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ASSOCIATION BETWEEN LOWER-LIMB EXPLOSIVE STRENGTH WITH SELECTED MORPHOLOGICAL CHARACTERISTICS IN SOCCER PLAYERS AGED 13–15 YEARS

Original research

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ABSTRACT

This study aimed to determine the relationship between lower-limb explosive strength and selected morphological characteristics in soccer players aged 13, 14, and 15 years, as well as to identify differences between the age groups. The sample consisted of 45 youth soccer players (n = 45), with 15 participants in each age category, recruited from a local soccer club.

The morphological characteristics assessed included body height, body mass, leg length, body fat percentage, and muscle mass. Lower-limb explosive strength was evaluated using the following tests: squat jump, countermovement jump, drop jump, stiffness test, and standing long jump.

The results demonstrated that muscle mass and leg length positively correlated with explosive performance, whereas body fat percentage showed a negative correlation. Statistically significant differences were also found between the age groups for most variables, with the oldest players (15 years) achieving superior performance across all explosive strength tests.

Keywords: motor abilities, anthropometry, body composition, adolescents

INTRODUCTION

Soccer is a sport that requires a combination of aerobic and anaerobic capacities, explosive strength, agility, speed, and technical–tactical skills. Its structure includes activities that demand the production of maximal muscular force in the shortest possible time, which represents one of the core definitions of explosive strength (Bajramović et al., 2015). Due to the dynamic nature of the game, players must be capable of rapid accelerations, quick changes of direction, jumps, and repeated sprints, while maintaining high endurance throughout the match. A positive relationship between lower-limb explosive strength and motor abilities, such as speed and agility, in football players has been well-documented (Ajay & Devarshi, 2015; Ajay & Devarshi, 2013; Đošić, 2016). These authors emphasise the importance of developing explosive lower-limb strength in youth football training, as it significantly contributes to improvements in agility, speed, and overall fitness performance. Furthermore, Baze et al. (2025) demonstrated that greater lower-limb explosive strength is correlated with better agility and sprint performance. Similarly, Hammami et al. (2025) found that the application of plyometric training improves performance in youth soccer players. According to Zhang and Yu (2023), complex strength training significantly enhances the explosive power of the lower limbs in young footballers.

In practice, this means that improving lower-limb explosive strength elevates other motor abilities of football players to a higher level. Lower-limb explosive power is one of the key determinants of success in football, as it enables rapid starts, changes of direction, jumping, and striking actions. Vertical jump height largely depends on an athlete's anthropometric characteristics, with body mass and lower-limb length directly influencing the ability to generate force and movement velocity (Marković & Jarić, 2007).

During the pubertal period (ages 13–15), significant changes occur in morphological characteristics and motor abilities. Mroczek et al. (2022) reported that increases in age are accompanied by increases in height, body mass, and muscle tissue, while body fat percentage tends to decrease. As noted by Zanini et al. (2020), a higher percentage of body fat is associated with poorer agility in young football players. The results of their study confirmed a significant negative correlation between body fat and lower-limb explosive strength.

These developmental changes indicate that systematic training and biological maturation strongly influence body composition and the gradual formation of a morphological profile typical for youth football players. Toselli et al. (2022) observed that the greatest differences in body composition and physical performance assessments were found among younger age groups (U12–U14).

METHODS

Sample of Participants

This cross-sectional study included 45 youth soccer players aged 13, 14, and 15 years (15 players in each age group), with an average age of 14.0 ± 0.8 years. All participants were active players from a local football club and had a minimum of three years of training and competitive experience.

Variables

B Morphological characteristics: body height (BH), body mass (BM), leg length (LL), body fat percentage (BF%), muscle mass (MM).

Lower-limb explosive strength tests: squat jump (SJ), countermovement jump (CMJ), drop jump (DJ), stiffness test (ST), and standing long jump (SLJ).

Instruments and Procedure

The selected variables of lower-limb explosive strength (squat jump, countermovement jump, drop jump, and stiffness test) were measured using the Optojump Next system (Microgate, Bolzano, Italy), while the standing long jump was assessed using a long-jump mat with a distance scale marked in centimetres. Optojump Next is an optical measurement system composed of a transmitting and a receiving bar. The laser beams emitted from the transmitting bar continuously "communicate" with those on the receiving bar. The system detects any interruption in this communication and calculates its duration, allowing for the measurement of flight time and ground contact time during jumping tasks with an accuracy of 1/1000 of a second.

Morphological characteristics were assessed using the InBody 370 body composition analyser, the InBody BSM370 stadiometer/scale, and a standard anthropometer. All morphological measurements were performed in accordance with standardised protocols defined by the International Biological Programme (IBP), following procedures described by Mišigoj et al. (2008). The instruments used included: an anthropometer with an accuracy of 0.01 cm (for measuring leg length, according to Martin's protocol), the InBody 370 analyzer (for body fat percentage and muscle mass), and the InBody BSM370 (for body height and body mass).

Bioelectrical impedance analysis (BIA) was used to assess body composition. Based on the entered data (height, sex, and date of birth), the device software calculates total and segmental body fat percentage (%BF), as well as total muscle mass (kg MM). Before body composition testing, participants refrained from consuming food and from engaging in physical activity for at least three hours.

