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ORIGINAL SCIENTIFIC PAPER

Relationship Between Agility and Speed With Explosive Power of Lower Limbs in Youth Football Players: Field and Laboratory-Based Assessment

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Abstract

The main objective of this study was to investigate the relationship between agility and speed and the explosive power of the lower limbs in youth football players. A total of 45 male athletes (ages 12–14) participated in this study. Anthropometric measurements (body height, body weight, and waist circumference) were recorded, and participants completed a series of motor performance tests. These included field-based assessments such as the agility 10x5m test, the agility T-test, sprint tests (10m and 20m), and the standing long jump. Laboratory-based assessments included the Leonardo Mechanography platform for measuring maximal force during a two-legged jump (S2LJ), and isometric strength tests using a dynamometric chair to determine maximal torque in both lower limbs. Descriptive statistics and Pearson correlation analyses were used to examine the associations between agility and speed with explosive lower limb power. Results indicated significant correlations between agility tests and all explosive power measures, particularly between the agility T-test and both isometric torque and S2LJ force. Similarly, sprint performance (10m and 20m) showed strong inverse correlations with the standing long jump, S2LJ, and isometric torque, suggesting that greater explosive strength is associated with faster sprint times. These findings highlight the importance of developing lower limb explosive power in youth football training, as it contributes to improved agility and sprinting ability.

Keywords: *youth football, agility, speed, explosive power, standing long jump*

Introduction

The development of speed, agility, and explosive power of the lower limbs represents a cornerstone in the performance profile of youth football players. These physical capacities are critical for match-related actions—such as sprinting, rapid changes of direction (COD), and jumping—and serve as key indicators of overall athletic potential and injury prevention strategies (França et al., 2022; Malý et al., 2014; Leão et al. 2022). In youth football, where intermittent and high-intensity efforts dominate gameplay, optimizing lower limb power is emphasized to enhance performance outcomes (Malý et al., 2014).

A substantial body of literature has linked vertical jumping ability with both speed and agility, reinforcing the idea that lower-body explosive strength is associated with reduced sprint and COD times. França et al. (2022) identified that superior performance in vertical jump tests corresponded with enhanced sprint and agility performances in adolescent football players. Similarly, two other studies (Križaj, 2020; Gísladóttir et al., 2024) reported moderate to strong correlations between countermovement jump performance and sprint speed, underscoring the predictive value of vertical jump metrics for assessing explosive power. Salles et al., (2012) emphasized this relationship by demonstrating that vertical jump tests are valid and reproducible measures of explosive lower limb strength, which is instrumental in executing short sprints and directional changes.

Age and maturation are influential factors in the evolution of these performance metrics, as illustrated by the work of

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Spencer et al. (2011), who documented significant improvements in repeated-sprint ability from under-11 to under-15 age groups, followed by a plateau in older adolescents. Such findings are consistent with studies examining the effects of targeted training interventions. Ateş (2018) found that prepubescent soccer players engaged in sport-specific training exhibited superior performances in speed, agility, and lower limb power compared to their less active peers. Similarly, Makhlouf et al., (2018) revealed that training focused on agility combined with plyometric exercises provides benefits comparable to those achieved with balance training, highlighting the adaptability of the neuromuscular system during growth. Additionally, Zhang et al., (2023) demonstrated that strength training can significantly enhance the explosive power of the lower limbs, improving the execution of dynamic football actions.

Body composition and anthropometric characteristics further contribute to the performance outcomes of youth football players (Muca. 2022). Zanini et al. (2020) explored the relationship between body composition and physical abilities, finding associations between reduced body fat and enhanced agility and explosive power. Leão et al. (2022) asserted that soccer's intermittent nature necessitates a high proportion of lean mass to support explosive movements, although factors such as body mass index have not been consistently linked to performance gains (Esco et al., 2018). These insights suggest that while morphological characteristics provide a foundational basis, neuromuscular adaptations acquired through specialized training are critical to developing speed and agility.

Research has also explored the role of laterality and positional differences in shaping these physical attributes. Lipecki (2019) reported no significant differences in lower limb explosive strength between right and left-footed players across various youth age groups, indicating that footedness may not be a determinant factor in physical performance. Conversely, Kounga (2023) highlighted that playing position correlates with specific physical fitness requirements, implying that individualized training approaches may be necessary to optimize speed, agility, and explosive power according to positional demands. Such findings are corroborated by Gaurav et al. (2015), who noted that performance metrics in football necessitate distinct physical adaptations.

In summary, the literature converges on the view that lower limb explosive power, as evidenced by vertical jump performance, is critical for executing rapid sprints and agile maneuvers in youth football players. The interplay of neuromuscular strength, morphological attributes, and targeted training regimens—including plyometric, strength, and agility-focused exercises—collectively enhance on-field performance (França et al., 2022; Križaj, 2020; Gísladóttir et al., 2024; Salles et al., 2012; Makhlouf et al., 2018). These findings underscore the necessity for coaches and practitioners to implement training programs that consider the maturation and anthropometric profiles of athletes while focusing intensively on improving neuromuscular power and coordination. Such an integrative approach is essential for maximizing the athletic potential of youth football players and ensuring their progression to elite levels of performance. The main objective of this study was to investigate the relationship between agility and speed to lower limb explosive power in youth football players, using both field-based (Standing Long Jump) and laboratory-based (Leonardo S2LJ and Isometric Torque) tests.

Methods

In this study, a total of 45 youth football players aged 10–12 years (U13 age group) participated in a comprehensive assessment protocol aimed at evaluating their anthropometric characteristics and motor performance. The anthropometric measurements included body weight, height, and waist circumference, recorded using standardized procedures to ensure reliability and accuracy. The motor performance assessment was composed of a battery of field (speed, agility and explosive power of lower limbs) and laboratory-based tests (strength and power of lower limbs) designed to measure fundamental components of physical fitness relevant to youth football. These included tests of lower-body explosive power, linear sprinting speed over short distances (10 m and 20 m), and agility through multidirectional movement tasks. In addition, isometric muscular strength and dynamic lower-limb power were assessed under controlled laboratory conditions using specialized medical-grade equipment: the Easytech isokinetic dynamometer and the Leonardo mechanography platform, respectively. All tests were conducted following standardized protocols with appropriate warm-up periods and rest intervals to ensure safety and optimal performance.

Protocols of the test

Standing Long Jump test

The athlete stands behind a line marked on the ground with his feet slightly apart. A two-legged take-off and landing is used, with swinging of the arms and bending of the knees to provide forward motion. The athlete attempts to jump as high as possible, landing on both feet without falling backwards. Three repetitions are allowed.

The measurement is taken from the take-off line to the nearest point of contact on landing (back of the heels). The longest distance jumped is recorded, the best of three attempts.

Sprint test 10m and 20m

To perform the test, you must perform a maximum sprint over a certain distance and record the time you complete it. The test is performed at different distances, such as 10, 20, meters, depending on what is required to be measured.

The starting position is achieved by standing still behind the starting line. If you have equipment such as timing gates, you can measure the time to run separate distances (e.g., 5, 10, 15, 20 m) during the same run, and it is also possible to determine the maximum speed. Normally, a good warm-up of the body and continuous motivation for it to complete the test are required.

Agility T test

The preparations that must be made before testing are: Preparing the terrain and the test by placing the points according to the distances of 10m, 5m, 5m in the shape of the letter T. For example, point A is placed at a height of 10 meters from point B while points C and D are placed 5 meters away from point B, in this shape the letter T is also achieved. Normally, a good preparatory phase before executing the test is very necessary. Three to five minutes after warming up, the test is started.

Agility 10x5m test

Cones and/or marking lines are placed five meters apart. The start is with one foot on one marker. When instructed by the timer, the athlete runs to the opposite marker, turns, and returns to the starting line. This is repeated five times without stopping (covering a total of 50 meters). At each marker, both feet must completely cross the line.

Isometric force (Isokinetic Dynamometer Device) in the UST laboratory

The "Easytech" Force Measurement Chair is a First Class medical device. Through a hermetic mechanism and computer programs, it serves for testing isometric force.

Force and power of lower limbs (Leonardo platform) in the UST laboratory

The "Leonardo Mechanography" electronic platform is part of the group of medical devices. It consists of two platforms with 4 (four) sensors each. Its software contains a protocol with 17 different tests, from which numerous data are obtained. The test used is S2LJ (Single Two Leg Jump): A two-legged jump - with momentum / Jump for Maximum Height.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics (version 22.0). Descriptive statistics (mean, standard deviation, minimum, and maximum values) were calculated for all measured variables, including anthropometric characteristics (body height, body weight, waist circumference), field-based motor tests (agility 10x5m, agility T-test, sprint 10m and 20m, and standing long jump), and laboratory-based measures (Leonardo Mechanography S2LJ and isometric torque for both limbs). To assess the relationships between agility and speed performances with lower limb explosive power, Pearson correlation coefficients were calculated. Separate analyses were performed to examine the associations of field-based performance metrics (e.g., sprint and agility tests) with both the standing long jump (as a field measure of explosive power) and laboratory-based tests (S2LJ and isometric torque). Significance levels were set at $p < 0.05$ and $p < 0.01$. Assumptions of normality and linearity were visually assessed through Q-Q plots and scatterplots before conducting the correlation analysis. Only complete cases were included in the final analysis, and sample sizes varied slightly across tests depending on the availability of laboratory data.

Results

Table 1. Descriptive stastistics for anthopometrics

	N	Minimum	Maximum	Mean	Std. Deviation
Body Height	45	1.33	1.84	1.5945	.11052
Body Weight	45	30.0	92.0	51.395	12.6254
Waist	45	63.0	99.0	74.956	9.3419
Valid N (listwise)	45				

Table 1 presents the descriptive statistics for the anthropometric characteristics of the 45 youth football players included in the study. The average body height was 1.59 meters (SD = 0.11), with values ranging from 1.33 m to 1.84 m, indicating a relatively wide range in stature within this age group. The mean body weight was 51.40 kg (SD = 12.63), with a minimum of 30.0 kg and a maximum of 92.0 kg, reflecting notable variability likely influenced by differences in biological maturation and physical development. Waist circumference had a mean value of 74.96 cm (SD = 9.34), with a minimum of 63.0 cm and a maximum of 99.0 cm.

Table 2. Descriptive statistics for speed and agility

	N	Minimum	Maximum	Mean	Std. Deviation
Agility 10x5m	45	17.7	25.1	20.495	1.6748
Agility T test	45	10.7	16.8	13.038	1.5186
Sprint 10m	45	1.2	1.9	1.512	.1618
Sprint 20m	45	3.0	4.2	3.482	.2767
Valid N (listwise)	45				

Table 2 displays the descriptive statistics for selected motor performance tests assessing speed and agility among the 45 youth football players. The results from the 10x5m agility test show an average completion time of 20.50 seconds (SD = 1.67), with values ranging from 17.7 to 25.1 seconds, indicating variation in repeated change-of-direction ability among participants. In the T-test of agility, which measures multidirectional movement efficiency, the average performance was 13.04 seconds (SD = 1.52), with a minimum of 10.7 seconds and a maximum of 16.8 seconds. Sprint performance over 10

Table 3. Descriptive statistics for strength and power

	N	Minimum	Maximum	Mean	Std. Deviation
Standing Long Jump	45	116.8	213.4	168.269	23.0003
S2LJ: Force max- kn	45	.7	1.8	1.187	.2822
Isometric- max Torque right	45	45.0	170.0	92.739	32.1971
Isometric- max Torque left	45	41.0	177.0	84.826	33.0862
Valid N (listwise)	45				

Note: S2LJ (Single Two Leg Jump)

meters had a mean time of 1.51 seconds (SD = 0.16), while the 20-meter sprint had a mean of 3.48 seconds (SD = 0.28), suggesting a progressive increase in speed over distance.

