (2023). Sleep and Performance in Professional Athletes. *Current Sleep Medicine Reports*, *9*(1), 56–81. https://doi.org/10.1007/s40675-022-00243-4

Copenhaver, E. A., & Diamond, A. B. (2017). The Value of Sleep on Athletic Performance, Injury, and Recovery in the Young Athlete. *Pediatric Annals*, *46*(3). https://doi.org/10.3928/19382359-20170221-01

Costa, J., Figueiredo, P., Nakamura, F. Y., & Brito, J. (2022). The Importance of sleep in athletes. In *Exercise Physiology*. IntechOpen. https://www.intechopen.com/chapters/80371

Erlacher, D., Ehrlenspiel, F., Adegbesan, O. A., & Galal El-Din, H. (2011). Sleep habits in German athletes before important competitions or games. *Journal of Sports Sciences*, *29*(8), 859–866. https://doi.org/10.1080/02640414.2011.565782

Fullagar, H. H. K., Skorski, S., Duffield, R., Hammes, D., Coutts, A. J., & Meyer, T. (2015). Sleep and Athletic Performance: The Effects of Sleep Loss on Exercise Performance, and Physiological and Cognitive Responses to Exercise. *Sports Medicine*, *45*(2), 161–186. https://doi.org/10.1007/s40279-014-0260-0

Fullagar, H. H., Vincent, G. E., McCullough, M., Halson, S., & Fowler, P. (2023). Sleep and sport performance. *Journal of Clinical Neurophysiology*, *40*(5), 408–416.

George, A. S., George, A. H., & Shahul, A. (2024). The Science and Timing of Power Naps: Investigating the Cognitive and Physical Benefits of Brief Daytime Sleep. *Partners Universal Innovative Research Publication*, *2*(1), 70–84.

Günal, A. M. (2023). Sleep, activity, and diet in harmony: Unveiling the relationships of chronotype, sleep quality, physical activity, and dietary intake. *Frontiers in Nutrition*, *10*. https://doi.org/10.3389/fnut.2023.1301818

Gupta, L., Morgan, K., & Gilchrist, S. (2017a). Does Elite Sport Degrade Sleep Quality? A Systematic Review. *Sports Medicine*, *47*(7), 1317–1333. https://doi.org/10.1007/s40279-016-0650-6

Gupta, L., Morgan, K., & Gilchrist, S. (2017b). Does Elite Sport Degrade Sleep Quality? A Systematic Review. *Sports Medicine*, *47*(7), 1317–1333. https://doi.org/10.1007/s40279-016-0650-6

Halson, S. L., Johnston, R. D., Appaneal, R. N., Rogers, M. A., Toohey, L. A., Drew, M. K., Sargent, C., & Roach, G. D. (2022). Sleep Quality in Elite Athletes: Normative Values, Reliability and Understanding Contributors to Poor Sleep. *Sports Medicine*, *52*(2), 417–426. https://doi.org/10.1007/s40279-021-01555-1

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., Hazen, N., Herman, J., Katz, E. S., & Kheirandish-Gozal, L. (2015). National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. *Sleep Health*, *1*(1), 40–43.

Hossain, J., Azim, A., & Author, M. H. (2024). Kinetics and kinematic analysis of different phases in 100m sprints. *International Journal of Physical Education, Sports and Health*, *11*(3), 183–190.

Islam, Z., Hsan, K., Islam, S., Gozal, D., & Hossain, M. (2021a). Assessment of sleep quality and its association with problematic internet use among university students: A cross-sectional investigation in Bangladesh. *Sleep Science*, *14*(S 01), 8–15. https://doi.org/10.5935/1984-0063.20200069

Islam, Z., Hsan, K., Islam, S., Gozal, D., & Hossain, M. (2021b). Assessment of sleep quality and its association with problematic internet use among university students: A cross-sectional investigation in Bangladesh. *Sleep Science*, *14*(S 01), 8–15. https://doi.org/10.5935/1984-0063.20200069

Juliff, L. E., Halson, S. L., & Peiffer, J. J. (2015a). Understanding sleep disturbance in athletes prior to important competitions. *Journal of Science and Medicine in Sport*, *18*(1), 13–18.

Juliff, L. E., Halson, S. L., & Peiffer, J. J. (2015b). Understanding sleep disturbance in athletes prior to important competitions. *Journal of Science and Medicine in Sport*, *18*(1), 13–18.

Kirschen, G. W., Jones, J. J., & Hale, L. (2020). The impact of sleep duration on performance among competitive athletes: A systematic literature review. *Clinical Journal of Sport Medicine*, *30*(5), 503–512.

Lastella, M., Halson, S. L., Vitale, J. A., Memon, A. R., & Vincent, G. E. (2021). To Nap or Not to Nap? A Systematic Review Evaluating Napping Behavior in Athletes and the Impact on Various Measures of Athletic Performance. *Nature and Science of Sleep*, *Volume 13*, 841–862. https://doi.org/10.2147/NSS.S315556

Leduc, C., Tee, J., Weakley, J., Ramirez, C., & Jones, B. (2020). The Quality, Quantity, and Intraindividual Variability of Sleep Among Students and Student-Athletes. *Sports Health: A Multidisciplinary Approach*, *12*(1), 43–50. https://doi.org/10.1177/1941738119887966

Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., & Pedlar, C. (2012). Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *Journal of Sports Sciences*, *30*(6), 541–545. https://doi.org/10.1080/02640414.2012.660188

Li, J., Cao, D., Huang, Y., Chen, Z., Wang, R., Dong, Q., Wei, Q., & Liu, L. (2022). Sleep duration and health outcomes: An umbrella review. *Sleep and Breathing*, *26*(3), 1479–1501. https://doi.org/10.1007/s11325-021-02458-1

Mah, C. D., Kezirian, E. J., Marcello, B. M., & Dement, W. C. (2018a). Poor sleep quality and insufficient sleep of a collegiate student-athlete population. *Sleep Health*, *4*(3), 251–257.

Mah, C. D., Kezirian, E. J., Marcello, B. M., & Dement, W. C. (2018b). Poor sleep quality and insufficient sleep of a collegiate student-athlete population. *Sleep Health*, *4*(3), 251–257.

Mah, C. D., Mah, K. E., Kezirian, E. J., & Dement, W. C. (2011). The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*, *34*(7), 943–950.

Mao, Z., Yang, Y., & Wang, M. (2018). Sleepless nights in hotels? Understanding factors that influence hotel sleep quality. *International Journal of Hospitality Management*, *74*, 189–201.

Markwald, R. R., Melanson, E. L., Smith, M. R., Higgins, J., Perreault, L., Eckel, R. H., & Wright, K. P. (2013). Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain. *Proceedings of the National Academy of Sciences*, *110*(14), 5695–5700. https://doi.org/10.1073/pnas.1216951110

Mondal, H., Mondal, S., & Baidya, C. (2018). Comparison of perceived sleep quality among urban and rural adult population by Bengali Pittsburgh Sleep Quality Index. *Advances in Human Biology*, *8*(1), 36–40.

O'Donnell, S., Bird, S., Jacobson, G., & Driller, M. (2018). Sleep and stress hormone responses to training and competition in elite female athletes. *European Journal of Sport Science*, *18*(5), 611–618. https://doi.org/10.1080/17461391.2018.1439535

Ohayon, M., Wickwire, E. M., Hirshkowitz, M., Albert, S. M., Avidan, A., Daly, F. J., Dauvilliers, Y., Ferri, R., Fung, C., & Gozal, D. (2017). National Sleep Foundation's sleep quality recommendations: First report. *Sleep Health*, *3*(1), 6–19.

Roberts, S. S. H., Teo, W.-P., & Warmington, S. A. (2019). *Effects of training and competition on the sleep of elite athletes: A systematic review and meta-analysis*. https://doi.org/10.1136/bjsports-2018-099322

Romdhani, M., Souissi, N., Chaabouni, Y., Mahdouani, K., Driss, T., Chamari, K., & Hammouda, O. (2020). Improved physical performance and decreased muscular and oxidative damage with postlunch napping after partial sleep deprivation in athletes. *International Journal of Sports Physiology and Performance*, *15*(6), 874–883.

Sargent, C., Lastella, M., Halson, S. L., & Roach, G. D. (2014). The impact of training schedules on the sleep and fatigue of elite athletes. *Chronobiology International*, *31*(10), 1160–1168. https://doi.org/10.3109/07420528.2014.957306

Silva, S. S. da, Silveira, M. A. C. da, Almeida, H. C. R. de, Nascimento, M. C. P. do, Santos, M. A. M. dos, & Heimer, M. V. (2022). Uso de telas digitais por adolescentes e associação com a qualidade do sono: Uma revisão sistemática. *Cadernos de Saúde Pública*, *38*, e00300721.

Swinbourne, R., Gill, N., Vaile, J., & Smart, D. (2016). Prevalence of poor sleep quality, sleepiness and obstructive sleep apnoea risk factors in athletes. *European Journal of Sport Science*, *16*(7), 850–858. https://doi.org/10.1080/17461391.2015.1120781

TABASSUM, N., & AZİM, A. (2024). Active & Healthy Aging. *Health*, *2*(2), 53–59.

Zitser, J., Allen, I. E., Falgàs, N., Le, M. M., Neylan, T. C., Kramer, J. H., & Walsh, C. M. (2022). Pittsburgh Sleep Quality Index (PSQI) responses are modulated by total sleep time and wake after sleep onset in healthy older adults. *PloS One*, *17*(6), e0270095.

ORIGINAL SCIENTIFIC PAPER

The Impact of Organized Exercise on the Functional Abilities of Individuals with Obesity

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Abstract

The aim of this research was to determine whether there is a difference in the improvement of lung function and reduction in abdominal fat thickness in obese individuals who follow a reduced diet programme and engage in regular organised exercise, compared to those who only follow the diet. This prospective study included 50 obese patients from the Obesity Outpatient Clinic of the Internal Medicine Clinic at Clinical Hospital Center Rijeka. It was conducted from October 2023 to May 2024. All participants followed a reduced diet and were given the option to take part in organised exercise sessions. They were divided into two groups: those who exercised (n=25) and those who did not (n=25). Data on gender, age, weight, height, BMI, waist circumference, abdominal fat thickness, and lung function parameters (FVC, FEV1, VC) were collected at the beginning and end of the intervention. The results showed no statistically significant differences between the two groups in final BMI ($p = 0.154$), waist circumference ($p = 0.382$), abdominal fat thickness ($p = 0.435$), FVC ($p = 0.741$), FEV1 ($p = 0.676$), or VC ($p = 0.892$). However, a statistically significant improvement ($p < 0.001$) was observed in all measured parameters between the first and second measurement for all participants. There was no confirmed difference between those who exercised and those who did not. Nonetheless, significant improvements were observed in all subjects over time.

Keywords: *functional abilities, obesity, organized exercise*

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Introduction

Obesity is a global epidemic and represents a serious health and social problem. The World Health Organisation defines obesity as a condition characterized by a body mass index (BMI) exceeding 30 kg/m². Adipose tissue is a metabolic, immune and endocrine organ, and its excessive accumulation is directly related to an increased risk of developing vascular, pulmonary, endocrinological, musculoskeletal and other diseases. The most common cause of obesity is excessive consumption of foods rich in fat and refined sugar, as well as a lack of physical activity (Ghesmaty Sangachin, Cavuoto, & Wang, 2018).

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In obese individuals, structural changes in the thoraco-abdominal region lead to reduced diaphragmatic mobility and reduced rib movement, which impairs adequate breathing mechanics. Adipose tissue produces a large number of cytokines and bioactive mediators, leading to a condition associated with reduced lung development and an increased risk of developing certain diseases in obese individuals. Ferreira et al. report that adolescents with increased visceral adipose tissue exhibit altered lung function, characterized by an increased forced vital capacity (FVC). They also observed a reduction in forced expiratory volume in the first second (FEV 1) within this population (Ferreira et al., 2022). Excess body mass is associated with significant changes in lung volume and capacity values and altered respiratory mechanics in individuals with increased waist and hip circumference, which are more pronounced in women than in men (Shanmugasundaram, Bade, Sampath, & Talwar, 2023). Obesity has a detrimental effect on respiratory mechanics. This is probably due to compression of the lungs, which causes a decrease in expiratory parameters and leads to a compensatory increase in inspiratory parameters to maintain a constant vital capacity (VC). Impaired respiratory function can lead to broncho-obstruction, i.e. reduced airflow through the airways, and the occurrence of local and systemic hypoxia, which can be the cause of pathological changes in all organ systems (Bhatti, Laghari, & Syed, 2019).

Excessive accumulation of adipose tissue in the abdominal and ches wall regions can impair normal pulmonary function. This leads to a reduction in respiratory volumes, particularly functional residual volume and expiratory reserve volume, due to restricted chest wall motion. The stress caused by obesity reduces the mobility of the chest wall and increases the respiratory rate. One of the main causes of respiratory insufficiency is the pattern of rapid and shallow breathing, which is a predictive factor for the reduction of vital lung capacity. Disorders related to respiratory mechanics lead to an increased need for ventilation. This leads to a weakening of the respiratory muscles, which is a key feature of most diseases that predispose to respiratory insufficiency (Chlif, Keochkerian, Choquet, Vaidie, & Ahmaidi, 2009). Obesity, especially severe and extreme central obesity, impairs the physiology of the respiratory system, both at rest and during physical activity. The reduction of the reserve expiratory volume, the functional residual capacity and the impaired mechanics of the respiratory system lead to a restrictive ventilatory defect. Low functional residual capacity and reduced expiratory reserve volume increase the risk of expiratory flow limitation and airway obstruction during sleep. Consequently, obesity can cause expiratory flow limitation and the development of intrinsic positive end-expiratory pressure, especially in the supine position. This increases the respiratory rate and the strain on the respiratory muscles, leading to dyspnoea. Significantly reduced expiratory reserve volume values can lead to ventilation flow disturbances with airway obstruction in certain lung zones, causing ventilation-perfusion mismatch and gas exchange abnormalities. Obesity can also impair upper airway mechanical function and neuromuscular strength and increase oxygen consumption, which in turn increases the work of breathing and impairs ventilatory drive. The combination of disturbances in respiratory mechanics, excessive production of carbon dioxide and reduced ventilatory surface area in obese individuals may favour the occurrence of hypoventilation syndrome (C.-K. Lin & Lin, 2012).

By normalising the values of the respiratory parameters, respiratory mechanics are improved and ventilatory restriction is alleviated. Improving respiratory volume values improves respiratory function, exercise intolerance and therefore quality of life (Maloča Vuljanko & Petković, 2023). This considerations lead to the aim of our study, which is to compare the values of FVC and FEV1, the values of VC and the thickness of abdominal fat tissue in obese people who exercise regularly with those who do not.

Methods

Study design

The prospective study was conducted over a six-month period, from October 2023 to May 2024, at the Clinical Hospital Centre Rijeka, in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the hospital's Ethics Committee (Ref. No.: 2170-29-02/1-23-2). The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational research ("STROBE," n.d.).

Setting of the study

The respondents are patients of the Obesity Outpatient Clinic, which operates in the Department of Endocrinology, Diabetes and Metabolic Diseases of the Clinical Hospital Centre Rijeka (KBC). In the obesity outpatient clinic, all patients receive dietary instructions based on an internal examination and individual findings, are advised by a physiotherapist on the importance of physical activity and receive psychological counselling from a psychologist. Participation in organised exercise classes under the expert supervision of a physiotherapist twice a week was voluntary.

Inclusion criteria: BMI over 27 kg/m2, patients registered in the obesity outpatient clinic of Clinical Hospital Center Rijeka in 2023 with a recommendation for organised exercise by a doctor and physiotherapist.

Exclusion criteria: Presence of chronic lung disease, history of pulmonary embolism, history of angina pectoris, history of myocardial infarction, loss of consciousness for any reason in the last 6 months, irregular exercise.

50 male and female subjects from the working population with a diagnosis of obesity were included in the study. The subjects were divided into two groups, the control group (KS) and the experimental group (ES), and there were 25 subjects in each group. The control group consisted of patients who received lifestyle change instructions at the Clinical Hospital Center Rijeka Obesity Clinic in the form of a restrictive diet adapted to medically determined individual needs and were not interested in organised exercise, while the experimental group consisted of patients who, in addition to a restrictive diet, exercised twice a week for 60 minutes.

Outcome Measures

Testing of subjects was carried out twice, before the start of the organised training and after six months of participation in the study for both groups. Body mass and height were measured, on the basis of which BMI was calculated, as well as abdominal fat thickness and waist circumference. The thickness of the abdominal adipose tissue was measured with a calliper and expressed in centimetres. The measurement was taken in a standing position. The examiner lifted the transverse skin fold 2 cm to the side of the navel with his hand, covered it with the tips of the caliper and read the result. In addition to the anthropological measurements, spirometric tests, including forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and vital capacity (VC), were performed using a portable Spirolab

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Mini Flowmeter device. During the spirometric test, subjects sat on a chair and held the spirometer attachment with their hand, which has a sensor and a disposable mouthpiece. A special clip was attached to the subject's nose to prevent air from escaping from the nose. The test subjects were also instructed to hold the mouthpiece firmly with their lips to prevent the airflow along the mouthpiece from being lost. The subjects were then asked to inhale as much air as possible through the mouthpiece and then blow all the air from the lungs into the mouthpiece of the spirometer in such a way that the exhalation lasts for 6 seconds, which the examiner monitors on the screen. This is followed by two more inhalations and exhalations in continuity in the same manner described, without separating the lips from the mouthpiece at any time (Maloča Vuljanko & Petković, 2023).

Statistical data processing

The programme Statistica 14.0.0.15 (TIBCO Software Inc.) was used for statistical data processing. Nominal variables, gender and group, are given in absolute and relative frequencies and are compared using the chi-square test. Other variables tested in this study are expressed on an interval scale (FVC, FEV1, VC and abdominal adipose tissue thickness) and are also the dependent variables of this study. As the variables were expressed on an interval scale but deviated from the normal distribution, they were described by median, interquartile range (IQR), minimum and maximum values. The Wilcoxon test was performed to investigate whether subjects differed in body mass, body mass index, waist circumference, abdominal fat thickness, forced vital capacity (FVC), forced expiratory volume in the first second (FEV1) and vital capacity (VC) at the first and second measurement in terms of participation in physical activity (NV1 – 1st and 2nd measurement, NV2 – participation or non-participation in physical activity). The Friedman ANOVA was used to analyse the difference between the subjects' parameters at the first and second measurement depending on whether or not they took part in sport (NV1 – 1st and 2nd measurement, NV2 – participation or non-participation in sport). The parameters analysed were body mass, body mass index, waist circumference, abdominal fat thickness, forced vital capacity (FVC), forced expiratory volume (FEV1) and vital capacity (VC). The Mann-Whitney U-test was used to measure the differences between the group of exercisers and the group of non-exercisers after the second measurement. The level of statistical significance was set at $p<0.05$.

Results

Demographic characteristics of the respondents

The sample on which the study was conducted is homogeneous in terms of age, gender and number of respondents in both the experimental group (N=25) and the control group (N=25). 19 (76%) women and 6 (24%) men were randomly selected in both groups. Significantly more women participated in the study ($p<0.001$). Median age and interquartile range was 52 (49-59) for ES and 52 (48-61) for the control group. ES had an age range of 23-64 years and KS of 26-64 years.

The demographic characteristics of the respondents can be found in Table 1.

The Wilcoxon test confirmed that the subjects had a statistically significant lower body mass ($p<0.001$), a lower body mass index ($p<0.001$), a lower waist circumference ($p<0.001$) and a lower abdominal fat thickness ($p<0.001$) at the second measurement. (Table 1).

Table 1. Descriptive data for the analysed parameters of the anthropological measurements

Variables	Measurements	Median	IQR	Min-max	Wilcoxon test p
Body mass	1.	103	92-114	69-157	<0.001
	2.	97	88-105	66-144	
Body mass index	1.	35.18	33-41	28-64	<0.001
	2.	34.16	31-39	27-56	
Waist circumference	1.	117	110-124	92-145	<0.001
	2.	114	105-120	88-140	
Abdominal fat thickness	1.	13	11-16	8-23	<0.001
	2.	12	10-15	6-20	

Legend: IQR= interquartile range; min-max= minimum and maximum result;

In the second measurement, the Wilcoxon test confirmed that the subjects achieved statistically significantly higher values for all measured parameters than in the first measurement: forced vital capacity ($p<0.001$), forced expiratory volume in the first second ($p<0.001$) and vital capacity ($p<0.001$) (Table 2).