Table 3 provides descriptive data on explosive strength and isometric force performance for the sample of 45 youth football players. In the standing long jump test, which reflects lower-body explosive power, participants achieved an average distance of 168.27 cm (SD = 23.00), with a range from 116.8 to 213.4 cm, demonstrating a wide spread in performance levels. The maximum force output recorded during the Single Two Leg Jump (S2LJ) on the Leonardo mechanography platform averaged 1.19 kN (SD = 0.28), ranging from 0.7 to 1.8 kN, indicating varying degrees of neuromuscular efficiency. For isometric strength measured with the dynamometer, maximum torque values showed greater force in the right leg (M = 92.74 Nm, SD = 32.20) compared to the left leg (M = 84.83 Nm, SD = 33.09), though both limbs displayed high variability.

Table 4. Correlations between agility and explosive power of lower limbs for field and laboratory tests

		Standing Long Jump	S2LJ: Force max- kn	Isometric- max Torque right	Isometric- max Torque left
Agility 10x5m	Pearson Correlation	-.419**	-.374*	-0.319	-0.256
	Sig. (2-tailed)	0.001	0.025	0.138	0.238
	N	60	36	23	23
Agility T test	Pearson Correlation	-.647**	-.476**	-.722**	-.749**
	Sig. (2-tailed)	0.000	0.004	0.000	0.000
	N	60	35	23	23

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Table 4 presents the correlation coefficients between agility performance and measures of lower limb explosive and isometric strength. Significant negative correlations were observed between the Agility 10x5m test and both the Standing Long Jump (r = –.419, p = .001) and S2LJ Force Max (r = –.374, p = .025), suggesting that higher explosive power is associated with better (i.e., faster) agility performance. Although non-significant, negative trends were also found between 10x5m agility and isometric torque in both the right and left legs. The Agility T-test demonstrated even stronger and statistically significant negative correlations with all power and strength measures, including the Standing Long Jump (r = –.647, p < .001), S2LJ (r = –.476, p = .004), and isometric torque for both the right (r = –.722, p < .001) and left leg (r = –.749, p < .001).

Table 5. Correlations between speed and explosive power of lower limbs for field and laboratory tests

		Standing Long Jump	Leonardo CMJ: Force max- kn	Isometric- max Torque right	Isometric- max Torque left
Sprint 10m	Pearson Correlation	-.734**	-.430*	-.699**	-.789**
	Sig. (2-tailed)	0.000	0.020	0.000	0.000
	N	48	29	23	23
Sprint20m	Pearson Correlation	-.700**	-.436**	-.468*	-.534**
	Sig. (2-tailed)	0.000	0.008	0.024	0.009
	N	61	36	23	23

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Table 5 illustrates the correlations between sprint performance (10 m and 20 m) and lower limb explosive power and strength, assessed through both field and laboratory tests. Both sprint tests showed strong and statistically significant negative correlations with the Standing Long Jump (10 m: r = –.734, p < .001; 20 m: r = –.700, p < .001), indicating that better jump performance is associated with faster sprint times. Similarly, significant negative correlations were observed between sprint times and Leonardo CMJ Force Max, particularly for the 20 m sprint (r = –.436, p = .008), suggesting that greater lower limb force output enhances sprint ability. Notably, isometric torque values for both the right and left legs were significantly and negatively correlated with both sprint distances, with the strongest relationship observed between the 10 m sprint and left leg torque (r = –.789, p < .001).

Discussion

The main objective of this study was to investigate the relationship between agility and speed to lower limb explosive power in youth football players, using both field-based (standing long jump) and laboratory-based (leonardo S2LJ and isometric torque) tests. The results indicate that agility performance, particularly in the T-test, showed significant moderate to strong negative correlations with all measures of explosive power, including the Standing Long Jump (r = –.647, p < .001), Leonardo S2LJ Force max (r = –.476, p = .004), and Isometric Torque of both right (r = –.722, p < .001) and left leg (r = –.749, p < .001) **. These findings suggest that athletes with higher levels of explosive power and force production tend to perform better in agility tasks, especially those requiring rapid changes of direction and acceleration. Similarly, the analysis of speed performance in relation to lower limb power, revealed strong and statistically significant negative correlations across all tests. Both 10 m and 20 m sprint times were significantly associated with Standing Long Jump performance (10 m: r = –.734; 20 m: r = –.700, both p < .001), confirming the importance of horizontal jump ability in sprint acceleration. Additionally, sprint speed correlated with Leonardo CMJ Force max and

Isometric Torque for both legs, with the highest correlation found between the 10 m sprint and isometric torque of the left leg (r = –.789, p < .001). These results emphasize the strong connection between lower limb explosive strength—assessed in both dynamic and static laboratory conditions—and sprinting speed over short distances, highlighting the relevance of targeted strength and power training in youth football development. The literature consistently demonstrates a significant relationship between lower limb explosive power and key performance indicators such as speed and agility in youth football players. Several studies have identified that measures of explosive power—whether assessed through dynamic, field-based tests like the Standing Long Jump or through controlled laboratory evaluations such as isometric torque assessments—are strongly correlated with superior performance in sprinting and change-of-direction tasks (França et al., 2022; McKinlay et al., 2017). This relationship is evidenced by the observed negative correlations; as players exhibit greater explosive force production, they typically display reduced sprint times and improved agility performance, which reinforces the critical role of lower limb power in athletic success (França et al., 2022; Rajesh & KV, 2021). Field-based assessments, particularly the Standing Long Jump, have been widely acknowledged as robust and cost-effective indicators of lower limb power. Such tests have been instrumental in youth athletic screening and have established normative reference values across populations (Aandstad, 2021; Marques et al., 2021). When complemented with laboratory-based protocols, the reliability of power assessment is further enhanced by capturing more isolated neuromuscular contributions through devices such as the Leonardo S2LJ and isometric torque measurement apparatus (Palmer et al., 2020). This multi-modal assessment approach not only increases the validity of the measurements but also provides a comprehensive profile of an athlete's neuromuscular capabilities, which is essential for tailoring training interventions (Aandstad, 2021). The importance of lower limb power development is underscored by training studies that highlight the efficacy of targeted strength and power training interventions. For instance, research on speed-based training specifically designed for football players has demonstrated that improvements in lower limb strength translate into enhanced sprint and agility outcomes (Rajesh & KV, 2021; Additionally, interventions that incorporate both dynamic core exercises and agility drills have shown significant benefits in improving overall athletic performance, including faster sprint times and more responsive directional changes Başkaya et al., 2023; Padrón-Cabo et al., 2020). These findings collectively suggest that integrating exercises aimed at boosting explosive power into football development programs could provide a critical competitive advantage, particularly in youth athletes whose training and maturation stages favor rapid neuromuscular adaptations (Rajesh & KV, 2021; Başkaya et al., 2023). The current literature review synthesizes these findings by confirming that both field-based and laboratory-based assessments converge in their ability to predict speed and agility performance among youth football players. This dual-methodological approach not only validates the importance of lower limb power in elite sport but also offers practical insights for the development of targeted training regimens. The empirical evidence supports the conclusion that enhancing lower limb explosive power is a strategic priority for coaches and trainers aiming to optimize the overall athletic performance of young football players (França et al., 2022; McKinlay et al., 2017). As such, future training programs should emphasize strength and power development, utilizing both dynamic and isometric testing to monitor progress and guide individualized interventions (Aandstad, 2021; Padrón-Cabo et al., 2020). One limitation of this study is the relatively small and homogeneous sample, composed solely of 45 youth male football players from a similar age group and training background. This limits the generalizability of the findings to broader populations, such as female athletes, players from other age groups, or those engaged in different levels of competition. Additionally, the cross-sectional nature of the study prevents establishing causality between variables. While correlations suggest associations, they do not confirm that improvements in explosive power directly cause improvements in speed or agility. Furthermore, performance in field-based and laboratory-based tests can be influenced by factors such as motivation, fatigue, and familiarity with testing procedures, which were not controlled for in this study.

Conclusion

Future research should consider a longitudinal design to explore how changes in explosive power over time may influence agility and sprint performance. Expanding the sample to include athletes of different sexes, age groups, and training levels would provide more comprehensive insight into the generalizability of the results. Additionally, incorporating biomechanical and neuromuscular assessments could help explain the underlying mechanisms linking lower limb explosive power to agility and speed. Exploring the effects of specific training interventions targeting explosive strength on agility and speed outcomes in youth athletes would also be a valuable direction for applied sports science and coaching practice.

The findings of this study support the main objective, which was to investigate the relationship between agility and speed in relation to lower limb explosive power among youth football players, using both field-based (Standing Long Jump) and laboratory-based (Leonardo S2LJ and Isometric Torque) assessments. The significant negative correlations observed indicate that players with higher levels of explosive power tend to perform better in both agility and sprint tasks. These results underscore the importance of lower limb power development—whether measured through dynamic field-based tests or controlled laboratory protocols—as a key component in enhancing speed and agility in young athletes. Incorporating targeted strength and power training into football development programs may therefore be crucial for improving overall athletic performance.

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ORIGINAL SCIENTIFIC PAPER

Age-Related Differences in Anthropometric and Motor Skill Development Among Youth Football Players: Implications for Tailored Training Programs

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Abstract

This study aimed to evaluate the anthropometric characteristics and motor skill performance of youth football players in Tirana, Albania, across three age groups: (U9, U11, and U13). A total of 68 participants were assessed for body weight, body height, BMI, waist circumference, and four motor skills: flexibility (sit-and-reach), agility (10x5 meter test), lower-body power (standing long jump), and speed (20-meter sprint). The results revealed significant age-related differences in body weight, body height, and waist circumference, with U9 players being significantly smaller and lighter compared to U11 and U13 players. Performance in motor skills also improved with age, particularly in agility, standing long jump and sprint time, with U13 players demonstrating superior performance. Statistical analysis revealed significant differences in body weight ($p = .000$), body height ($p = .000$), and sprint performance ($p = .000$), but no significant differences in BMI ($p = .293$) sit-and-reach flexibility ($p = .071$). The findings suggest that motor skill development and anthropometric changes are strongly influenced by age, highlighting the need for age-appropriate training programs. Coaches should tailor training sessions to match the physical and motor developmental stages of each age group to optimize performance and minimize injury risk.

***Keywords:** anthropometry, motor skills, agility, flexibility, strength, speed*

Introduction

The development of anthropometric characteristics and motor skills in children participating in football is crucial for understanding their athletic potential and guiding training practices tailored to specific age groups. The literature reveals significant variations in both anthropometric measures and motor competencies as children progress through their formative years, highlighting the role of age in physical development and sports performance. Anthropometric characteristics such as height, weight, and body composition have been examined across various studies, demonstrating a relationship with performance in football. For instance, taller players often have advantages in areas that require overhead abilities such as headers and aerial duels, while optimal weight and body fat composition can influence speed and agility on the field (Doyle et al., 2020; Ramos et al., 2021; Zeleznik et al. (2023). Notably, Ramos et al. (2021) emphasize that comparative analyses of physical fitness and anthropometric profiles across age groups—including U15 and senior categories—indicate that systematic differences begin to emerge correlated with the stage of physical maturity. Similarly, Faude et al., (2010) highlight improvements in motor skills and overall exercise capacity among children, attributing these benefits to the positive influence of regular football participation, particularly for those who might be overweight (Hansen et al., 2013). Motor skills, including coordination, agility, and speed, exhibit developmental trajectories influenced by age. For example, motor skills training is posited to be especially critical during junior years, as this phase coincides with sensitive periods for skill acquisition and refinement (Tatarcan, 2021; Anđelić et al., 2021). In a study conducted by Pratama et al., (2020) it is noted that children's basic skills in football improve significantly

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alongside their motor abilities; thus, interventions focusing on motor skills can yield better technical capabilities. Furthermore, Ghosh et al., (2023) reinforce this notion, indicating that enhancements in physical fitness directly correlate with rigorous training regimens over time, allowing young players to develop necessary skills progressively through structured practice sessions. Moreover, specific training methods such as small-sided games have been shown to improve not only motor skills but also overall game intelligence and adaptability (Pratama et al., 2020). The evidence suggests that integrating age-appropriate drills that focus on both technical and non-technical aspects can yield substantial improvements in children's football skills, facilitating a smoother transition from youth to competitive levels. Comparative studies among age groups reveal substantial differences in physical capacities. Zeleznik et al., (2023) highlight that morphological characteristics such as lean body mass and height variation play a vital role in dictating performance metrics as players mature from U13 to U19. As children transition through these stages, physiological growth often impacts their approach to training and competition, necessitating a careful analysis of individual and group characteristics to tailor training effectively (Gontarev et al., 2016). This study aimed to evaluate the anthropometric characteristics and motor skill performance of youth football players in Tirana, Albania, across three age groups: (U9, U11, and U13).

Methods

Participants

The study sample consisted of 68 youth football players from various football clubs in Tirana, Albania. Participants were divided into three age groups: Under 9 (U9, n = 19), Under 11 (U11, n = 28), and Under 13 (U13, n = 21). All participants were active football players who regularly participated in training sessions and competitions. Ethical approval for this study was obtained from the institutional review board, and informed consent was gathered from the players' parents or guardians prior to participation.

Anthropometric Measurements

Anthropometric data were collected to assess the physical characteristics of the participants, including body weight, body height, body mass index (BMI), and waist circumference. These measurements were taken using standardized procedures: body weight was measured using a digital scale (±0.1 kg), body height was measured using a stadiometer (±0.1 cm), BMI was calculated using the usual formula and waist circumference was measured at the level of the iliac crest using a flexible tape measure (±0.1 cm).

Motor Skill Assessments

Four motor skills were assessed to evaluate the physical performance of participants: sit-and-Reach Test (Flexibility): The sit-and-reach test was used to measure flexibility. Participants sat on the floor with their legs extended and reached forward to touch their toes or beyond. 10x5 Meter Agility Test (Agility): This test involved running back and forth over a 5-meter distance, completing a total of 10 laps. Time taken to complete the test was recorded. Standing Long Jump (Lower-Body Power): Participants were asked to jump as far as possible from a standing position. The longest distance achieved was recorded. 20-Meter Sprint (Speed): Participants were asked to sprint 20 meters as quickly as possible. The time taken to complete the sprint was recorded.

All motor skill assessments were performed under the supervision of trained personnel to ensure consistent and accurate results.

Procedure

All participants were assessed on the same day, and the testing was conducted at the football training facilities of their respective clubs. Anthropometric measurements were taken first, followed by the motor skills tests. The participants were given adequate rest between each motor skill test to avoid fatigue.

Statistical Analysis

Descriptive statistics (mean, standard deviation) were calculated for each anthropometric parameter and motor skill variable by age group (U9, U11, U13). One-Way Analysis of Variance (ANOVA) was used to determine whether there were significant differences in the anthropometric parameters (body weight, body height, BMI, waist circumference) and motor skills (sit-and-reach, agility, standing long jump, 20m sprint) across the three age groups. Post-hoc Tukey's HSD (significant difference) test was used to identify which specific age groups differed significantly from each other, where appropriate. The significance level was set at $p < 0.05$ for all statistical tests. All statistical analyses were performed using SPSS Version 20.0.

Results

The descriptive statistics (Table 1) for the total sample of 68 youth football players across the U9, U11, and U13 age groups provide an overall profile of their anthropometric characteristics. The average body weight was 41.17 kg (SD = 12.60), indicating a wide range likely due to the inclusion of three distinct developmental stages. Similarly, the mean height was 1.44 meters (SD = 0.13), again reflecting expected growth differences between younger and older players. The average BMI was 19.47 kg/m² (SD = 3.60), which falls within the normal range for children and adolescents but with some variability suggesting differing body compositions across individuals or age groups. Waist circumference averaged 68.10 cm (SD = 9.90), a result that appears consistent with age-appropriate norms but may also highlight individual variation in fat distribution.

Table 1. Descriptive statistics for anthpometric parameters

	N	Mean	Std. Deviation
Body_Weight	68	41.166	12.6014
Body_Height	68	1.439	.1251
BMI	68	19.466	3.5970
Waist_Circumference	68	68.103	9.8982
Valid N (listwise)	68		

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Table 2. Descriptive statistics for motor skills

	N	Mean	Std. Deviation
Sit_Reach	68	22.015	4.2584
Agility_10x5m	68	21.756	1.6452
Standing_Long_Jump	68	136.000	21.7942
Sprint_20m	68	4.426	.5187
Valid N (listwise)	68		

Table 2 presents the descriptive statistics for the motor skills performance of the 68 youth football players across the U9, U11, and U13 age groups. The sit-and-reach test, which assesses flexibility, had a mean score of 22.02 cm (SD = 4.26), suggesting an overall moderate level of flexibility within the group. Agility, measured by the 10x5 meter shuttle run, showed a mean time of 21.76 seconds (SD = 1.65), indicating relatively good coordination and quick directional change, although the variation suggests differences in neuromuscular development or training experience. The average distance for the standing long jump was 136.00 cm (SD = 21.79), a measure of lower-body explosive power; the wide standard deviation reflects expected developmental disparities among the different age groups. Sprint performance over 20 meters had a mean of 4.43 seconds (SD = 0.52), demonstrating average sprinting speed for children in this age range, again with some variability.

Table 3. Descriptive statistics for anthpometric parameters bu age group

		N	Mean	Std. Deviation
Body_Weight	U9	19	33.589	8.0185
	U11	28	39.411	10.7650
	U13	21	50.362	13.0388
	Total	68	41.166	12.6014
Body_Height	U9	19	1.332	.0821
	U11	28	1.423	.0749
	U13	21	1.557	.1132
	Total	68	1.439	.1251
BMI	U9	19	18.784	3.5247
	U11	28	19.179	3.7106
	U13	21	20.467	3.4592
	Total	68	19.466	3.5970
Waist_Circumference	U9	19	64.632	7.8117
	U11	28	67.607	9.6469
	U13	21	71.905	10.9859
	Total	68	68.103	9.8982

Table 3 displays the anthropometric measurements of youth football players in Tirana categorized by age groups (U9, U11, and U13), showing clear trends in physical development consistent with expected growth patterns. Body weight increased progressively across age groups, from a mean of 33.59 kg in U9 to 50.36 kg in U13, reflecting natural

Table 4. One-Way Analysis of Variance (ANOVA) for comparison by age groups for anthopometrics

		Sum of Squares	df	Mean Square	F	Sig.
Body_Weight	Between Groups	2952.798	2	1476.399	12.485	.000
	Within Groups	7686.474	65	118.253		
	Total	10639.272	67			
Body_Height	Between Groups	.519	2	.260	31.877	.000
	Within Groups	.529	65	.008		
	Total	1.049	67			
BMI	Between Groups	32.173	2	16.087	1.253	.293
	Within Groups	834.699	65	12.842		
	Total	866.872	67			
Waist_Circumference	Between Groups	539.370	2	269.685	2.910	.052
	Within Groups	6024.909	65	92.691		
	Total	6564.279	67			

physical maturation. Similarly, mean body height rose from 1.33 m in U9 to 1.56 m in U13, with standard deviations indicating more variation among older participants, likely due to the onset of puberty. Body Mass Index (BMI) also showed a gradual increase from 18.78 in the youngest group to 20.47 in the oldest, suggesting age-related changes in body composition. Waist circumference followed the same upward trend, increasing from 64.63 cm in U9 to 71.91 cm in U13, which may reflect both growth and fat distribution changes as children age.

The one-way ANOVA results indicate statistically significant differences in body weight and body height across the three age groups (U9, U11, and U13). Specifically, body weight showed a significant effect of age group, F(2, 65) = 12.485, p < .001, with older players being significantly heavier on average. Similarly, body height differences were highly significant, F(2, 65) = 31.877, p < .001, reflecting the expected growth progression with age. In contrast, no significant difference was found in BMI across the age groups, F(2, 65) = 1.253, p = .293, suggesting that while both weight and height increase with age, the overall body composition relative to height remains relatively stable. Waist circumference showed a marginally non-significant trend, F(2, 65) = 2.910, p = .062, indicating that while older participants tended to have larger waist measurements, the variation was not strong enough to reach conventional significance.

Table 5. Descriptive statistics for motor skills by age group

		N	Mean	Std. Deviation
Sit_Reach	U9	19	23.789	2.2256
	U11	28	21.750	4.1866
	U13	21	20.762	5.2811
	Total	68	22.015	4.2584
Agility_10x5m	U9	19	22.474	2.0419
	U11	28	21.918	1.3902
	U13	21	20.890	1.1799
	Total	68	21.756	1.6452
Standing_Long_Jump	U9	19	126.868	16.3559
	U11	28	134.068	21.1476
	U13	21	146.838	23.2144
	Total	68	136.000	21.7942
Sprint_20m	U9	19	4.945	.3032
	U11	28	4.424	.4547
	U13	21	3.959	.2334
	Total	68	4.426	.5187

Table 5 presents the descriptive statistics for motor skills across the three age groups, revealing clear age-related trends in physical performance. Flexibility, as measured by the sit-and-reach test, showed a decreasing trend with age, with U9 players achieving the highest average score (M = 23.79 cm), while U13 players had the lowest (M = 20.76 cm), suggesting that younger children may retain greater flexibility, or that flexibility may decline without targeted training as players age. Agility, assessed through the 10x5 meter shuttle run, improved with age, with average times decreasing from 22.47 seconds in U9 to 20.89 seconds in U13, indicating better coordination and change-of-direction speed in older players. Similarly, lower-body power, as indicated by the standing long jump, increased steadily from 126.87 cm in U9 to 146.84 cm in U13,

Table 6. One-Way Analysis of Variance (ANOVA) for comparison by age groups for motor skills

		Sum of Squares	df	Mean Square	F	Sig.
Sit_Reach	Between Groups	94.768	2	47.384	2.749	.071
	Within Groups	1120.217	65	17.234		
	Total	1214.985	67			
Agility_10x5m	Between Groups	26.280	2	13.140	5.508	.006
	Within Groups	155.068	65	2.386		
	Total	181.348	67			
Standing_Long_Jump	Between Groups	4155.608	2	2077.804	4.881	.011
	Within Groups	27668.412	65	425.668		
	Total	31824.020	67			
Sprint_20m	Between Groups	9.701	2	4.851	37.870	.000
	Within Groups	8.325	65	.128		
	Total	18.026	67			

reflecting progressive development of muscular strength. The 20-meter sprint times also improved with age, decreasing from 4.95 seconds in U9 to 3.96 seconds in U13, demonstrating significant gains in sprint speed as children grow and mature.