Table 2. Descriptive data for the lung function parameters tested

Variables	Measurements	Median	IQR	Min-max	Wilcoxon test p
FVC	1.	3.11	2.77-3.52	2.25-5.20	<0.001
	2.	3.25	2.87-3.59	2.25-5.47	
FEV1	1.	2.66	2.33-3.04	1.86-4.2	<0.001
	2.	2.70	2.77-3.52	2.25-5.2	
VC	1.	2.76	2.55-3.03	2.34-4.23	<0.001
	2.	2.80	2.58-3.07	2.35-4.27	

Legend: FVC- forced vital capacity; FEV1- forced expiratory volume in the first second; VC- vital capacity; IQR= interquartile range; min-max= minimum and maximum result;

Functional outcomes

As differences were found between the first and second measurements for all parameters, only the parameters determined in the second measurement for the group of test subjects who exercised (experimental group) and for the group of test subjects who did not exercise (control group) were analysed further. The differences were calculated using the Mann-Whitney U test.

Tables 3 and 4 show the medians and interquartile ranges of the parameters of the subjects who were divided into two test groups – subjects who exercised (1) and subjects who did not exercise (2). The parameters for body mass, body mass in-

Table 3. Medians and interquartile ranges for the parameters of the anthropological measurements between the two test groups

Variables	Exercise	Measurements	Median	IQR	p
Body mass	1.	1.	101	92-108	< 0.001
		2.	95	88-103	
	2.	1.	106	87-110	< 0.001
		2.	100	87-110	
	p*	0.244			
Body mass index	1.	1.	35	33-39	< 0.001
		2.	33	31-35	
	2.	1.	38	33-41	< 0.001
		2.	37	31-40	
	p*	0.154			
Waist circumference	1.	1.	118	107-123	< 0.001
		2.	100	102-118	
	2.	1.	117	111-124	< 0.001
		2.	115	108-120	
	p*	0.382			
Abdominal fat thickness	1.	1.	13	11-15	< 0.001
		2.	12	10-14	
	2.	1.	13	11-16	< 0.001
		2.	12	10-15	
	p*	0.435			

Legend: Exercise– 1 = group that trained, 2 = group that did not train; measurement – 1. first measurement, 2. second measurement; IQR = interquartile range; P*significance determined by the Mann-Whitney test for the second measurement between the groups of exercisers (1) and non-exercisers (2);

Table 4. Medians and interquartile ranges for lung function parameters between the two test groups

Variables	Exercise	Measurements	Median	IKR	p
FVC	1.	1.	3.11	2.82-3.63	< 0.001
		2.	3.25	2.99-3.65	
	2.	1.	3.13	2.64-3.54	< 0.001
		2.	3.25	2.81-3.62	
	p*	0.741			
FEV1	1.	1.	2.66	2.37-3.13	< 0.001
		2.	2.69	2.4-3.16	
	2.	1.	2.71	2.29-3.05	0.009
		2.	2.76	2.33-3.12	
	p*	0.676			
VC	1.	1.	2.72	2.55-3.35	< 0.001
		2.	2.77	2.58-3.38	
	2.	1.	2.78	2.51-3.01	< 0.001
		2.	2.85	2.56-3.03	
	p*	0.892			

Legend: Exercise – 1 = group that exercised, 2 = group that did not exercise; measurement – 1. first measurement, 2. second measurement; IQR = interquartile range; P*significance determined by the Mann-Whitney test for the second measurement between the groups of exercisers (1) and non-exercisers (2);

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dex, waist circumference, abdominal fat thickness, forced vital capacity (FVC), forced expiratory volume (FEV1) and vital capacity (VC) are shown. The differences between the groups were calculated using Friedman's ANOVA.

Discussion

The research results showed that there were no differences in functional recovery of lung function and anthropological characteristics between the group that exercised and the group that did not exercise in any of the variables tested. Examining Table 3 and the descriptive statistics between groups, most variables show better outcomes in the exercising group compared to the non-exercising group. However, the additional effect of physical activity may be difficult to detect statistically, likely due to the calorie-restrictive diet to which both groups were subjected.

The proportion of women in the research was significantly higher than that of men. A meta-analysis by Mabira et al. on the influence of age, gender and BMI on the effect of fast walking in obese people also shows a higher representation of women compared to men. The above data supports the hypothesis that women are more prone to developing obesity, but at the same time are more willing to accept the consequences. They are more willing to adopt lifestyle habits that have an impact on improving their condition, which is most likely related to social factors (Mabire, Mani, Liu, Mulligan, & Baxter, 2017).

Chheda et al. investigated the effect of 6 weeks of exercise on FEV1 in obese people and found no statistically significant improvement in the measured parameter. They concluded that regular physical activity can have a positive effect on improving lung function, but that other lifestyle habits of the subjects, such as diet and environmental factors, should also be taken into account (Chheda & Manwadkar, 2021).

Sa-nguanmoo et al. investigated the influence of physical activity on lung function and respiratory muscle strength in obese young adults. They were categorised into groups according to the metabolic equivalent of physical activity. They concluded that higher FEV1 and MIP (maximum inspiratory pressure) measured in physically active young adults indicate that regular physical activity positively affects lung function and inspiratory muscle strength in overweight individuals (Sa-nguanmoo, Chuatrakoon, Pratanaphon, Thanagosai, & Sriarpon, 2023).

Chlif et al. also investigated the effect of aerobic exercise training on ventilatory efficiency and respiratory drive in obese individuals. The subjects exercised five times a week for eight weeks. The results showed that there was no significant difference in the predictive values of predicted FEV and FVC1 before and after the study (Chlif, Chaouachi, & Ahmaidi, 2017).

Numerous studies highlight various factors influencing the functional improvement of lung function in overweight patients. The statistically significant improvement in the measured parameters relates not only to physical activity, but also to other aspects of obesity, such as BMI and the extent of central obesity. In their study, Svartengren et al (2020) used data from the Swedish EpiHealth cohort study, which was conducted with the primary aim of investigating how interactions between lifestyle factors and genotypes contribute to the development of certain disorders in humans. They found that increased waist circumference was associated with lower FEV1 independently of BMI, and similar results were found for FVC. They found that only subjects with a high level of physical activity had an improvement in FVC values; FEV1 and VC (C.-K. Lin & Lin, 2012).

The relative improvement in respiratory parameters was also confirmed in the study by Silva-Rais et al., which looked at the effect of physical activity in combination with resistance training and aerobic exercise on improving lung function and mechanics in overweight or obese women. After a 12-week physical activity programme, they concluded that combined training had a beneficial effect on reducing visceral adipose tissue and improving functional capacity in middle-aged women who had increased body mass or obesity. It was also found that people with overweight and 1st degree obesity have an increased amount of visceral fat, which negatively affects the mechanics of the lungs by damaging the airways, resistance and elasticity of the tissue (Silva-Reis et al., 2022).

The influence of intensity and duration of physical activity on the reduction of adipose tissue was analysed by a group of Canadian experts (Cowan et al). The subjects were divided into groups that exercised at different intensities, determined by the percentage of maximum oxygen uptake, and there was a control group of non-exercisers. The loss in the amount of subcutaneous abdominal fat thickness was not statistically different between the groups of exercisers, but a statistically significant difference was confirmed between the group of non-exercisers and exercisers. In addition, body weight and waist circumference decreased in all groups that exercised compared to the non-exercising group. The study confirmed a significant reduction in total and abdominal fat thickness and concluded that exercise is a good strategy for reducing obesity when done appropriately (Cowan et al., 2018).

Performing aerobic training to test respiratory function in obese men emphasises the positive result of the study by İşleyen and Dağlıoğlu (İŞleyen & Dağlioğlu, 2020). They concluded that after performing an aerobic training programme 3 times a week at 70% of maximal oxygen uptake, there was an improvement in respiratory parameters, namely VC, FVC and FEV1 (İŞleyen & Dağlioğlu, 2020). A very similar study was conducted to determine the effect of selected aerobic exercises on lung function in obese adolescents. A statistically significant difference was found for VC, FVC and FEV1 between the experimental groups that performed aerobic physical activity and the control group that did not exercise (Irandoust, 2015).

Scientists from California investigated the effects of aerobic exercise and an anti-atherosclerotic diet on the amount of visceral adipose tissue and subcutaneous abdominal adipose. They concluded that there was no statistically significant difference between the results of subjects who performed aerobic physical activity and followed an anti-atherosclerotic diet and subjects who followed a diet alone, i.e. the control group who neither exercised nor followed a diet (J.-H. Lin, Liang, Fang, & Teng, 2021). As both groups followed a calorie-restrictive diet, the diet itself could have significantly influenced the results and partly masked the effects of physical activity. Caloric restriction mobilises body fat, reducing both visceral and subcutaneous fat depots, which decreases skinfold thickness and body mass index regardless of physical activity level. Fat reduction in the abdominal and thoracic regions lowers the mechanical load on the lungs and diaphragm, potentially improving pulmonary function (FEV_1, FVC) and ventilatory parameters. The combination of diet and exercise may have reduced differences between groups, as the diet alone already induced metabolic and biological changes affecting the respiratory system and body composition.

Kordi et al. (2015) investigated the effect of abdominal muscle strengthening exercises on abdominal fat tissue in obese women. After a 12-week intervention with abdominal muscle strengthening exercises and a diet programme compared to a diet-only programme, no significant differences were found in measurements of subcutaneous adipose tissue thickness, waist circumference, hip circumference and BMI, although all participants lost body weight (Kordi, Dehghani, Noormohammadpour, Rostami, & Mansournia, 2015).

Limitations of the study

This study has several methodological and statistical limitations that should be considered when interpreting the results. The wide age range (from 23 to 64 years) may have influenced outcomes due to age-related differences in physiological responses to exercise. In addition, the inability to precisely monitor exercise intensity limits interpretation of the dose–response relationship between physical activity and the observed changes. Moreover, information on whether participants in the control group engaged in independent physical activity outside the programme was not collected, which could have influenced the results. From a statistical perspective, interaction effects between group and time were not assessed, preventing definitive conclusions regarding differential changes in outcomes between exercisers and non-exercisers over the study period.