The ANOVA results in Table 6 demonstrate significant age-related differences in most of the motor skill variables tested among the youth football players. Agility, measured by the 10x5 meter shuttle run, showed a statistically significant difference across age groups, F(2, 65) = 5.508, p = .006, indicating that agility improved with age. Standing long jump, a test of lower-body power, also differed significantly between groups, F(2, 65) = 4.881, p = .011, with older players achieving longer jump distances, reflecting enhanced muscular strength and coordination. Sprint performance over 20 meters revealed the most pronounced difference, F(2, 65) = 37.870, p < .001, indicating a clear and strong improvement in sprint speed with age, likely due to increased neuromuscular efficiency and maturation. In contrast, flexibility, as measured by the sit-and-reach test, did not differ significantly between age groups, F(2, 65) = 2.749, p = .071, although the p-value approaches significance, suggesting a potential trend that may warrant further investigation

Discussion

The current study investigated the anthropometric parameters and motor skill performance of youth football players (U9, U11, and U13) in Tirana, Albania. The results indicated significant developmental differences in both physical attributes and motor skills, with age playing a crucial role in shaping these outcomes. These findings are consistent with the existing literature, which highlights the significant impact of age and maturation on physical and motor performance in young athletes (Malina et al., 2004; Lloyd & Oliver, 2012). Significant age-related differences were observed in body weight and body height (both p < .001), confirming that growth in these physical attributes is clearly influenced by age. Specifically, U9 players had the lowest body weight and height, while U13 players were significantly heavier and taller. This aligns with previous research that identifies a period of rapid growth between the ages of 10 and 13, typically marked by the onset of puberty (Mirwald et al., 2002). BMI, however, did not show significant differences across the groups, suggesting that while weight and height increase, the ratio of weight to height remains relatively stable in this age range. This finding suggests that during childhood, body mass is distributed in a way that does not drastically impact BMI, and other factors such as nutrition or training may play a more significant role in determining BMI than age alone (Ward et al., 2018).

The waist circumference also showed a trend toward larger measurements in older children, with a significant result (p = .052), suggesting that as children mature, there may be an increase in body fat distribution around the waist. This finding is consistent with research that demonstrates the effect of puberty on fat distribution (Zhu et al., 2002). Coaches should consider these age-related changes in body composition when planning training sessions, as older children may have different metabolic and energy needs compared to younger players.

The ANOVA results for motor skills further illustrate the differences between age groups in terms of performance. Statistically significant improvements were observed in agility, standing long jump and sprint performance with age. Specifically, agility improved from U9 (M = 22.47 s) to U13 (M = 20.89 s), and standing long jump increased from U9 (M = 126.87 cm) to U13 (M = 146.84 cm), both of which are consistent with findings from Lloyd and Oliver (2012) that agility and power increase as children mature. These improvements can be attributed to increased neuromuscular coordination and strength, which are common during the pre-adolescent and adolescent periods. The 20-meter sprint times also improved significantly with age, demonstrating that older players possess greater sprinting speed, likely due to the development of sprinting mechanics and faster neuromuscular adaptations (Gabbett, 2008). However, flexibility, as measured by the sit-and-reach test, did not show significant differences across age groups (p = .071), indicating that flexibility may not be as strongly influenced by age in this population. Previous studies have shown that flexibility may peak earlier in childhood and then plateau (Zhou et al., 2013), which could explain the lack of significant differences between age groups in this study.

Implications for Coaches and Training Sessions

The results of this study suggest that coaches should tailor their training sessions based on the developmental characteristics of each age group. The significant differences in body weight, height, and motor skills imply that U9, U11, and U13 players have distinct physical and motor capabilities, which could influence how they respond to training loads and the type of exercises that are most beneficial for them. For younger players (U9), training should focus more on developing fundamental motor skills such as balance, coordination, and flexibility. Since these players are still in the early stages of motor development, activities that promote body awareness and agility should be prioritized, as they are essential for laying the foundation for future performance (Balyi & Hamilton, 2004). Additionally, considering the lower body mass and height, exercises that enhance flexibility, agility, and basic strength could help prevent injury and promote balanced growth. In contrast, U11 and U13 players, who have already undergone significant physical growth, could benefit from more structured training aimed at improving specific motor skills such as sprinting, jumping, and strength. The increase in sprinting speed and standing long jump distance observed in U13 players suggests that strength and power development should become a focal point for these groups. Coaches should consider incorporating more explosive movements and sprint training to further enhance performance, ensuring that training loads are progressively adjusted to match the athlete's growing physical capabilities (Faigenbaum et al., 2014).

The significant age-related differences in motor skills, particularly agility and sprinting, suggest that training intensity and volume may need to be adjusted according to age. Younger athletes (U9) may benefit from more frequent, shorter training sessions with a greater emphasis on fun and basic skills, while older athletes (U11, U13) can handle longer sessions with more advanced drills targeting specific skills such as speed, agility, and endurance. The load of training for U13 players may also be higher, considering their more developed musculoskeletal system, allowing for more intense and longer sessions focused on strength and power (Kraemer et al., 2004). The exploration of anthropometric characteristics and motor skill development presents an intricate but essential narrative for understanding youth football players. Differences attributable to age are evident in both physical dimensions and skill acquisition, suggesting that tailored training programs that recognize these developmental stages can optimize young athletes' performance in football.

Conclusion

In conclusion, this study highlights the significant age-related differences in anthropometric characteristics and motor skills among youth football players in Tirana, Albania. These differences have important implications for training, as coaches should tailor their sessions to the specific needs of each age group. For U9 players, training should emphasize basic motor skills and flexibility, while for U11 and U13 players, more focus should be placed on strength, speed, and agility. Understanding the developmental stages of young athletes is crucial for optimizing their performance and ensuring safe, effective training. Future research could explore the effects of specific training interventions on motor skill development and the impact of different training loads on youth performance.

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ORIGINAL SCIENTIFIC PAPER

A Comparative Study Between Genders in Ball Coordination Skills in Children in the Volleyball Discipline

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Abstract

This study aimed to examine gender differences in coordination skills among children aged 10–12 years who have one year of experience in volleyball. Coordination is a fundamental component of motor development and plays a critical role in sports performance, particularly in team sports such as volleyball. A total of 34 children (16 boys and 18 girls) participated in the study. Anthropometric measurements (height, weight, waist circumference), flexibility (sit-and-reach test), speed (20-meter sprint), and coordination skills (plate tapping test with dominant and non-dominant hands, and KTK plate movement test) were assessed. Descriptive statistics were calculated, and independent samples t-tests were performed to compare gender differences. Levene's test was used to assess the homogeneity of variances. Based on the anthropometric comparisons, no significant gender differences were found in height, weight, or waist circumference. These results suggest that at this age, boys and girls engaged in regular volleyball training are relatively similar in basic body measurements. In contrast, analysis of motor abilities revealed significant gender differences in flexibility and sprint performance. Girls demonstrated significantly greater flexibility than boys, and boys were significantly faster than girls in the 20-meter sprint. No significant gender differences were observed in the coordination tasks, including the plate tapping test (dominant and non-dominant hand) and the KTK Plate Movement test. Overall, these findings suggest that while flexibility and sprint speed differ between genders at this age, coordination skills appear largely comparable when boys and girls have similar sports exposure. This highlights the value of offering the same motor skill training to both genders in early sport specialization phases such as volleyball.

Keywords: *coordination skills, gender differences, volleyball, children, motor performance, physical education*

Introduction

The execution of athletic skills depends heavily on coordination skills, which are essential elements of motor performance. Despite their importance, coordination requirements are frequently overlooked in sports training, particularly during young athletes' formative years. The multifaceted structure of coordination makes it difficult, with many elements contributing differently to performance based on the needs of a certain sport (Měkota, 2000; Schmid & Lee, 2011; Nurja & Caushi, 2019). In terms of motor control, coordination is the process by which the musculoskeletal and central nervous systems work together to create fluid, precise, and effective movements (Holmann & Hettinger, 1990). Thus, the neuromuscular system, movement control mechanisms, and the functioning of sensory analyzers like the visual, vestibular, and proprioceptive systems are all necessary for effective coordination. The spatial, temporal, and force-related components of motor control in response to task-oriented goals are all encompassed under the phrase "coordinated movement," according to Mechling (1983). This more comprehensive

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understanding emphasizes that coordination is a complicated system of interconnected subskills rather than a single skill. Raczek and Mynarski (1992) provided support for this by identifying five primary coordination skills through a factor analysis of 30 markers of coordination in school-aged children (7–18 years). Waskiewicz, Juras, and Raczek (1999) established a hierarchical model of coordination abilities by further subdividing these into subskills. This paradigm emphasizes how coordination is multifactorial, with different components—like rhythm, balance, spatial orientation, and reaction time—rarely functioning independently but rather combining to create a coherent motor output (Kirchem, 1992). Therefore, it is crucial to view coordination as an interconnected system rather than just a collection of distinct abilities when assessing young athletes' performance, especially in complicated games like volleyball where agility, timing, and spatial awareness are constantly tested. In order to gain a better understanding of how early exposure to a particular activity may affect the development of coordination skills, this study will investigate gender-specific coordination disparities among children aged 10 to 12 who had previously trained in volleyball.

Methods

The purpose of this study is to compare gender in coordination skills in the discipline of volleyball to see and understand whether the age group 10-12 years old has a difference or not. 34 children (18 girls and 16 boys) respectively of the age group 10-12 years old with sports experience in the volleyball field for one year participated in this study. In this study, the tests evaluated were: anthropometric parameters such as: body mass, waist circumference, height measured with the Health-O-meter device. Also, flexibility measured with the sit and reach device,. Speed test such as 20m and two coordination tests such as touching the plate with the dominant and non-dominant hand, as well as the displacement of the KTK plates.

Protocol of measurements performed in this study

For the first measurements such as body mass and height, we needed the Health-O-meter device where the child climbs onto the device to measure body mass, stands straight without moving, then lowers or raises the length measuring part to the maximum level of the head.

The waist circumference is measured with a tape measure. The child is positioned facing forward, his condition should be as free and without strain as possible. The tape measure is described around the waist and at the point where the beginning touches the rest, the correct result is obtained.

In the Flexibility test, the child is measured with the Sit and Reach device. The device is supported on a solid and flat surface so that the device does not move and the measurement is as accurate as possible. After we have placed the device, the child sits, legs straight and placed inside the middle of the device, then places his hands straight and palms on top of each other, and begins to push the meter to the maximum point without bending his legs and without stopping the movement of his arms.

20 meter sprint test, in this test we measured the maximum speed of the child who describes a distance of 20 m in length. The child is positioned one step away from two landmarks and starts at maximum speed to the distance of 20m where the other two landmarks are located. We look at the stopwatch to measure the speed in seconds that the child described.

Moving the tiles is a very valuable test to see how fast and attentive the coordination of children is. The child is placed in front of him, and is attached to one of the tiles. When the child starts moving the tiles left or right, the stopwatch is pressed, during the time that the child performs the move we look at the stopwatch until it reaches 20 seconds, and at the end of the time we write down the result of how many moves the child has made in 20 seconds.

Also, the test, touching the plates, plays a very important role in seeing the coordination in this age group. The child is sitting in a chair and in front of him there is a table where three sheets are placed on the table where the two side sheets have a sphere drawn on them to create and base the child on the position of the plate, while the middle sheet is empty to place the hand. The child does 2 tests, one test with the dominant hand and one test with the non-dominant hand. When the child starts to touch the plates with only one hand, then the 25-second time begins, after the time is up we count how many touches the child has made.

Statistical Analysis

In this study, descriptive statistics were calculated for all measured variables, including flexibility, 20-meter sprint speed, plate tapping (dominant and non-dominant hand), and KTK plate movement, separately for boys and girls. The descriptive measures included mean, standard deviation, minimum, and maximum values.

To compare anthropometric and motor coordination variables between genders, independent samples t-tests were performed. Levene's Test for Equality of Variances was applied to assess the homogeneity of variances for each variable before conducting the t-tests. All statistical analyses were conducted using IBM SPSS 22.0 Statistics software, and the level of significance was set at $p < .05$.

Table 1. Descriptive Statistics for anthopometric by gender

Gender		N	Minimum	Maximum	Mean	Std. Deviation
Boys	Height	16	136.0	162.0	145.688	8.5066
	Weight	16	29.0	70.0	41.375	12.8264
	Waist	16	59.0	98.0	72.813	12.6239
	Valid N (listwise)	16				
Girls	Height	18	124.5	165.0	143.056	10.7278
	Weight	18	28.0	63.1	39.994	10.0648
	Waist	18	50.0	92.0	68.278	9.8924
	Valid N (listwise)	18				

Results

The data in Table 1 show the minimum, maximum, mean and standard deviation of anthropometric measurements by gender in children involved in the sport of volleyball. For each anthropometric measurement that is included (height, weight and waist circumference), 16 male athletes and 18 female athletes were measured. In measuring the body height of boys, the average is 145.9 cm (SD 8.5 cm), the minimum is 136 cm and the maximum is 162 cm. While in terms of body weight, the average is 41.4 kg (SD 12.8 kg), the minimum is 27 kg and the maximum is 70 kg. Also, the average waist circumference is 72.8 cm (SD 12.6 cm), the minimum is 59 cm and the maximum is 98 cm. The average body length of girls is 143.1 cm (SD 10.7 cm), the minimum is 124.5 cm and the maximum is 165 cm. While the average body weight is 40 kg (SD 10.1 kg), the minimum is 28 kg and the maximum is 63.1 kg. Also, in terms of waist circumference, the average in girls is 68.3 cm (SD 9.9 cm), the minimum is 50 cm and the maximum is 92 cm.

Table 2. Independent samples t-tests comparing boys and girls on height, weight, and waist circumference

		Levene's Test		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
		F.	Sig.					
Height	Equal variances assumed	.475	.496	.786	32	.438	2.6319	3.3500
	Equal variances not assumed			.797	31.624	.432	2.6319	3.3040
Weight	Equal variances assumed	.823	.371	.351	32	.728	1.3806	3.9316
	Equal variances not assumed			.346	28.405	.732	1.3806	3.9887
Waist	Equal variances assumed	1.233	.275	1.173	32	.250	4.5347	3.8673
	Equal variances not assumed			1.156	28.383	.257	4.5347	3.9239

Table 2 displays the results of independent samples t-tests comparing boys and girls on height, weight, and waist circumference. Levene's test for equality of variances indicated that the assumption of equal variances was met for all three variables ($p > .05$). No statistically significant differences were found between boys and girls in height ($t(32) = 0.786$, $p = .438$), weight ($t(32) = 0.351$, $p = .728$), or waist circumference ($t(32) = 1.173$, $p = .250$).

Table 3. Descriptive Statistics by gender for motor abilities

Gender		N	Minimum	Maximum	Mean	Std. Deviation
Boys	Flexibility	16	12.0	30.0	18.688	5.1084
	Speed_20m	16	3.9	5.1	4.520	.3782
	P Tapping Dominant	16	13.4	16.6	14.683	1.0398
	P Tapping no Dominant	16	14.0	18.6	15.930	1.1514
	KTK Plate Movement	16	15.0	25.0	21.063	2.8395
	Valid N (listwise)	16				
Girls	Flexibility	18	15.0	43.0	26.500	8.2782
	Speed_20m	18	4.2	5.5	4.805	.3806
	P Tapping Dominant	18	12.7	15.8	14.264	.8140
	P Tapping no Dominant	18	13.9	19.4	16.043	1.3719
	KTK Plate Movement	18	16.0	29.0	22.944	3.2805
	Valid N (listwise)	18				

The data in table no. 3 show the minimum, maximum, mean and standard deviation of motor skills (flexibility, 20 m speed, plate touch with dominant hand, plate touch with non-dominant hand and plate displacement) by gender in children involved in the sport of volleyball. In each motor skill test, 16 male athletes and 18 female athletes were tested. In the flexibility test, the average for boys is 18.7 cm (SD 5.1 cm), the minimum is 12 cm and the maximum is 30 cm. While in the 20 m speed test, the average is 4.5 sec (SD 0.4 sec), the minimum is 3.9 sec and the maximum is 5.1 sec.

Also, in terms of the plate tapping test with the dominant hand, the average is 14.7 sec (SD 1 sec), the minimum is 13.4 sec and the maximum is 16.6 sec. While in the tapping test with the non-dominant hand, the average is 16 sec (SD 1.2 sec), the minimum is 14 sec and the maximum is 18.6 sec. In the plate movement test, the average is 21.1 sec (SD 2.8 sec), the minimum is 15 sec and the maximum is 25 sec. On the other hand, in the flexibility test, the average for female athletes is 26.5 cm (SD 8.3 sec), the minimum is 15 cm and the maximum is 43 cm. In terms of the 20 m speed test, the average for girls is 4.8 sec (SD 0.4 sec), the minimum is 4.2 sec and the maximum is 5.5 sec. While in the plate tapping test with the dominant hand the average is 14.3 sec (SD 0.8 sec), the minimum is 12.7 sec and the maximum is 15.8 sec. In the non-dominant hand tapping test the average is 16 sec (SD 1.4 sec), the minimum is 13.9 sec and the maximum is 19.4 sec. Finally in the plate moving test the average is 23 sec (SD 3.3 sec), the minimum is 16 sec and the maximum is 29 sec.

Table 4 presents the results of independent samples t-tests comparing boys and girls on various motor ability measures. Levene's test showed that the assumption of equal variances was generally satisfied, except for flexibility ($p = .049$), where equal variances were borderline violated. Statistically significant differences were found in flexibility and 20-meter sprint

Table 4. Independent samples t-tests comparing boys and girls comparing motor abilities

		Levene's Test		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
		F	Sig.					
Flexibility	Equal variances assumed	4.200	.049	-3.260	32	.003	-7.8125	2.3963
	Equal variances not assumed			-3.350	28.713	.002	-7.8125	2.3320
Speed_20m	Equal variances assumed	.040	.843	-2.186	32	.036	-.2850	.1304
	Equal variances not assumed			-2.187	31.581	.036	-.2850	.1303
P Tapping Dominant	Equal variances assumed	.747	.394	1.317	32	.197	.4192	.3184
	Equal variances not assumed			1.298	28.366	.205	.4192	.3231
P Tapping no Dominant	Equal variances assumed	.597	.446	-.258	32	.798	-.1128	.4375
	Equal variances not assumed			-.261	31.909	.796	-.1128	.4329
KTK Plate Movement	Equal variances assumed	.083	.775	-1.777	32	.085	-1.8819	1.0588
	Equal variances not assumed			-1.793	31.983	.082	-1.8819	1.0496

performance. Girls demonstrated significantly greater flexibility than boys (t(32) = -3.260, p = .003), with a mean difference of -7.81 cm, indicating superior flexibility among female participants. Additionally, boys performed significantly faster in the 20-meter sprint test compared to girls (t(32) = -2.186, p = .036), with a mean difference of -0.285 seconds. No significant differences were observed between boys and girls in hand tapping speed for the dominant and non-dominant hands (p > .05) or in the KTK Plate Movement test (p > .05).

Discussion

The purpose of this study was to examine gender differences in coordination skills and selected physical parameters among 10–12-year-old volleyball players. Thirty-four children (18 girls and 16 boys) with approximately one year of volleyball experience participated. Based on the anthropometric comparisons, no significant gender differences were found in height, weight, or waist circumference. These results suggest that at this age, boys and girls engaged in regular volleyball training are relatively similar in basic body measurements. This finding aligns with previous research indicating that gender-related differences in body composition become more pronounced only after the onset of puberty (Malina et al., 2004).

The anthropometric data revealed that there were no statistically significant differences between boys and girls in terms of height, body mass, and waist circumference, even though boys were slightly taller and heavier on average. These findings are consistent with previous literature which suggests that during preadolescence, physical differences between boys and girls are minimal due to similar developmental rates before puberty (Malina et al., 2004; Côté et al., 2009; Nurja et al., 2022; Peev et al., 2024).

In contrast, analysis of motor abilities revealed significant gender differences in flexibility and sprint performance. Girls demonstrated significantly greater flexibility than boys, consistent with prior findings that females generally outperform males in flexibility tasks, particularly during childhood (Nobre et al., 2021). This advantage may be attributed to physiological and anatomical factors favoring greater joint range of motion in females. Conversely, boys were significantly faster than girls in the 20-meter sprint, a finding that echoes the results of other studies highlighting earlier development of muscular power and sprinting abilities in young male athletes (Vandorpe et al., 2012). Generally, boys of this age tend to perform better in speed-based tasks, which has been attributed to slightly greater muscle mass and neuromuscular efficiency (Lloyd et al., 2011).

No significant gender differences were observed in the coordination tasks, including the plate tapping test (dominant and non-dominant hand) and the KTK Plate Movement test. This suggests that, despite slight differences in physical characteristics, boys and girls in this age group exhibit similar levels of hand coordination and lower-limb coordination. These results are in line with the findings of Vandorpe et al. (2011), who reported minimal gender differences in coordination performance among prepubescent children when training experience was comparable. This aligns with findings from previous research indicating that boys may have a slight edge in reaction-based coordination tasks (Bardid et al., 2015), although this difference often diminishes with more training and experience in sport-specific tasks.

Limitations and Suggestions for Further Research

This study presents valuable insights into gender differences in coordination skills among children aged 10–12 with volleyball experience; however, several limitations should be acknowledged. One primary limitation is the small sample size (N = 34), which may affect the generalizability of the findings. Larger and more diverse samples across different regions and schools would help increase external validity. Additionally, the study included only children with one year of volleyball experience, which limits the ability to compare results across different levels of motor expertise or training backgrounds. The cross-sectional design of the study does not allow for conclusions about developmental changes or causal relationships between coordination skills and anthropometric factors. A longitudinal approach could provide more insight into how coordination abilities evolve over time in relation to training, growth, and maturation. Future studies should consider: using longitudinal designs to track changes in coordination over time and expanding the sample size and including participants from various sports disciplines and non-athletes for comparative analysis. These findings suggest that both genders perform similarly in gross motor coordination tasks when exposed to similar sports training regimens (Roth et al., 2021).

Overall, these findings suggest that while flexibility and sprint speed differ between genders at this age, coordination skills appear largely comparable when boys and girls have similar sports exposure. This highlights the value of offering the same motor skill training to both genders in early sport specialization phases such as volleyball.

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ORIGINAL SCIENTIFIC PAPER

Effects of a 12-Week Coordination Training Program on Agility, Speed, Flexibility, and Lower Limbs Power in Youth Basketball Players

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Abstract

This study sought to investigate the impact of a 12-week coordination-focused training regimen on physical performance parameters in youth basketball athletes. Ninety-four participants (mean age = 11.3 years; SD = 1.16) from Tirana, Albania, were allocated into two groups: an intervention group (n = 48) and a control group (n = 46). Both groups performed assessments before and after the intervention, evaluating anthropometric characteristics, agility, speed, flexibility, and explosive power of the lower limbs. The control group maintained their usual training, while the intervention group incorporated coordination activities, including ladder drills, cone work, and reaction-based tasks, into their weekly routines. ANOVA indicated significant enhancements in agility (10x5m shuttle run and T-test) and standing long jump performance in the intervention group relative to the control group ($p < 0.05$). Nonetheless, no substantial differences were observed in the 20m sprint or flexibility results. The findings indicate that integrating coordination exercises into routine training improves dynamic movement skills and lower limb explosive power, but may not substantially affect linear sprint speed or flexibility in young basketball players.