Conclusion

There was no confirmed difference between subjects who exercised in an organised manner and those who did not, but a statistically significant difference was found between the first and second measurement in all subjects. The results obtained suggest that the application of a restrictive diet has a positive effect on the improvement of anthropometric characteristics and lung function parameters in overweight or obese subjects.

Despite the lack of significant differences between the exercise and non-exercise groups in this study, existing research demonstrates that weight loss contributes to functional recovery. Therefore, it remains essential to include regular physical activity as a primary method for restoring the functions of various organ systems in individuals with obesity and for reducing numerous associated risk factors.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Disclosure statement

The authors declare that there is no conflict of interest with any financial organization in relation to the research problem discussed in the manuscript.

Ethical Approval Information

Measurements were taken according to the ethical standards of the Declaration of Helsinki.

References

Bhatti, U., Laghari, Z. A., & Syed, B. M. (2019). Effect of Body Mass Index on respiratory parameters: A cross-sectional analytical Study. *Pakistan Journal of Medical Sciences*, *35*(6), 1724–1729. https://doi.org/10.12669/pjms.35.6.746

Chheda, H., & Manwadkar, S. (2021). *A Comparative Study of Pulmonary Function between Exercising and Non-Exercising Obese Adults*. Retrieved from https://www.semanticscholar.org/paper/A-Comparative-Study-of-Pulmonary-Function-between-Chheda-Manwadkar/2b6050ba5019c8287e3d70588f1899c4232ac276

Chlif, M., Chaouachi, A., & Ahmaidi, S. (2017). Effect of Aerobic Exercise Training on Ventilatory Efficiency and Respiratory Drive in Obese Subjects. *Respiratory Care*, *62*(7), 936–946. https://doi.org/10.4187/respcare.04923

Chlif, M., Keochkerian, D., Choquet, D., Vaidie, A., & Ahmaidi, S. (2009). Effects of obesity on breathing pattern, ventilatory neural drive and mechanics. *Respiratory Physiology & Neurobiology*, *168*(3), 198–202. https://doi.org/10.1016/j.resp.2009.06.012

Cowan, T. E., Brennan, A. M., Stotz, P. J., Clarke, J., Lamarche, B., & Ross, R. (2018). Separate Effects of Exercise Amount and Intensity on Adipose Tissue and Skeletal Muscle Mass in Adults with Abdominal Obesity. *Obesity (Silver Spring, Md.)*, *26*(11), 1696–1703. https://doi.org/10.1002/oby.22304

Ferreira, M. S., Marson, F. A. L., Wolf, V. L. W., Zambon, M. P., Antonio, M. Â. R. de G. M., Ribeiro, J. D., & Mendes, R. T. (2022). Association between Pulmonary Function and Body Composition in Children and Adolescents with and without Obesity. *Journal of Clinical Medicine*, *11*(24), 7410. https://doi.org/10.3390/jcm11247410

Ghesmaty Sangachin, M., Cavuoto, L. A., & Wang, Y. (2018). Use of various obesity measurement and classification methods in occupational safety and health research: A systematic review of the literature. *BMC Obesity*, *5*(1), 28. https://doi.org/10.1186/s40608-018-0205-5

Irandoust, K. (2015). The Effects of Selected Aerobic Exercises on Pulmonary Functions of High School Obese Girls. *International Journal of School Health*, *2*(4), 32–36. https://doi.org/10.17795/intjsh29288

İŞleyen, G., & Dağlioğlu, Ö. (2020). The Effect of Aerobic Exercise on Pulmonary Function and Aerobic Capacity in Sedentary Men. *International Journal of Sport, Exercise & Training Sciences*. https://doi.org/10.18826/useeabd.784339

Kordi, R., Dehghani, S., Noormohammadpour, P., Rostami, M., & Mansournia, M. A. (2015). Effect of abdominal resistance exercise on abdominal subcutaneous fat of obese women: A randomized controlled trial using ultrasound imaging assessments. *Journal of Manipulative and Physiological Therapeutics*, *38*(3), 203–209. https://doi.org/10.1016/j.jmpt.2014.12.004

Lin, C.-K., & Lin, C.-C. (2012). Work of breathing and respiratory drive in obesity. *Respirology (Carlton, Vic.)*, *17*(3), 402–411. https://doi.org/10.1111/j.1440-1843.2011.02124.x

Lin, J.-H., Liang, M. T. C., Fang, C.-L., & Teng, W.-P. (2021). Effect of Aerobic Exercise and Dietary Intervention on Visceral and Subcutaneous Adipose tissue in Sedentary Overweight Adults: A Magnetic Resonance Imaging Study. *Journal of Rehabilitation Practices and Research*, *2*(2). https://doi.org/10.33790/jrpr1100126

Mabire, L., Mani, R., Liu, L., Mulligan, H., & Baxter, D. (2017). *The Influence of Age, Sex and Body Mass Index on the Effectiveness of Brisk Walking for Obesity Management in Adults: A Systematic Review and Meta-Analysis*. https://

 DOI 10.26773/mjssm.260309

doi.org/10.1123/jpah.2016-0064
Maloča Vuljanko, I., & Petković, G. (2023). Testovi plućne funkcije u predškolskoj dobi. *Liječnički vjesnik*, *145*(Supp 1), 72–77. https://doi.org/10.26800/LV-145-supl1-11
Sa-nguanmoo, P., Chuatrakoon, B., Pratanaphon, S., Thanagosai, J., & Sriarpon, J. (2023). Impact of Physical Activity on Pulmonary Function and Respiratory Muscle Strength in Obese Young Adults. *Trends in Sciences*, *20*(11), 6802–6802. https://doi.org/10.48048/tis.2023.6802
Shanmugasundaram, K., Bade, G., Sampath, M., & Talwar, A. (2023). Effect of Obesity on Airway Mechanics. *Indian Journal of Endocrinology and Metabolism*, *27*(2), 161–166. https://doi.org/10.4103/ijem.ijem_363_22
Silva-Reis, A., Rodrigues Brandao-Rangel, M. A., Moraes-Ferreira, R., Gonçalves-Alves, T. G., Souza-Palmeira, V. H., Aquino-Santos, H. C., … Vieira, R. P. (2022). Combined resistance and aerobic training improves lung function and mechanics and fibrotic biomarkers in overweight and obese women. *Frontiers in Physiology*, *13*, 946402. https://doi.org/10.3389/fphys.2022.946402
STROBE. (n.d.). Retrieved February 1, 2024, from STROBE website: https://www.strobe-statement.org/
Svartengren, M., Cai, G.-H., Malinovschi, A., Theorell-Haglöw, J., Janson, C., Elmståhl, S., … Lindberg, E. (2020). The impact of body mass index, central obesity and physical activity on lung function: Results of the EpiHealth study. *ERJ Open Research*, *6*(4), 00214–02020. https://doi.org/10.1183/23120541.00214-2020

ORIGINAL SCIENTIFIC PAPER

Physical Performance and Muscle Soreness in Tennis Players After Plyometric Training Performed at Different Weekly Frequencies

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Abstract

High-frequency plyometric jump training (PT) may benefit tennis players, but little is known about how its weekly distribution affects performance and acute perceived soreness. The aim was to investigate the effects of PT, conducted at different weekly frequencies, on physical performance and muscle soreness in competitive tennis players. Eighteen competitive tennis players were randomly assigned to PT-1 (1 session/week) (n=9; age 17.0±2.0 yrs) or PT-3 (3 sessions/week) (n=9; age 19.0±3.9 yrs), both performing 180 jumps over 8 weeks. Countermovement vertical (CMVJ) and squat jumps (SJ), single-leg horizontal hop (SLHH), 10- and 20-m sprints, and a repeated change-of-direction (COD) test were measured pre- and post-intervention. Muscle soreness was recorded before and immediately after each PT session using a 7-point Likert scale. Both groups improved jump height, hop distance, sprint time, and repeated COD performance ($p<0.05$). No between-groups differences were noted for CMVJ ($p=0.419$), SJ ($p=0.692$), SLHH ($p=0.512$), 10- and 20-m sprints ($p=0.658$ and $p=0.741$), nor repeated COD performance ($p=0.191$). Distributing the same PT volume over three weekly sessions produces performance gains comparable to a single weekly session. However, the increase in muscle soreness was significantly lower in PT-3 than in PT-1 group. Higher-frequency, lower-dose PT may reduce acute muscle soreness perception while maintaining performance improvements.

Keywords: *Plyometric exercise; Athletic performance; Human physical conditioning; Stretch-shortening cycle*

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Introduction

The stretch-shortening cycle (SSC) involves a rapid eccentric-concentric muscle action that underpins plyometric training (PT). By leveraging the SSC, PT enhances force and power in multidirectional movements (Moran et al., 2017).

In tennis, players frequently engage in high-intensity SSC movements across the court (Hughes & Meyers, 2005), including accelerations, decelerations, jumps, and lateral movements (Trecroci et al., 2024), often under unpredictable conditions. PT is recognized for its efficacy in enhancing these critical demands by inducing neuromuscular adaptations that improve key performance determinants (Markovic & Mikulic, 2011) such as reactive strength, speed, and change of direction (COD) ability (Sinkovic et al., 2023). Previous research has investigated the effects of PT combined with regular tennis-specific training on upper- and lower-body physical performance in young players (Fernandez-Fernandez et al., 2016) reporting positive effects on vertical and horizontal jump, 20-m sprint, and modified 505 COD test. However, tennis-specific evidence on high-frequency PT (≥ 3 sessions/week) is scarce, especially regarding how distributing an equivalent volume across in-season weeks may impact physical performance and perceptual responses (e.g., muscle soreness).

Recent studies have examined how different PT session distributions (i.e., 1 vs. 2 sessions per week) impact physical performance in young athletes of multidirectional sports (Bouguezzi et al., 2020; Moran et al., 2024; Ramirez-Campillo et al., 2018; Yanci et al., 2017), revealing comparable results. Similarly, no significant differences were observed between 1 vs. 2 PT sessions per week in jump performance, sprint and service speed among volleyball players (Hernandez-Martinez et al., 2023). Of note, tennis has distinct biomechanical (e.g., lateral push-offs and unilateral stroke actions) and temporal (i.e., intermittent rally–rest patterns) constraints compared with team sports (Hughes & Meyers, 2005). Therefore, tennis-specific evidence is required to confirm whether the potential frequency-response association applies to tennis.