Keywords: *basketball, youth, speed, agility, strength*

Introduction

Coordination training typically includes multiple physical aspects, including strength, agility, speed, and flexibility, resulting in a comprehensive improvement of athletic performance (Bilali & Spahi, 2017; Isrefi et al., 2020). An extensive review of the current research indicates a consensus on multiple key factors concerning the effects of this training. Recent evidence underscores the clear correlation between agility training and enhanced performance in youth basketball players. The training protocols incorporating agility drills, as evidenced by research conducted by Deliceoğlu et al. (2024) and Yalçin (2025), exhibit substantial improvements in performance on agility assessments such as CODAT. These activities activate key muscle areas and enhance the neuromuscular reflexes vital for basketball maneuvers, marked by swift directional shifts. A meta-analysis reveals that plyometric activities, commonly included in these training regimens, further enhance performance measures by improving lower limb explosive power, as shown by Özen et al. (2020) and Kryeziu et al. (2019). Plyometric exercises, when incorporated into a comprehensive agility training regimen, markedly improve the speed of young athletes. Research indicates that structured training regimens using plyometric activities affect agility and speed, as demonstrated by various studies (Li et al., 2024). A study by Demir & Dağlıoğlu (2022) contends that plyometric training consistently enhances explosive muscle power, essential for sprinting performance in basketball athletes. The association is further corroborated by Hadi et al. (2024), demonstrating that integrated speed and agility training can produce significant enhancements within a brief training cycle, highlighting the efficacy of a coordinated training regimen. Flexibility, an essential element in basketball, is enhanced by extensive coordination training. Literature repeatedly asserts that flexibility training is essential for comprehensive athletic development, facilitating an expanded range of motion and

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diminishing injury risks. Live (2019). These data indicate that integrating flexibility training with strength and agility exercises commonly results in significant enhancements in performance indicators. Flexibility exercises used in these 12-week programs enhance players' ability to perform intricate motions more effectively, underscoring the significance of a comprehensive training strategy. Emphasizing lower limb power with specific resistance and plyometric training has demonstrated improvements in on-court performance. Research by Lehnert et al. (2013) and Trecroci et al. (2020) demonstrates that regular participation in power exercises significantly enhances vertical leap and sprint performance, highlighting the critical role of leg strength in basketball. This study aimed to examine the effects of a 12-week coordination-focused training program on physical performance metrics in youth basketball players.

Methods

Participants

The overall number of participants was 94 youth basketball players. The average age of the participants was 11.3 years (SD = 1.16). Basketball players were categorized into two groups: an intervention group and a control group, each consisting of two teams, resulting in a total of four teams. The intervention group (n = 48) received pre- and post-intervention assessments and engaged in a 12-week coordination-focused training regimen incorporated into their standard basketball practices. The control group (n = 46) underwent pre- and post-tests while maintaining their usual basketball training regimen over the same 12-week duration, without any supplementary intervention. A intervention study approach employing pre- and post-testing was utilized to assess the impact of the coordination training intervention. Anthropometric variables (height, weight, BMI), speed (20-meter sprint), agility (10x5m shuttle run and T-test), flexibility (sit-and-reach test), and lower limb explosive power (standing long jump) were evaluated before to and following the intervention period. All measurements were performed under standardized conditions in a sports hall by professional evaluators adhering to the same protocol at both time intervals.

Intervention

The intervention program comprised coordination-focused activities aimed at enhancing agility, balance, rhythm, and body control. These were executed during routine training sessions, 2–3 times weekly, spanning a duration of 12 weeks. The exercises comprised ladder drills, cone drills, multi-directional movement patterns, and reaction-based activities. The control group maintained their standard basketball training regimen without any supplementary coordination activities.

The intervention program for each training session consisted in four type of exercises aiming as follows:

1. Coordination (3 times x 1 min with 30 seconds rest)
2. Speed/ agility without the ball (3 times x 1 min with 30 seconds rest)
3. Speed/ agility with the ball (5 times x 30 seconds with 30 seconds rest)
4. Strength/ endurance (2 to 4 times x 1 min with 30 seconds rest)

Statistics

Descriptive statistics, including the mean and standard deviation, were computed for all variables. Differences between groups before and after the intervention were assessed using Analysis of Variance (ANOVA). A significance criterion of $p < 0.05$ was employed to ascertain statistically significant differences among groups.

Results

Table 1 shows the descriptive statistics for body height, weight, and BMI before and after the intervention. The intervention group had higher mean height and weight at both time points compared to the control group. Both groups showed slight increases in height and weight post-intervention. BMI slightly decreased in both groups, with a more notable reduction in the intervention group.

Table 1. Descriptive statistics for anthopometric (pre and post) by group

		N	Mean	Std. Deviation
Body_Height_pre	Control	46	152.85	9.98
	Intervention	48	161.44	11.28
	Total	94	157.23	11.45
Body_Height_post	Control	46	154.28	9.89
	Intervention	48	162.77	11.40
	Total	94	158.62	11.45
Body_Weight_pre	Control	46	48.56	11.95
	Intervention	48	53.91	11.81
	Total	94	51.29	12.12
Body_Weight_post	Control	46	49.72	11.92
	Intervention	48	55.10	11.20
	Total	94	52.47	11.81
BMI_pre	Control	46	7.59	3.48
	Intervention	48	6.37	3.12
	Total	94	6.96	3.34
BMI_post	Control	46	7.22	3.16
	Intervention	48	6.00	2.51
	Total	94	6.59	2.90

Table 2. Descriptive statistics for speed and agility (pre and post) by group

		N	Mean	Std. Deviation
Agiilty_10x5m_pre	Control	46	22.7	2.2
	Intervention	48	20.2	1.4
	Total	94	21.5	2.2
Agiilty_10x5m_post	Control	46	22.6	2.3
	Intervention	48	19.8	1.8
	Total	94	21.2	2.5
Sprint_20m_pre	Control	46	4.2	0.4
	Intervention	48	3.8	0.4
	Total	94	4.0	0.4
Sprint_20m_post	Control	46	4.2	0.4
	Intervention	48	3.7	0.3
	Total	94	4.0	0.5
Agiilty_T_test_pre	Control	44	16.0	2.1
	Intervention	46	14.8	1.9
	Total	90	15.4	2.1
Agiilty_T_test_post	Control	44	15.7	1.8
	Intervention	46	13.5	1.7
	Total	90	14.6	2.0

Table 2 presents descriptive statistics for speed and agility measures before and after the intervention. The intervention group consistently outperformed the control group in all tests, both pre- and post-intervention. In the 10x5m agility test, the intervention group improved from a mean of 20.2 seconds to 19.8 seconds, while the control group remained relatively unchanged. Similar improvements were observed in the 20m sprint, where the intervention group decreased their time from 3.8 to 3.7 sec-

Table 3. Descriptive statistics for flexibility and explosive power lower limbs (pre and post) by group

		N	Mean	Std. Deviation
Sit_Reach_pre	Control	45	19.9	5.6
	Intervention	47	21.2	5.1
	Total	92	20.5	5.4
Sit_Reach_post	Control	45	20.9	5.4
	Intervention	47	22.3	5.0
	Total	92	21.6	5.2
Standing_long_jump_pre	Control	46	148.1	25.7
	Intervention	48	156.4	25.1
	Total	94	152.3	25.6
Standing_long_jump_pre	Control	46	150.3	24.9
	Intervention	48	161.5	24.7
	Total	94	156.0	25.3

Table 4. ANOVA comparison for agility and speed (differences= post -pre) by group

		Sum of Squares	df	Mean Square	F	Sig.
Agility_diff_sec_post_pre	Between Groups	3.072	1	3.072	4.449	0.038
	Within Groups	63.539	92	0.691		
	Total	66.611	93			
Sprint_20m_diff_sec_post_pre	Between Groups	0.196	1	0.196	2.362	0.128
	Within Groups	7.627	92	0.083		
	Total	7.822	93			
Agility_T_test_diff_sec_post_pre	Between Groups	18.778	1	18.778	11.872	0.001
	Within Groups	140.767	89	1.582		
	Total	159.545	90			

onds, compared to no change in the control group (4.2 seconds). In the T-test for agility, the intervention group showed a notable improvement from 14.8 to 13.5 seconds, whereas the control group improved slightly from 16.0 to 15.7 seconds.

Table 3 displays the descriptive statistics for flexibility and lower limb explosive power, assessed through the sit-and-reach and standing long jump tests. The intervention group showed slightly higher flexibility and jump performance both before and after the intervention. In the sit-and-reach test, flexibility improved modestly in both groups, with the intervention group increasing from 21.2 cm to 22.3 cm, and the control group from 19.9 cm to 20.9 cm. In the standing long jump, the intervention group improved from 156.4 cm to 161.5 cm, while the control group increased from 148.1 cm to 150.3 cm.

Table 4 presents the ANOVA results for group differences in speed and agility improvements (post minus pre). A significant difference was found in the 10x5m agility test (F(1,92) = 4.45, p = 0.038), and a highly significant difference was observed in the T-test for agility (F(1,89) = 11.87, p = 0.001), both favoring the intervention group. However, no significant difference was found between groups in the 20m sprint performance (F(1,92) = 2.36, p = 0.128).

Table 5. ANOVA comparison for flexibility and explosive power lower limbs (differences= post -pre) by group

		Sum of Squares	df	Mean Square	F	Sig.
Sit_Reach_diff_cm_post_pre	Between Groups	0.443	1	0.443	0.047	0.829
	Within Groups	852.478	90	9.472		
	Total	852.921	91			
Standing_Long_Jump_diff_cm_post_pre	Between Groups	198.224	1	198.224	13.935	0.000
	Within Groups	1308.716	92	14.225		
	Total	1506.940	93			

Table 5 presents ANOVA comparisons of pre-post differences in flexibility and lower limb explosive power between groups. There was no significant difference in sit-and-reach flexibility gains between the control and intervention groups (F(1,90) = 0.047, p = 0.829), indicating similar improvements in both. However, a significant difference was found in the standing long jump test (F(1,92) = 13.94, p < 0.001), favoring the intervention group.

Discussion

The intervention study evaluating the effects of a training program on basketball players in Tirana, Albania, produced significant results regarding agility and explosive power, while demonstrating non-significant outcomes for sprint speed and flexibility (mean age 11.3 years; SD 1.16 yrs). Specifically, the intervention group showed greater improvements in both the 10x5m agility test and the T-test, as well as in the standing long jump performance, compared to the control group. In contrast, no statistically significant differences were found between groups in the 20m sprint or the sit-and-reach flexibility test. These findings suggest that the intervention was particularly effective in enhancing dynamic movement skills and muscular power, rather than linear sprint speed or flexibility.

The findings align with current literature that emphasizes the efficacy of plyometric training and agility drills in improving dynamic movement skills and lower limb power (Spahi et al., 2016a; Spahi et al., 2016b). A meta-analysis by Zhou et al., (2024) indicated that plyometric training markedly enhances athletic performance characteristics, including muscle power and agility, especially in young basketball players. Ramírez-Campillo et al., (2022) highlighted that plyometric jump training enhances jumping performance and muscle strength, corroborating the current study's observation of enhanced standing long jump performance. The noted increases in agility, evidenced by advancements in the 10x5m agility test and the T-test, align with findings by Saeterbakken et al., (2022) who indicated that agility and change-of-direction speed are affected by linear sprint speed and leg muscle power. In juvenile sports, dynamic movements, as assessed by these tests, are frequently improved through targeted interventions emphasizing explosive training techniques. This correlation emphasizes that agility is more successfully developed through specific training protocols aimed at skill enhancement rather than broad speed improvement. The non-significant results concerning sprint speed and flexibility indicate that the intervention failed to provide the anticipated improvements in these domains.

Despite the implementation of a 12-week coordination training program, no substantial differences were observed in the 20-meter sprint or flexibility results among youth basketball players. These findings align with previous research indicating that improvements in agility and power do not necessarily translate to gains in linear sprint speed or flexibility. For instance, Chaouachi et al. (2014) reported significant enhancements in lower-limb explosive power following a short-term plyometric training intervention, yet found no notable improvements in sprint performance among professional soccer players. Similarly, Faigenbaum et al. (2007) demonstrated that while integrative neuromuscular training in children led to increased strength and agility, it did not result in significant changes in flexibility or sprint speed. These outcomes suggest that while coordination and neuromuscular interventions are effective for certain aspects of physical performance, they may have limited impact on straight-line speed and flexibility in young athletes.

This conclusion is corroborated by Moran et al., (2016) who observed diversity in reactions to sprint training among juvenile athletes, suggesting that certain strategies may be less beneficial for less advanced individuals. Thomas et al., (2017) investigated the correlation among strength, speed, and agility, concluding that although significant associations are present, enhancements in sprint performance may not necessarily result in agility improvements, suggesting the possible constraints of training methods focused solely on sprint speed without incorporating agility-specific exercises.

Conclusion

The study did not identify significant variations in flexibility outcomes, corroborating previous research that indicates flexibility improvements may necessitate independent training methods, separate from those aimed at enhancing explosive power and agility. Although certain flexibility protocols employ static stretching techniques, dynamic motions prevalent in basketball may not result in substantial flexibility enhancements, indicating a necessity for targeted training regimens to promote flexibility in athletes (Jovanović et al., 2024). The intervention resulted in significant improvements in agility and lower limb explosive power among the youth basketball players. The absence of enhancement in sprint speed and flexibility signifies a necessity to optimize the training methodologies utilized. Future research could enhance athletic performance by incorporating diverse training methodologies to effectively target agility, explosive strength, sprint speed, and flexibility.

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ORIGINAL SCIENTIFIC PAPER

Kinematic and biophysical analysis of elite Portuguese swimmer with loco motor disability between Charcot-Marie-Tooth disease and wrist amputee

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Abstract

The aim of this study was to compare biophysical characteristics of Paralympic swimmers. This case study includes two swimmers with loco motor disability classes S9, according to functional classification by international Paralympic committee – IPC. These swimmers completed a 7 x 200m crawl stroke protocol with increasing speed 0.05 05m s-1 in each level and 30s interval. Interval speeds were based on 400m race speed. VO2 consumption was measured each 200 meter directly and continuously with a telemetric portable gas analyzer (K4 b2, Cosmed, Rome, Italy) connected to a respiratory snorkel (AquaTrainer Snorkel, Cosmed, Rome, Italy). The trails were recorded on 6 video cameras each 200m swim. If the swimmer reached the Lactate plateau before completing the seventh repetition, the test was stopped. Test showed that CMT swimmer achieved a lower oxygen consumption than amputee swimmer when they reach their max speed. Video analysis of 17 and 18 body segments helped us to define some stroke parameters. Results indicated that the right arm showed larger joint angle than left. Also, amputee swimmer had larger linear displacement. Swimmers performed active drag test 10 ± 1.3s, vertical 5.4 ± 1.4 horizontal floating time 6.5 ± 1.5 and glide distance 6.6 ± 0.5m.

Keywords: *biomechanics, front crawl swimming, loco-motor displacement*

Introduction

Front crawl is the fastest discipline in swimming. When examining crawl swimming technique, there is no generally accepted protocol on what needs to be examined. There is even no consensus regarding a simple matter such as defining arm movement phases. We must note that this becomes even more difficult with persons who have locomotor impairment.

In Paralympic swimming, swimmers go through a classification process that has two crucial roles: To determine eligibility to compete; and to assign athletes to corresponding groups for competition (International Paralympic Committee, 2007). The goal and main purpose of the classification system is to enhance participation in people with disability, while minimizing the impact of impairment on the competition outcome (Tweedy & Vanlandewijck, 2011). The Paralympic swimming classification system uses a numerical calculation of locomotor ability as a guideline. This is expressed in figures showing the variation in propulsion effectiveness of swimmers with different locomotors abilities based on a dryland test (International Paralympic Committee, 1998).

It has been concluded that current classification is effective with respect to generally fair competition for most swimmers (Wu et al., 1999). However, current classification does not make any distinctions between long and short distance events.

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That can be also big advantage or disadvantage depending on the impairment group. When examining sprint events and long distance, legs can have crucial distinctive role. In long distance events legs have a tendency to sink, relative to sprint events where legs are less likely to sink (Daly & Vanlandewijck, 1999). With research Vilas-Boas et al., (2001) we can see how impairment can have positive or negative influence on swimmers performance and propulsion.

This present study applies several research procedures that will help us to introduce complexity to this study. Research procedures include an active drag test, body floating measurement, joint angle displacement and swimmer linear displacement. We hope that this will help us get a better picture and shed light on classification complexity.

Havriluk et al., (2005) found that the faster swimmers had a lower coefficient of drag. This supports the hypothesis that faster swimmers have a more hydro dynamically effective streamline. Many factors have influence on propulsion, such as wave resistance, pressure resistance and skin friction resistance (Webb et al., 2011). Body structure is not the only predictor for good propulsion. Also, it's important to say that a swimmers body changes configuration. When swimming velocity increases, active drag will decrease (Zamparo et al., 2009). In that case, it's also important to remember how the different swimming technique of different swimmer with impairment can influence active drag. Many studies show us that swimmer with limb loss (Prins & Nathan Murata, 2008) and other impairment have inability to maintain stability, rhythm of their body and reduce the potential for swimming propulsion. From research (Osborough et al., 2010) it has been seen that single arm amputee swimmer uses an asymmetric strategy to maintain the stable repetition of their overall arm stroke cycle. Swimmer with lack of lower extremity control, can have problem to maintain trunk stability (Prins et al., 2007).

Further procedures will introduce and examine differences in cardiorespiratory endurance. Cardiorespiratory endurance represents ability of the body to maintain long-term physical activity and involves relatively large muscle groups. The gold standard for testing cardiorespiratory endurance is considered to be a combination of spiro-ergometric testing and a determination of the lactate thresholds level. The parameters obtained are then used to define the objectives and to create a precise plan and training programs, as well as for the subsequent evaluation of the effects of training (Radovanović, 2013). From (Whipp, 2010) we can consider that depending on how much muscle mass we use (upper or lower limbs), VO2 max can be smaller or bigger. VO2 max is a standard of maximal aerobic power (Fernandes et al, 2008).

Aim of this study was to examine differences between swimmers who compete in the same swimming class, and also to examine some claims regarding Paralympic swimming classification. This study checked individual difference between two swimmers. We assume that this will help us to better understand difference and see technique of these two swimmer with different impairment. The second aim of the study is to see the difference between amputee side and non-amputee side in active patterns is a single swimmer. With kinematic analysing, we can analyse all necessary measurement as linear and angular displacement, velocity and acceleration. All this information can help our swimmer make some corrections and improve swimming techniques.

The following research questions were tested to judge the differences in performance between the two swimmers studied: a) arm stroke patterns, b) active drag time c) VO2 use, d) buoyancy, e) different in active arms patterns between amputee side and non-amputee side.

Methods

Two male Paralympic swimmer class (S9) Portugal National team according to the functional classification of the International Paralympic Committee IPC, volunteered to take part in this study swimming in competition conditions. Swimmers difference in body mass (77.9±4.6 kg of, and 178±12cm in height), best performance in 400m freestyle shown in the Table 1 put them on 3, and 73 place on World Record standing for year 2015. One swimmers was an arm amputee, and the econd was with Charcot-Marie-Tooth disease (CMT).

All measurement were done in Faculty of Sport, University of Porto (FADEUP). Swimmers were informed about the procedures of data collection and signed the consent form, participating voluntarily. Reanimation equipment was available. Information was used only for research purposes, and was made available to all participants. Participants could ask questions at any time during the procedure. Participants swam only one time for the purpose of the research. This was approved by the ethics committee of the University of Porto 2014.

Testing protocol

Hydrodynamic drag (HD) was tested to evaluate their hydrodynamic abilities. For evaluation of HD the active drag was determined as described by Kolmogorov & Duplishcheva (1992), based on the principle of conservation of mechanical maximal propulsion power (P) of the swimmer. For this study we used two distinct swimming programs, both with maximal speed: Each swimmer performed two 25m crawl swims starting in the water. Each swimmer accelerated progressively in the first 10 m of the swimming pool and then maintain the same speed until the end of pool. An interval of 20 minutes rest was taken. Thirteen meter of pure swimming time was timed using video pictures from both swimming trials. External references, were placed at 11m of origin of the wall and ending at 24m of arrival of the wall. In the second trial the swimmer towed a body with known hydrodynamic properties (Vila-Boas et al., 2001). This body was attached to the waist of the swimmer and at a 10m distance, in order to minimize the influence of hydrodynamic wave produced by the swimmer. For our research we used only digital timer for timing performance of swimmer for active drag. At the end, times were compared between two swimmers.

Horizontal, vertical buoyancy and glide protocol

Swimmers were tested for vertical, horizontal buoyancy and ventral glide. For vertical buoyancy, swimmers keep straight position, hands are next to the body and for 15-20 seconds, swimmers need to exhale air from their body. Second persons need to time his buoyancy until head is totally submerged into the water. Horizontally floating position: swimmer lays on the water, and from strength position needs to relax his body. Second person needs to time until the body goes into vertical position in the water. At the end, swimmer pushes his body from the edge and tries to make the longest glide distance (Cazorla, 1993).

Incremental protocol

Later, swimmers participated in an incremental intermittent protocol which consisted of seven times 200m front crawl swim vVO2max, with an increase of 0.05ms-1 in each level and a 30s rest interval. The speed of the first level was determined, based on the swimmers best 400m time. Each swimmer completed no more than seven repetitions. If one of the swimmer reached a plateau, the procedure ended. The VO2 max sampling was breath by breath and started at the beginning of the 1st repetition recording the data until the last one, continuously. Telemetric portable gas analyzer (K4 b2 COsmed, Rome, Italy) was used to measure VO2. We obtained averaged value of VO2 from each 200m step. In this protocol, their total time per each 200 m swimming phase and increased speed in m/s also was measured.

During the protocol, lights (GBK-Pacer2, GBKEletronica Aveiro-Portugal) were used at the bottom of the 25m pool to control the speed of swimming and to help swimmers obtain an even pace throughout each step. After coming to the pool, swimmers were assessed by the bioelectrical impedance analysis method, using a bio impedance scale (Tanita TBF 305, Japan) for the measurement of body composition, and height. VO2 was directly and continuously measured with a portable analyser of telemetric gases (K4 b2 COsmed, Rome, Italy) connected to a respiratory snorkel (Aqua Trainer Snorkel ®, Cosmed, Rome, Italy). For kinematic analysing, the body was divided into 17 and 18 segments. We need these body points to analyze and calibrate with The Ariel Performance Analysis System (APAS). This software can measure, analyses and presents movement characteristics. Body points include: head, mouth, shoulders, elbow, wrist, fingers, hips, knees, knee joint, and foot finger. Also, all this parts are divided on the left and right side. Before the incremental protocol, preference markers were added to the body, using tape and put on specific body spots. After that, three photographers, using three cameras (twelve megapixel), simultaneously photographed the swimmer in the frontal view as well as right and left view.

Regarding the video acquisition, six cameras (four underwater and two above water cameras) were used for calibration. Calibration box can harmonize all cameras in one and get much more reliable data. With the video obtained from each camera, arm stroke cycle was analyzed twice for each step:

(1) between 75 and 100 meter

(2) between 175 and 200 meter

Our protocol measure will consider only two swim times, one at 100 meter and another at 175 meter. We use Mean (M) to see percentage joint angle and linear displacement for forearm of both swimmer and then analyse and compare asymmetric stroke strategy. With this measurement we can see which swimmer makes M to easily analyze and see deviation between each stroke. This overall M will help us to give conclusion about difference between phases. Also, we can compare the difference between each of this 7 phases, and how much they change during swimming. For this protocol, we need to use APAS system program (Ariel Dynamic, San Diego, USA). Figure two present body point that we will use for analyzed body segments after swimming time.