On one hand, the appropriate frequency of PT for optimal physical performance improvements has not yet been elucidated, even though a high number of weekly sessions (>2 per week) has previously been suggested for court-based sports such as tennis (Booth & Orr, 2016). This approach would help athletes to better tolerate the in-season training load by a lower PT dose per session. On the other hand, evidence comparing low- versus high-frequency PT programs (e.g., 1 vs. ≥ 3 sessions/week) under volume-matched conditions, is still limited.

While PT remains an effective strategy for enhancing athletic performance, it can also impact muscle soreness, especially if introduced without proper caution alongside regular tennis-specific training (Kovacs, 2006). Given the neuromuscular and biomechanical demands of tennis activities, players often experience muscular fatigability due to frequent stop-and-start movements, and prolonged periods of rapid first-step explosiveness (Kovacs, 2006).

In this scenario, without appropriate recovery strategies, the integration of PT sessions during the week could exacerbate muscle soreness by exceeding the capacity to tolerate repetitive, high compressive and shear forces, consequently increasing injury risk (Davies et al., 2015; Kovacs, 2006). Hence, the implementation of PT requires careful attention, not only to training structure and volume but also to session frequency, as previously reported in adolescent soccer players (Trapletti et al., 2025).

Although a high-frequency PT distribution may be desirable, there is still limited evidence on how various training distributions influence physical performance and muscle soreness in tennis players. This remains a key aspect to effectively manage the weekly training load and recovery.

Therefore, the aim of this study was to investigate the effects of PT, conducted at different weekly frequencies, on physical performance and muscle soreness in competitive tennis players. We hypothesized that PT weekly distribution would lead to comparable improvements in physical performance (Liu et al., 2024), regardless of session frequency. We also hypothesized that a high-frequency distribution would elicit a lower acute perceived soreness response potentially due to the reduced PT dose per session.

Methods

Participants

Eighteen competitive tennis players from the same club volunteered to participate and were randomly allocated to two experimental groups. Nine participants (7 males, 2 females) underwent PT once per week (PT-1; age = 17.0 ± 2.0 yrs, height = 175.0 ± 10.8 cm, body mass = 64.0 ± 11.8 kg, ranking 2.8 ± 4.0 arbitrary units) while the other nine participants (7 males and 2 females) received a total volume-matched program distributed over three weekly sessions (PT-3, n = 7 males and 2 females, age = 19.0 ± 3.9 yrs, height = 176.0 ± 8.1 cm, body mass = 67.0 ± 5.7 kg, ranking 2.8 ± 5.0 arbitrary units) for an 8-week training period. The ranking of each participant refers to the Italian Tennis and Padel Federation. To be included, participants had to engage in a minimum of 3 training sessions per week (90 min/session), and one official game per week. Participants were excluded if they had chronic conditions (e.g., asthma), illnesses (e.g., flu-like conditions), musculoskeletal and osteoarticular disorders (i.e., injuries). As only the 18 recruited players who met all eligibility criteria were available during the in-season period, we performed a sensitivity analysis in G*Power 3.1.9.7 (F tests, RM-ANOVA within-between interaction; groups = 2; measurements = 2; r = 0.50; ε = 1). With the available sample of 18 players, α = 0.05 and power = 0.80, our study could detect an interaction effect of at least f = 0.66 on the primary outcome (i.e., single-leg horizontal hop). Prior to the intervention, players and their parents or legal guardians were informed about the protocol used and provided a signed informed consent. The Ethics Committee of the local University approved the study (approval number 29/24), which was conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

A randomized parallel group design was conducted at a single tennis academy during the 2023/2024 season. Participants were familiarized with all procedures prior to the experiment. Testing occurred at the same time of day, one week before and after the intervention over a three-day period. First, stature and body mass were measured using a stadiometer (SECA 213, Germany) and portable scale (SECA 813, Germany) with an accuracy of 0.1 cm and 0.1 kg, respectively. To minimize fatigue, performance assessments were split: vertical and horizontal jumps on day two, and sprints on day three. A standardized 10-min warm-up consisting of slow running, dynamic mobility exercises, progressive acceleration and deceleration drills, bilateral and unilateral jumping activities

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preceded physical tests (Trecroci, Bongiovanni, et al., 2020; Trecroci, Rossi, et al., 2020). All tests were conducted indoors with players wearing habitual tennis shoes.

Field-based physical performance assessment

Jump performance. Participants performed countermovement vertical jump (CMVJ), squat jump (SJ) and a single-leg horizontal hop (SLHH) tests. In the CMVJ, the participants performed three maximal vertical jumps interspersed by 2 min of rest. During each jump, the participants were asked to keep their hands on the hips without bending the legs from the take-off and landing phases (Bongiovanni et al., 2021). In the SJ, players also performed three maximal attempts starting from a static semi-squat position with no countermovement. For both CMVJ and SJ, the Ergojump® system (Ergojump apparatus, Globus Italia, Codogne, Italy) recorded contact and flight times while returning jump height. The highest jump performance in both tests was used for the analysis. The SLHH consisted of a horizontal single-leg jump with the toe at the starting line and free use of the arms. Each participant was instructed to sink to a self-selected depth as quickly as possible and then jump as far forward as possible. They were instructed to land on the same leg by holding the final position for at least 2 s. The distance was measured by a measuring tape (accuracy of 0.1 cm) from the starting line to the heel of the foot, at the point of impact on the landing surface. Participants performed three jumps with the right and left leg, and the longest jump with each leg was used for analysis.

Sprint performance. Each subject performed three maximal 10 m and 20 m sprints with a free departure, interspersed by 2 min of passive recovery. The starting position was in a two-staggered stance. The best performance time was considered in the analysis. An electronic timing system based on photocells (Witty, Microgate, Bolzano, Italy) was employed to measure sprinting time. The photocells were placed at a height of 0.7 m near the start and finish lines. The athletes were positioned 0.3 m away from the start timing gates to prevent an early trigger of the electrical instrumentation due to the leaning trunk.

Shuttle run test 6×8 m. This test consisted of six maximal sprints over 8 m, requiring a 180° COD at each 8-m interval course. It is traditionally used by the Italian Tennis and Padel Federation as part of the athletes' assessment protocol of their repeated COD ability. Indeed, the 8-m distance closely replicates the standard width of a single tennis court. Completion time was recorded using the same timing gate system employed for linear sprint assessment.

Perceptual assessments. Players' muscle soreness was recorded by a 7-point Likert scale (Impellizzeri & Maffiuletti, 2007) that includes seven descriptive values, from 0 to 6, where 0 corresponds to complete absence of muscle soreness and 6 to soreness that limits the participant's ability to move. In an upright position, participants reported thigh and leg muscle soreness from the nondominant limb, operationally defined as the leg not preferred for push-off when jumping. The 7-point Likert scale was administered before and immediately after each PT session. The delta values (post–pre) were computed for each PT session and averaged within each week for analysis.

Training intervention

The PT intervention in both PT-1 and PT-3 lasted 8 weeks, with 1 or 3 training sessions per week, respectively. During the intervention, players continued their sport-specific and habitual strength and conditioning activities, which were comparable between groups and unchanged throughout the study. The PT was integrated after the regular tennis-specific session. The PT combined double- and single-leg jumps in different directions, with a particular focus on horizontal jumps. The work-to-rest ratio was 1 to ≥7 to ensure recovery periods of at least ≥60 s between sets.

Participants were familiar with the drills included in the PT intervention, although they did not apply the drills systematically (nor with the same volume, intensity) into their regular tennis training sessions. The PT interventions followed a non-periodized structure, maintaining a consistent total training volume and session duration throughout the intervention. This approach was adopted to reflect the in-season practice and to minimize additional load fluctuations during the competitive period. Players were instructed to perform each jump with maximal effort, with minimal contact time and maximal propulsion phase. Additionally, each session was carefully monitored, maintaining a 1:4 coach-to-player ratio to ensure proper execution through demonstrations and continuous feedback.

The PT-1 involved 180 jumps per session (per week), distributed in three drills: Drill #1: 5 [sets] × 6 [repetitions] double-leg forward jumps and single-leg forward hops (both over hurdles of 30 cm); Drill #2: 6 × 6 double-leg forward jumps combined with double-leg lateral jumps and 6 × 4 single-leg forward hops combined with single-leg lateral jump; Drill #3: 4 × 7 double-leg forward jump followed by a vertical jump upon landing and 4 × 8 single-leg forward bounds with alternating foot contacts.

The PT-3 completed the same 180 jumps per week as the PT-1 group, although distributed in 60 jumps per session, with the same drill structure and content applied respectively to session #1, #2, and #3. The distribution considered that ≥50 foot contacts per session are suggested for court sport athletes (Booth & Orr, 2016).

Statistical Analyses

Normality was checked using the Shapiro–Wilk's test. Relative reliability was assessed with the intraclass correlation coefficient (ICC, model 3,k) and 95% confidence intervals (CI), interpreted as poor (< 0.50), moderate (0.5-0.74), good (0.75-0.90) and excellent (> 0.90) (Koo & Li, 2016). Absolute reliability utilized the coefficient of variation (CV = (SD/mean) × 100) categorized as poor (>10%), moderate (5–10%), or good (<5%) (Banyard et al., 2017). Sensitivity was determined by the Bland-Altman limits of agreement (LoA) calculated as the mean difference ± 1.96 times the standard deviation of the differences, providing the range within which most measurement differences are expected to fall (De Vet et al., 2006). A two-way repeated-measures ANOVA (group × time) was employed, followed by Bonferroni's post-hoc test for multiple comparisons. The Hedges' g (g) effect size (Wasserman et al., 1988) was calculated and reported as a point estimate, with thresholds: $g < 0.2$ (trivial), $0.2 < g \le 0.5$ (small), $0.5 < g \le 0.8$ (moderate), and $g > 0.8$ (large). The small worthwhile change (SWC) was computed as 0.2 × between-subject SD from baseline measures (Batterham & Hopkins, 2006), assessing practical significance. Data are reported as mean ± SD, and relative changes as mean ± 95% CI. All analyses were performed using JASP software (version 0.18.1, JASP team, Amsterdam, Netherlands).

Results

Table 1 presents reproducibility values of each physical performance variable. Absolute and relative data reported excellent reliability, with overall ICC > 0.9 and CV% < 2.5%. Sensitivity values expressed by LoA were narrow across all tests, upper and lower bounds close to zero. From pre- to post-intervention, all physical performance outcomes, percentage changes, and their effect sizes for PT-1 and PT-3 are shown in Table 2.