Data analyses

Video analyses will be digitalized using APAS system (Ariel Dynamic, San Diego, USA) at a frequency of 50Hz, manually and frame by frame, defining an 17 and 18 body segments model. The anthropometric biomechanical model will be used from Zatsiorsky adapted by de Leva (1996). The Zatsiorsky-Seluyanow's present model of 21 landmarks (vertex, 7th cervical, mandible, humeral heads, ulnohumeral joints, radio carpal joints, 3rd dactylions, trochanter major of femurs, tibiofemoral joints, talocrural joints, calcanei and acropodion). This model is used to analyse kinematic data.

Converting Swim Times to Point Scores

We use Converting Swim Times to Point Scores to compare performances among functional classes on the assumption that the able body events are about equally competitive (Daly et al., 1999). For this we use two specific formula:

WR- world record (for each event receives 1000 points) Cevent - present swimmer time

Formula: Cevent= WR(3) × 1.000

When all constants are known, each individual time can be assigned a point score specific to the event as:

Individual performance point = Cevent × individual event time(-3)

Results

Table 1. World Record standing 2015. Period begin – period end (01.01.14- 31.12.15)

Men's 400m Freeestule S9	World Standing	NPC	Birth	Swim - Time	Time (ms)	Points
IPC Swimming - World Record standing S9	1	AUS	1997	04:10.90	250.90	1000
	2	ITA	1999	04:17.50	257.50	911
	Amputee-3	POR	1988	04:23.79	263.79	850
	CMT-73	POR	1982	05:49.08	349.08	368
	74	MEX	2000	05:49.48	349.48	366

Table 2. Characteristic of the participants

Name	Class	Age	Weight	Height	Longitude (arm span)	WR-standing
Class 9 amputee	S9	27	81.5	1.90	1.72	3
Class 9 CMT	S9	33	77.9	1.78	1.78	73

Table 3. Results for drag test with - without towing device, horizontal - vertical floating and glide measurement

Name	Drag without (13m)	Drag with (13m)	Flot.Hor	Flt.Vert	Glide
Class S9 Amputee	7.65s	8.71s	4s	6.85s	7.20m
Class 9 CMT	10.03s	11.28s	8.92	4s	6.10m

Table 4. Present maximal oxygen consumption for this two swimmer true seven swimming phases, for the end of each test and presented VO2 (ml O2/kg/min)

Phase	Class S9 Amputee (ml O2/kg/min)	Class 9 CMT (ml O2/kg/min)
First 200m	39.7	25.43
Second	40.3	27.64
Third	41.3	30.94
Fourth	56.5	35.97
Fifth	55.9	39.45
Sixth	57.5	43.45
Seven	...	48.55

Table 5. First column present swimmer time for 200 meter and second, speed in meter/second

Phase	Class S9 Amputee	Speed m/s	Class 9 CMT	Speed m/s
First 200m	3.25s	0,97	4.06s	0,81
Second	3.16s	1,02	3.52s	0,86
Third	3.07s	1,07	3.39s	0,91
Fourth	2.59s	1,12	3.27s	0,96
Fifth	2.51s	1,17	3.18s	1,01
Sixth	2.44s	1,22	3.09s	1,06
Seven	...	...	3.0s	1,11

Table 6. Mean of swimmers joint angular displacement for forearm

		Right arm	Left arm	Right arm	Left arm
First	100	81	77	107	80
	175	93	76	47	60
Second	100	82	60	90	70
	175	93	88	45	50
Third	100	87	66	106	77
	175	95	72	47	54
Fourth	100	88	70	99	70
	175	94	65	45	51
Fifth	100	92	76	99	69
	175	91	75	44	55
Sixth	100	83	69	96	73
	175	86	75	45	51
Seven	100	…	…	96	70
	175	…	…	40	54
Averege	-	89	72	72	63

Table 7. Mean for swimmers linear-displacement for forearm. Measurement present m/s for each phase 100 and 175 swimming phase

		Right arm	Left arm	Right arm	Left arm
First	100	1.313	1.501	0.969	0.978
	175	1.351	1.509	1.023	1.235
Second	100	1.139	1.566	1.044	0.885
	175	0.911	2	1.068	1.117
Third	100	1.327	1.528	1.069	1.194
	175	1.052	1.5	1.078	1.117
Fourth	100	1.226	1.493	0.927	0.976
	175	1.217	1.529	1.1	1.15
Fifth	100	1.38	1.406	0.956	0.979
	175	1.163	1.413	1.154	1.092

(continued on next page)

(continued from previous page)

Table 7. Mean for swimmers linear-displacement for forearm. Measurement present m/s for each phase 100 and 175 swimming phase

		Right arm	Left arm	Right arm	Left arm
Sixth	100	1.13	1.42	1.008	1.005
	175	0.96	1.45	1.163	0.834
Seven	100	…	…	0.91	0.991
	175	…	…	1.137	0.941
Average		1.181	1.526	1.043	1.035

Discussion

This study had wide purpose: to describe difference between two swimmers who compete in the same swimming class, how different impairment had impact on drag, floating, glide, VO2max, joint angle displacement and linear displacement. Better Paralympic classification is needed in order to minimise the impact of impairment on the outcome of competition. Additionally, classification system needs to be able to describe type and severity of impairment, and methods used for allocating classes (Tweedy & Vanlandewijck, 2011).

Limb loss can be a big problem and affect on body position and laterally stability of torso, can also have an effect on cross-section area (Prins et al., 2008). Hypothetically, we can see difference between two hands for one stroke circle in joint angle and linear displacement. Depends on body roll, it can reduce ability of the trunk to provide stable anchor to upper and lower body, and at the end may cause increasing drag force (Prins et al., 2007). Satkunskiene et al., (2005) reported that "more-skilled" swimmers, with various locomotor disabilities, were characterized by greater amounts of superposition and higher stroke frequencies, when compared to "less-skilled" swimmers. This is related to our study because amputee swimmer was more skilled swimmer than CMT. This can tell us that people who don't train so hard and start to training late, cannot expect good results. They probably will have disadvantage comparing to another swimmers who have more experience. This is important to say, because physical ability and experience cannot be included in classification system. That's something that swimmer and person get with their years disclaimer. Chatard et al, (1992) they discussed that spastic swimmers can have more difficulty than amputations to maintaining their body in a balance position for a correct gliding position than other swimmers. Also VO2max depends to the degree of the physical disability. Unfortunately, this study did not compare swimmers by their swim class, but at least did give us a good observation and information about to which degree can the specific disability be advantage or disadvantage. Fernandes et al., (2008) this study included high-level swimmer, measured in swimming pool condition. It measured the time to exhaustion at the minimum velocity that elicits maximal oxygen consumption (TLim at vVO2 max), and the corresponding VO2 slow components (O2SC). VO2 was measured through direct oximetry and the swimming velocity was controlled using a visual light-pacer. Special purpose of this study was to assess, in free swimming conditions and with high level swimmers, the time to exhaustion at the minimum velocity that elicits VO2max. Results show how much influence individual training and body composition can have on VO2max. Out study also confirm constitution that VO2max will depend of swimmers surface area. That means that fastest swimmer had higher energy cost. Arm amputee swimmer needs to compensate swimming technique and gets tired easier than CMT swimmer.

With study (Kolmogorov et al., 1992) and our results we can hypothesis, that each swimmer because of their anthropometric and in this case different impairment, have their own swim style. This portion needs to be more researched because some swimmer can have advantage or disadvantage against another swimmer. Unfortunately, our study had only two swimmers and we cannot confirm that constitution. In this case, second research question present that because of his impairment, CMT swimmer had disadvantage comparing to amputee. CMT probably have less muscle mass. In that case he can have problem to absorb his lack of buoyancy. CMT swimmer has smaller surface aeria and his muscle atrophy disease in his legs can indicate that he had lower score for active drag. Still, small sample cannot conclude that. Also, because swimmers are too different in coaching, body structure, ages and even results present that difference.

Result from first chapter where we measure horizontal buoyancy maybe hide the answer to our fourth research question that swimmer who has more muscle tone, probably sinks into the water faster with horizontal position of the body. We need to consider that person with more body fat, will float easily than body with less body fat. Also greater muscle mass can be result for tendency of body sinking into the water (Katherine et al., 2011). In this case we can speculate that person with an amputation had greater muscle mass in legs than CMT, where his disease decrease his muscle tone in this case in his lover extremities. In the same time CMT swimmer have smaller drag when they push their own body from the wall. Again, this is probably because of smaller muscle tone, his legs are not able to absorb more energy and push himself-longer than swimmer with more muscle tone. For each swimmer, frontal profile present important rule to minimize drag force and swimmer with lack of lower extremity control can have problem keeping the perfect track control (Prins et al., 2007).

Conclusion

From our research we can see that amputee swimmer probably has a better body posture and he performs better time in drag with and without tube. Also he performed better result time in each 200 meter and increased per m/s. Also his glide it's longer than CMT swimmer. CMT swimmer showed lower oxygen consumption and he didn't reach lactate plateau. Again because of big difference of impairment any kind of conclusion without more participants, would not be correct. We can only hypothesize about all these results because swimmers had different posture of body, impairment and age. Right arm for both swimmers provide bigger joint angle than their left arm, but amputee swimmer had bigger angle in both arms if we compare with CMT swimmers results.

This research shows us some of the differences between swimmers and from the results we can also conclude that amputee swimmer has better results regarding linear displacement. Lot of studies compare different classes and impairment and they find how much each of them is different during swimming process. Results need to show us how much one disability has advantage over another in the competitive swimming. With all this knowledge we can see if some swimmers have advantage over another and where is that advantage.

Bio-mechanical characteristics of the physically impaired swimmers are not well known. Future studies will contribute to a better process of classification of these swimmers by The International Paralympic Committee. New analysis also needs to support and develop specific training methods to increase swimmers performance. One of the main ideas of this paper is to get information about the rules of classification and with that information make them even better if possible. People need to have same rights and rules which must be observed in order to create equality among disabilities so one does not have any advantage over other participants. If we want to confirm these findings, more swimmers need to be examined.

From shortcoming of the study, mistakes are possible, and we should have more participants to provide the accuracy of data that we want to achieve. This research needs to help us to see difference and improve awareness and modification of the classification system. That is the only way that we can improve fairness of classification system. Unfortunately it's not clear how this problem can be successfully resolved without any loopholes. All of this issues need to be researched so that in the future, we can expected this to help us create better system that provides equality between different classes of disability.

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May 2022

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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.

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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
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Word count: 2,980

Abstract word count: 236

Number of Tables: 3

Number of Figures: 3

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- ✓ In one study (Duffield & Marino, 2007), soccer players…
- ✓ In 2007, Duffield and Marino's study of soccer players…

Works by three or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Bangsbo et al. (2008) stated that…
- ✓ In one study (Bangsbo et al., 2008), soccer players…

Works by organization as an author: cite the source, just as you would an individual person

- ✓ 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/

2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word Note (italicized) followed by a period.

✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. $^{a, b, c}$), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript ^{a}.

✓ ^{a}One participant was diagnosed with heat illness and n = 19.^{b}n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

✓ *P<0.05,†p<0.01.

2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

✓ Table 1 (first letter in all capitals and no full stop)
✓ ...as shown in Tables 1 and 3. (citing more tables at once)
✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. IT-SPA prefers TIFF, EPS and PNG formats.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.

Figures and figure legends should be completely intelligible without reference to the text. The price of printing in color is 50 EUR per page as printed in an issue of IT-SPA.

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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