Table 1. Physical performance measure's reliability.

	ICC (95% CI)	CV (%)	Upper LoA	Lower LoA
Squat jump height (cm)	0.99 (0.98-0.99)	1.9	0.09	-0.45
Countermovement vertical jump height (cm)	0.98 (0.96-0.99)	2.5	0.01	-0.07
Single-leg (R) horizontal hop distance (cm)	0.96 (0.91-0.98)	2.3	0.00	-0.05
Single-leg (L) horizontal hop distance (cm)	0.97 (0.93-0.98)	1.9	0.01	-0.05
10-m sprint time (s)	0.91 (0.83-0.96)	1.7	0.02	-0.02
20-m sprint time (s)	0.94 (0.88-0.97)	1.7	0.04	0.00
6 x 8 m shuttle-test total time (s)	0.95 (0.87-0.98)	1.5	0.27	-0.03

Note: LoA = limits of agreement, ICC = intraclass correlation coefficient, CI = 95% confidence interval, CV = coefficient of variation, R = right, L = left.

Table 2. Changes in physical performance following PT interventions (PT-1 and PT-3).

	PT-1				PT-3			
	Mean	SD	%Δ	g	Mean	SD	%Δ	g
Squat jump height (cm)								
Pre	37.84	7.77	2.6	0.12	36.17	8.71	3.1	0.12
Post	38.82	8.22			37.28	8.60		
Countermovement vertical jump height (cm)								
Pre	38.74	7.67	2.5	0.12	36.57	8.00	2.1	0.09
Post	39.72	7.61			37.33	7.99		
Single-leg horizontal hop distance (cm)								
Pre	1.82	0.22	3.3	0.26	1.79	0.22	2.8	0.18
Post	1.88	0.22			1.84	0.20		
10 m sprint time (s)								
Pre	2.00	0.15	2.0	0.27	1.97	0.14	2.0	0.28
Post	1.96	0.13			1.93	0.13		
20 m sprint time (s)								
Pre	3.36	0.24	3.6	0.49	3.31	0.31	3.9	0.43
Post	3.24	0.23			3.18	0.27		
6 × 8 m shuttle-test total time (s)								
Pre	12.41	0.83	2.0	0.37	12.15	0.89	1.0	0.13
Post	12.17	0.83			12.03	0.89		

Note: PT-1 = plyometric training intervention with one session per week, PT-3 = plyometric training intervention with three sessions per week, SD = standard deviation, %Δ = post–pre percentage change, g = Hedges' g effect size.

The SWC values were as follows: SJ = 1.61 cm, CMVJ = 1.54 cm, SLHH = 0.04 cm, 10-m sprint = 0.028 s, 20-m sprint = 0.05 s, and 6 × 8-m = 0.17 s. For muscle soreness, a main effect of group ($F(1,16) = 45.44$, $p < 0.001$) was observed, although no interaction ($F(7, 112) = 0.13$, $p = 0.996$) nor main effect of time ($F(7, 112) = 0.60$, $p = 0.749$) were found between PT-3 and PT-1 (Figure 1).

For SJ height, no interaction ($F(1,16) = 0.16$, $p = 0.692$) nor group effect ($F(1,16) = 0.16$, $p = 0.687$) were found. However, a main effect of time ($F(1,16) = 42.70$, $p < 0.001$) was revealed. Similarly, CMVJ height and SLHH distance showed a main effect of time ($F(1,16) = 43.63$, $p < 0.001$ and $F(1,16) = 64.78$, $p < 0.001$, respectively), but no interaction ($F(1,16) = 0.68$, $p = 0.419$ and $F(1,16) = 0.45$, $p = 0.512$, respectively) nor group effect ($F(1,16) = 0.38$, $p = 0.546$ and $F(1,16) = 0.15$, $p = 0.697$, respectively) were found. In the 10 m and 20 m sprint, no interaction ($F(1,16) = 0.20$, $p = 0.658$; $F(1,16) = 0.11$, $p = 0.741$, respectively) nor group effect ($F(1,16) = 0.25$, $p = 0.620$; $F(1,16) = 0.17$, $p = 0.678$, respectively) were found. However, a main effect of time ($F(1,16) = 43.23$, $p < 0.001$; $F(1,16) = 70.75$, $p < 0.001$, respectively) was revealed. For 6 × 8 m sprint, no interaction ($F(1,16) = 1.86$, $p = 0.191$) nor group effect ($F(1,16) = 0.25$, $p = 0.623$) were found. However, a main effect of time ($F(1,16) = 19.87$, $p < 0.001$) was revealed.

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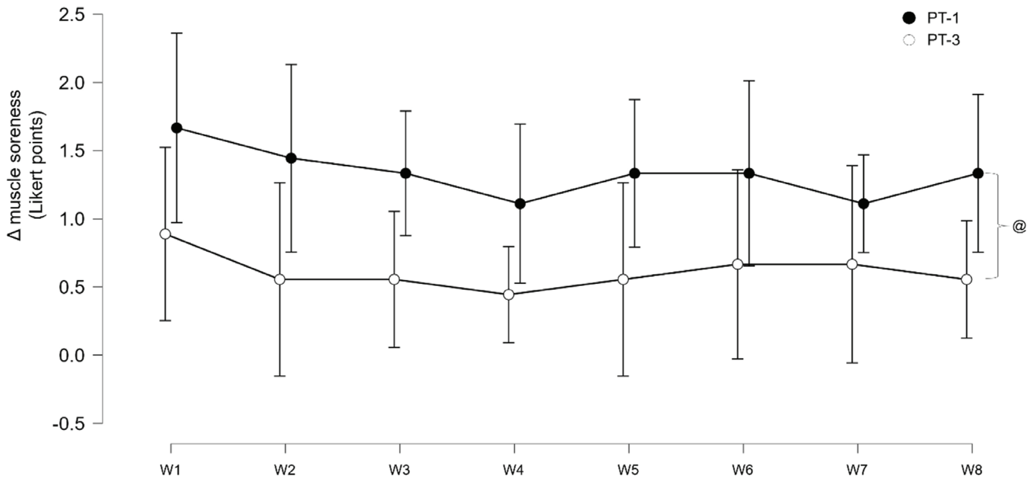

Figure 1. Weekly delta (Δ) muscle soreness (post–pre) in tennis players that performed one (PT-1) or three (PT-3) plyometric sessions per week (W) across the 8-week intervention.
Note: @ = denotes significant ($p < 0.05$) difference between groups.

Discussion

The PT-1 and PT-3 groups achieved similar improvements in performance (SJ, CMVJ, SLHH, COD). However, muscle soreness was significantly lower in PT-3, suggesting that a higher weekly frequency (3 sessions) may optimize PT stimuli while better managing perceived soreness. This strategy is particularly relevant given the high work-to-rest ratios (1:3 to 1:5) typical of competitive tennis (Kovacs, 2006), which demands high tolerance for repetitive, high-impact actions. However, no physiological responses on recovery can be drawn from the present data.

From a practical perspective, vertical jump improvements (SJ and CMVJ) were trivial (below SWC), suggesting limited relevance for tennis. According to this, the detected significant improvements should be inferred with caution. Conversely, changes in SLHH and sprint performance exceeded the SWC, indicating a practically meaningful enhancement. This disparity is likely due to the training program, which predominantly included horizontal and unilateral specificity (Watkins et al., 2021) that mirror the neuromechanical demands of tennis-specific actions like lateral movements, rapid push-offs, and stop-and-start actions (Trecroci et al., 2024; Watkins et al., 2021). These changes may contribute to faster court coverage during rallies, although such an interpretation is indirect, as no in-match tracking metrics were collected. Taken together, these findings, consistent with previous work on sprinting (Gonzalo-Skok et al., 2019), support prioritizing unilateral and horizontal jump exercises within PT programs for tennis players.

Our results align with existing evidence in team sports (Trapletti et al., 2025), which shows that PT enhances lower-limb power regardless of weekly frequency (7–10). For instance, both one and two weekly PT sessions provided equally effective improvements in jump performance, sprint, and service speed in young volleyball players. Similarly, comparable gains in sprint performance, COD ability, and horizontal jump were seen in futsal (Yanci et al., 2017), and in soccer when comparing two versus four weekly sessions (Liu et al., 2024). These results support the hypothesis that the weekly distribution of PT may not critically affect performance gains in explosive and multidirectional tasks, especially when volume is equated. It is worth noticing that evidence on ≥ 3 weekly PT sessions in tennis is scarce, thereby the present study provides novel insights into in-season performance and perceived soreness data. However, in light of the sample size, the non-significant group × time interaction between PT frequency distributions might not be interpreted as evidence of equivalence. Additional large-sample studies are desirable to corroborate the current results while reducing the chance of type II error in court-based sports.

An interesting side finding was the significant improvement in the 6 × 8 m shuttle test, albeit its practical relevance was limited. The higher per-session load in PT-1 (180 jumps) than in PT-3 (60 jumps) might have provided a greater neuromuscular stimulus. Nevertheless, this remains speculative and should be investigated employing a clear assessment of biochemical markers (i.e., creatine kinase) and neuromuscular function (i.e., vertical and horizontal jump kinetics) from pre to post PT.

The present study presents some limitations that should be acknowledged. First, the small and heterogeneous sample size limits the statistical power (i.e., type II error) and generalizability, even though comparable sizes have been previously employed (Ramirez-Campillo et al., 2018; Yanci et al., 2017). Additionally, the reliance on a subjective 7-point Likert scale for muscle soreness is also limited without objective confirmation on delayed soreness (>24 h), and pre-post-session data on physiological and neuromuscular status.

Conclusions

A volume-matched PT with different weekly frequencies led to similar performance gains, but only SLHH and sprint performance were practically meaningful for competitive tennis players. Crucially, distributing PT volume over three weekly sessions (~60 jumps each) may represent a viable alternative to compress volume within a single session, potentially reducing perceived soreness while eliciting comparable performance improvements.

Disclosure of interest

There are no relevant financial or non-financial competing interests to report.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Banyard, H. G., Nosaka, K., & Haff, G. G. (2017). Reliability and validity of the load–velocity relationship to predict the 1RM back squat. *Journal of Strength and Conditioning Research*, *31*(7), 1897–1904. https://doi.org/10.1519/JSC.0000000000001657

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57. https://doi.org/10.1123/ijspp.1.1.50

Bongiovanni, T., Trecroci, A., Rossi, A., Iaia, F. M., Pasta, G., & Campa, F. (2021). Association between change in regional phase angle and jump performance: A pilot study in serie A soccer players. *European Journal of Investigation in Health, Psychology and Education*, *11*(3), 860–865.

Booth, M. A., & Orr, R. (2016). Effects of plyometric training on sports performance. *Strength & Conditioning Journal*, *38*(1), 30–37. https://doi.org/10.1519/SSC.0000000000000183

Bouguezzi, R., Chaabene, H., Negra, Y., Ramirez-Campillo, R., Jlalia, Z., Mkaouer, B., & Hachana, Y. (2020). Effects of different plyometric training frequencies on measures of athletic performance in prepuberal male soccer players. *Journal of Strength and Conditioning Research*, *34*(6), 1609–1617. https://doi.org/10.1519/JSC.0000000000002486

Davies, G., Riemann, B. L., & Manske, R. (2015). Current concepts of plyometric exercise. *Int J Sports Phys Ther*, *10*(6), 760–786.

De Vet, H. C. W., Terwee, C. B., Knol, D. L., & Bouter, L. M. (2006). When to use agreement versus reliability measures. *Journal of Clinical Epidemiology*, *59*(10), 1033–1039. https://doi.org/10.1016/j.jclinepi.2005.10.015

Fernandez-Fernandez, J., De Villarreal, E. S., Sanz-Rivas, D., & Moya, M. (2016). The effects of 8-week plyometric training on physical performance in young tennis players. *Pediatric Exercise Science*, *28*(1), 77–86. https://doi.org/10.1123/pes.2015-0019

Gonzalo-Skok, O., Moreno-Azze, A., Arjol-Serrano, J. L., Tous-Fajardo, J., & Bishop, C. (2019). A Comparison of 3 Different Unilateral Strength Training Strategies to Enhance Jumping Performance and Decrease Interlimb Asymmetries in Soccer Players. *International Journal of Sports Physiology and Performance*, *14*(9), 1256–1264. https://doi.org/10.1123/ijspp.2018-0920

Hernandez-Martinez, J., Guzman-Muñoz, E., Ramirez-Campillo, R., Herrera-Valenzuela, T., Magnani Branco, B. H., Avila-Valencia, S., Luis Carter-Beltran, J., Aravena-Sagardia, P., Méndez-Cornejo, J., & Valdés-Badilla, P. (2023). Effects of different plyometric training frequencies on physical performance in youth male volleyball players: A randomized trial. *Frontiers in Physiology*, *14*, 1270512. https://doi.org/10.3389/fphys.2023.1270512

Hughes, M., & Meyers, R. (2005). Movement patterns in elite men's singles tennis. *International Journal of Performance Analysis in Sport*, *5*(2), 110–134. https://doi.org/10.1080/24748668.2005.11868331

Impellizzeri, F. M., & Maffiuletti, N. A. (2007). Convergent Evidence for Construct Validity of a 7-Point Likert Scale of Lower Limb Muscle Soreness. *Clinical Journal of Sport Medicine*, *17*(6), 494–496. https://doi.org/10.1097/JSM.0b013e31815aed57

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Kovacs, M. S. (2006). Applied physiology of tennis performance. *British Journal of Sports Medicine*, *40*(5), 381–386. https://doi.org/10.1136/bjsm.2005.023309

Liu, G., Wang, X., & Xu, Q. (2024). Microdosing Plyometric Training Enhances Jumping Performance, Reactive Strength Index, and Acceleration among Youth Soccer Players: A Randomized Controlled Study Design. *Journal of Sports Science and Medicine*, *23*(2), 342–350. https://doi.org/10.52082/jssm.2024.342

Markovic, G., & Mikulic, P. (2011). Discriminative ability of the yo-yo intermittent recovery test (level 1) in prospective young soccer players. *The Journal of Strength & Conditioning Research*, *25*(10).

Moran, J., Sandercock, G. R. H., Ramírez-Campillo, R., Meylan, C. M. P., Collison, J. A., & Parry, D. A. (2017). Age-related variation in male youth athletes' countermovement jump after plyometric training: a meta-analysis of controlled trials. *Journal of Strength and Conditioning Research*, *31*(2), 552–565. https://doi.org/10.1519/JSC.0000000000001444

Moran, J., Vali, N., Tallent, J., Howe, L., Clemente, F. M., Chaabene, H., & Ramirez-Campillo, R. (2024). Evaluating the effects of consecutive phases of plyometric jump training on athletic performance in male soccer players: the effect of training frequency and volume manipulations. *The Journal of Strength & Conditioning Research*, *38*(6), 1082. https://doi.org/10.1519/JSC.0000000000004756

Ramirez-Campillo, R., García-Pinillos, F., García-Ramos, A., Yanci, J., Gentil, P., Chaabene, H., & Granacher, U. (2018). Effects of different plyometric training frequencies on components of physical fitness in amateur female soccer players. *Frontiers in Physiology*, *9*, 934. https://doi.org/10.3389/fphys.2018.00934

Sinkovic, F., Novak, D., Foretic, N., Kim, J., & Subramanian, S. V. (2023). The plyometric treatment effects on change of direction speed and reactive agility in young tennis players: a randomized controlled trial. *Frontiers in Physiology*, *14*, 1226831. https://doi.org/10.3389/fphys.2023.1226831

Trapletti, M., Formenti, D., Moran, J., Merati, G., Esposito, F., & Trecroci, A. (2025). Essential role of weekly high-frequency plyometric training to enhance physical performance and manage muscle soreness in male adolescent soccer players. *International Journal of Sports Physiology and Performance*, *20*(11), 1580–1589. https://doi.org/10.1123/ijspp.2025-0006

Trecroci, A., Bongiovanni, T., Cavaggioni, L., Pasta, G., Formenti, D., & Alberti, G. (2020). Agreement between dribble and change of direction deficits to assess directional asymmetry in young elite football players. *Symmetry*, *12*(5), 787. https://doi.org/10.3390/sym12050787

Trecroci, A., Mantegazza, S., & Formenti, D. (2024). Exploring the relationship and agreement of asymmetry between lateral jump and change of direction in young tennis players. *International Journal of Performance Analysis in Sport*, *25*(4), 675–686. https://doi.org/10.1080/24748668.2024.2437598

Trecroci, A., Rossi, A., Dos'Santos, T., Formenti, D., Cavaggioni, L., Longo, S., Iaia, F. M., & Alberti, G. (2020). Change of direction asymmetry across different age categories in youth soccer. *PeerJ*, *8*, e9486. https://doi.org/10.7717/peerj.9486

Wasserman, S., Hedges, L. V., & Olkin, I. (1988). Statistical methods for meta-analysis. *Journal of Educational Statistics*, *13*(1), 75. https://doi.org/10.2307/1164953

Watkins, C. M., Gill, N. D., Maunder, E., Downes, P., Young, J. D., McGuigan, M. R., & Storey, A. G. (2021). The effect of low-volume preseason plyometric training on force-velocity profiles in semiprofessional rugby union players. *Journal of Strength and Conditioning Research*, *35*(3), 604–615. https://doi.org/10.1519/JSC.0000000000003917

Yanci, J., Castillo, D., Iturricastillo, A., Ayarra, R., & Nakamura, F. Y. (2017). Effects of Two Different Volume-Equated Weekly Distributed Short-Term Plyometric Training Programs on Futsal Players' Physical Performance. *Journal of Strength and Conditioning Research*, *31*(7), 1787–1794. https://doi.org/10.1519/JSC.0000000000001644

Guidelines for Authors

Revised Maj 2021

*** Please use the bookmark function to navigate within the guidelines. ***

When preparing the final version of the manuscripts, either NEW or REVISED authors should strictly follow the guidelines. Manuscripts departing substantially from the guidelines will be returned to the authors for revision or, rejected.

1. UNIFORM REQUIREMENTS

1.1. Overview

The *Montenegrin Journal of Sports Science and Medicine* (MJSSM) applies the Creative Commons Attribution (CC BY) license to articles and other works it publishes.

There is no charge for submissions and no page charge for accepted manuscripts. However, if the manuscript contains graphics in color, note that printing in color is charged.

MJSSM adopts a double-blind approach for peer reviewing in which the reviewer's name is always concealed from the submitting authors as well as the author(s)'s name from the selected reviewers.

MJSSM honors a six-weeks for an initial decision of manuscript submission.

Authors should submit the manuscripts as one Microsoft Word (.doc) file.

Manuscripts must be provided either in standard UK or US English. English standard should be consistent throughout the manuscripts.

Format the manuscript in A4 paper size; margins are 1 inch or 2.5 cm all around. Type the whole manuscript double-spaced, justified alignment.

Use Times New Roman font, size eleven (11) point.

Number (Arabic numerals) the pages consecutively (centering at the bottom of each page), beginning with the title page as page 1 and ending with the Figure legend page.

Include line numbers (continuous) for the convenience of the reviewers.

Apart from chapter headings and sub-headings avoid any kind of formatting in the main text of the manuscripts.

1.2. Type & Length

MJSSM publishes following types of papers:

Original scientific papers are the results of empirically- or theoretically-based scientific research, which employ scientific methods, and which report experimental or observational aspects of sports science and medicine, such as all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side. Descriptive analyses or data inferences should include rigorous methodological structure as well as sound theory. Your manuscript should include the following sections: Introduction, Methods, Results, and Discussion.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Original scientific papers should be:
- Up to 3000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 30;
- Maximum combined total of 6 Tables/Figures.

Review papers should provide concise in-depth reviews of both established and new areas, based on a critical examination of the literature, analyzing the various approaches to a specific topic in all aspects of sports science and medicine, such as all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

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Editorials are written or commissioned by the editors, but suggestions for possible topics and authors are welcome. It could be peer reviewed by two reviewers who may be external or by the Editorial Board.

☐Open Submissions ☑Indexed ☑Peer Reviewed

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- Up to 1000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 10.

Short reports of experimental work, new methods, or a preliminary report can be accepted as two page papers. Your manuscript should include the following sections: Introduction, Methods, Results, and Discussion.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Short reports should be:
- Up to 1500 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
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Peer review - fair review provides authors who feel their paper has been unfairly rejected (at any journal) the opportunity to share reviewer comments, explain their concerns, and have their paper reviewed for possible publication in MJSSM.

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Invited papers and award papers include invited papers from authors with outstanding scientific credentials. Nomination of invited authors is at the discretion of the MJSSM editorial board. MJSSM also publishes award papers selected by the scientific committee of the MSA annual conference.

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- A structured abstract of less than 250 words;
- Maximum number of references is 30;
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- Restricted to 250 words (including title, authors and institutions) and must include the following separate sections: [1] purpose; [2] methods; [3] results; [4] conclusion;
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Transfer of Learning on a Spatial Memory Task between the Blind and Sighted People Spatial Memory among Blind and Sighted

Original Scientific Paper

Transfer of learning on a spatial memory task

Selcuk Akpinar[1], Stevo Popović[1,2], Sadettin Kirazci[1]

[1]Middle East Technical University, Physical Education and Sports Department, Ankara, Turkey
[2]University of Montenegro, Faculty for Sport and Physical Education, Niksic, Montenegro

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S. Popovic
University of Montenegro
Faculty for Sport and Physical Education
Narodne omladine bb, 84000 Niksic, Montenegro
E-mail: stevop@ac.me

Word count: 2,980

Abstract word count: 236

Number of Tables: 3

Number of Figures: 3

2.1.1. Title

Title should be short and informative and the recommended length is no more than 20 words. The title should be in Title Case, written in uppercase and lowercase letters (initial uppercase for all words except articles, conjunctions, short prepositions no longer than four letters etc.) so that first letters of the words in the title are capitalized. Exceptions are words like: “and”, “or”, “between” etc. The word following a colon (:) or a hyphen (-) in the title is always capitalized.

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The form of an author’s name is first name, middle initial(s), and last name. In one line list all authors with full names separated by a comma (and space). Avoid any abbreviations of academic or professional titles. If authors belong to different institutions, following a family name of the author there should be a number in superscript designating affiliation.

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Affiliation consists of the name of an institution, department, city, country/territory(in this order) to which the author(s) belong and to which the presented / submitted work should be attributed. List all affiliations (each in a separate line) in the order corresponding to the list of authors. Affiliations must be written in English, so carefully check the official English translation of the names of institutions and departments.

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If an author belongs to more than one institution, all corresponding superscript digits, separated with a comma with no space in between, should be present behind the family name of this author.

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Whenever possible expand your authors' affiliations with departments, or some other, specific and lower levels of organization.

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Corresponding author's name with full postal address in English and e-mail address should appear, after the affiliations. It is preferred that submitted address is institutional and not private. Corresponding author's name should include only initials of the first and middle names separated by a full stop (and a space) and the last name. Postal address should be written in the following line in sentence case. Parts of the address should be separated by a comma instead of a line break. E-mail (if possible) should be placed in the line following the postal address. Author should clearly state whether or not the e- mail should be published.

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All authors are required to provide word count (excluding title page, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References), the Abstract word count, the number of Tables, and the number of Figures.

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The second page of the manuscripts should be the abstract and key words. It should be placed on second page of the manuscripts after the standard title written in upper and lower case letters, bold.

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Abstract

Results of the analysis of…
Key words: spatial memory, blind, transfer of learning, feedback

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- ✓ **Methods**

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- ✓ *Table position of the research football team*

2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

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All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

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References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

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MJSSM adheres to the American Psychological Association 7th Edition reference style. Check the Publication Manual of the American Psychological Association (2019), Seventh Edition that is the official source for APA Style, to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

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One work by one author

- ✓ In one study (Reilly, 1997), soccer players…
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- ✓ In 1997, Reilly's study of soccer players…

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- ✓ In one study (Duffield & Marino, 2007), soccer players…
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- ✓ Bangsbo et al. (2008) stated that…
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- ✓ According to the American Psychological Association (2000)…
- ✓ In the APA Manual (American Psychological Association, 2003), it is explained…

Two or more works in the same parenthetical citation: citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically); separated by a semi-colon

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that…

2.4.3. Examples for Reference list

Works by one author

Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Works by two authors

Duffield, R., & Marino, F. E. (2007). *Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. European Journal of Applied Physiology, 100*(6), 727–735. https://doi.org/10.1007/s00421-007-0468-x

Works by three to twenty authors

Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57–65. https://doi.org/10.26773/mjssm.2017.09.008

Works by more than twenty authors

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A.,… Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine & Science in Sports & Exercise, 35*(4), 697–705. https://doi.org/10.1249/01.mss.0000058441.94520.32

Works by group of authors

NCD-RisC. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet*, 390(10113), 2627-2642. https://doi.org/10.1016/s0140-6736(17)32129-3

Works by unknown authors

Merriam-Webster's collegiate dictionary (11th ed.). (2003). Merriam-Webster.

Journal article (print)

Scruton, R. (1996). The eclipse of listening. *The New Criterion, 15*(3), 5–13.

Journal article (electronic)

Aarnivala, H., Pokka, T., Soininen, R., Mottonen, M., Harila-Saari, A., & Niinimaki, R. (2020). Trends in age- and sex-adjusted body mass index and the prevalence of malnutrition in children with cancer over 42 months after diagnosis: a single-center cohort study. *European Journal of Pediatrics,* 179(1), 91-98. https://doi.org/10.1007/s00431-019-03482-w

Thesis and dissertation

Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport*. [Unpublished Doctoral Dissertation]. The Florida State University.

Book

Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Chapter of a book

Armstrong, D. (2019). Malory and character. In M. G. Leitch & C. J. Rushton (Eds.), *A new companion to Malory* (pp. 144-163). D. S. Brewer.

Reference to a Facebook profile

Little River Canyon National Preserve (n.d.). *Home* [Facebook page]. Facebook. Retrieved January 12, 2020 from https://www.facebook.com/lirinps/

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Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

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2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

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Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word Note (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. $^{a, b, c}$), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript ^{a}.

- ✓ ^{a}One participant was diagnosed with heat illness and n = 19.^{b}n =20.

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- ✓ *P<0.05,†p<0.01.

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- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
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2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. MJSSM prefers TIFF, EPS and PNG formats.

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Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of MJSSM.

2.6.1. Figure legends

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

2.6.2. Figure citation

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
- × figure 1
- × Figure 1.
- ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
- ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
- ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
- ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

2.6.3. Sub-figures

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

Signs should be placed immediately preceding the relevant number.		
✓ 45±3.4	✓ p<0.01	✓ males >30 years of age
× 45 ± 3.4	× p < 0.01	× males > 30 years of age

2.8. Latin Names

Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

- ✓ First time appearing: *musculus biceps brachii*
- ✓ Abbreviated: *m. biceps brachii*

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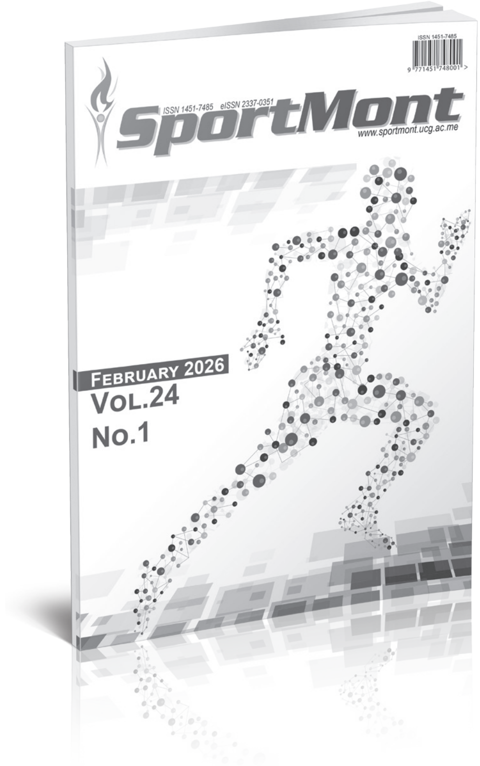

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Sport Mont Journal (SMJ) is a print (ISSN 1451-7485) and electronic scientific journal (eISSN 2337-0351) aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimize the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. Hence, it provides:

- Open-access and freely accessible online;
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- Peer review by expert, practicing researchers;
- Post-publication tools to indicate quality and impact;
- Community-based dialogue on articles;
- Worldwide media coverage.

SMJ is published three times a year, in February, June and October of each year. SMJ publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

SMJ covers all aspects of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

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MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

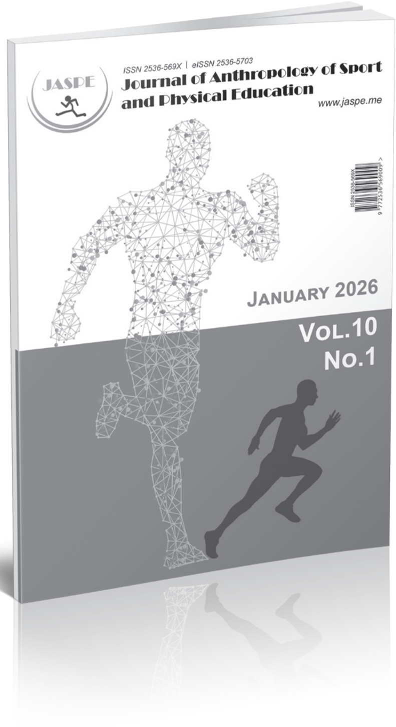
It is our great pleasure to announce the upcoming 24th Annual Scientific Conference of Montenegrin Sports Academy “Sport, Physical Activity and Health: Contemporary Perspectives” to be held in Budva, Montenegro, from 16 to 19 April, 2026. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).

MSA Conference 2026

The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.

Journal of Anthropology of Sport and Physical Education



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Journal of Anthropology of Sport and Physical Education (JASPE) is a print (ISSN 2536-569X) and electronic scientific journal (eISSN 2536-5703) aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimize the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. Hence, it provides:

- Open-access and freely accessible online;
- Fast publication time;
- Peer review by expert, practicing researchers;
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- Community-based dialogue on articles;
- Worldwide media coverage.

JASPE is published four times a year, in January, April, July and October of each year. JASPE publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Anthropology of Sport and Physical Education, as well as it can function as an open discussion forum on significant issues of current interest.

JASPE covers all aspects of anthropology of sport and physical education from five major fields of anthropology: cultural, global, biological, linguistic and medical.

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Fidanka VASILEVA, *Editor-in Chief – vasileva.jaspe@gmail.com*

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