Before testing, all participants submitted a consent form signed by a parent or legal guardian, confirming voluntary participation and acknowledgement of the procedures in accordance with the 10th edition of the Declaration of Helsinki (2024). All measurement instruments were calibrated, and their metric characteristics were verified before use.

Participants were informed about the procedures and the order of testing to prevent any factors that could compromise data quality. Due to their specific nature, morphological variables were assessed first to avoid fluctuations in body mass or hydration status and ensure optimal measurement precision. Following the morphological assessments, participants performed a standardised warm-up that included light-intensity running and dynamic and

static stretching exercises. After the warm-up, the explosive strength tests were administered. The temperature of the testing environment ranged between 22°C and 25°C.

Statistical Analysis

The collected data were analysed using the IBM SPSS Statistics software package (version 25). Descriptive statistics, Pearson's correlation coefficient, and one-way ANOVA were applied to compare differences between age groups. The level of statistical significance was set at $p < 0.05$ to ensure the validity of the conclusions.

RESULTS

The results of the study are presented through three analytical segments: descriptive statistics (Table 1), correlation coefficients between explosive strength variables and morphological characteristics (Table 2), and analysis of variance (Table 3).

Table 1. Descriptive statistics of the participants

Variables	N	Min	Max	Mean	SD
Age	45	13	15	14.00	.826
Body height – BH (cm)	45	148.40	189.50	169.74	10.51
Body mass – BM (kg)	45	37.70	82.80	57.72	11.77
Body fat percentage – BF (%)	45	5.40	29.90	12.94	5.07
Muscle mass – MM (kg)	45	17.40	42.80	27.89	6.46
Leg length – LL (cm)	45	75.00	103.00	89.89	7.13
Squat jump – SJ (cm)	45	17.20	37.40	26.11	5.20
Countermovement jump – CMJ (cm)	45	17.80	42.10	27.04	5.71
Drop jump (from 30 cm) – DJ (cm)	45	13.00	41.50	24.67	6.00
Stiffness test (7 jumps) – ST (s)	45	5.72	29.91	18.30	5.95
Standing long jump – SLJ (cm)	45	159.00	245.00	195.46	22.17

Abbreviations: N – Number of participants, MIN – Minimum values, MAX – Maximum values, MEAN – Mean values, SD – Standard deviation.

Based on the descriptive indicators presented (Table 1), it can be concluded that the sample of soccer players aged 13, 14, and 15 years demonstrates a continuous pattern of growth and development across all measured characteristics. The average values of height, body mass, muscle mass, and low body fat percentage indicate that the participants are in a phase of accelerated biological maturation, which is consistent with expected developmental changes during adolescence and with adaptations resulting from football training. The observed standard deviation values confirm a relatively homogeneous sample composition, which contributes to the reliability of the analysis.

The results of the correlation analysis (Table 2) further confirm the interrelationship between the selected explosive strength variables and morphological characteristics. A positive and statistically significant correlation was found between muscle mass and the performance in all explosive strength tests ($r = 0.40–0.58$; $p < 0.01$), while body fat percentage showed a negative correlation with the same tests ($r = –0.30$ to $–0.37$; $p < 0.05$). These findings indicate that a higher proportion of muscle mass enables greater force-generation capacity within a short time frame, whereas increased body fat has the opposite effect.

Table 3. Analysis of Variance – Comparison Across Age Groups (13, 14, and 15 Years)

Variables		SS	df	MS	F-value	p
Body height – BH (cm)	BG	2263.52	2	1131.765	18.274	0.000
	WG	2601.21	42	61.934		
Body mass – BM (kg)	BG	1999.87	2	999.938	10.235	0.000
	WG	4103.33	42	97.698		
Body fat percentage – BF (%)	BG	145.20	2	72.602	3.090	0.056
	WG	986.74	42	23.494		
Muscle mass – MM (kg)	BG	704.88	2	352.445	13.048	0.000
	WG	1134.47	42	27.011		
Leg length – LL (cm)	BG	1003.27	2	501.638	17.077	0.000
	WG	1233.72	42	29.374		
Squat jump – SJ (cm)	BG	514.33	2	257.170	15.938	0.000
	WG	677.70	42	16.136		
Countermovement jump – CMJ (cm)	BG	687.03	2	343.518	19.239	0.000
	WG	749.93	42	17.856		
Drop jump (from 30 cm) – DJ (cm)	BG	729.25	2	364.627	17.827	0.000
	WG	859.04	42	20.453		
Stiffness test (7 jumps) – ST (s)	BG	606.53	2	303.266	13.386	0.000
	WG	951.54	42	22.656		
Standing long jump – SLJ (cm)	BG	11232.13	2	5616.067	22.656	0.000
	WG	10411.06	42	247.883		

BG – Between groups, WG - Within groups SS – Sum of Squares, df – degrees of freedom, MS – Mean square, p -statistical significance level

Table 2. Correlations Between Explosive Strength Variables and Morphological Characteristics

	Variables	1	2	3	4	5	6	7	8	9	10	11
1	Age	1	.640**	.559**	-.208	.588**	.632**	.469**	.452**	.376*	.524**	.673**
2	Body height – BH (cm)	.640**	1	.842**	-.386**	.909**	.897**	.531**	.547**	.405**	.465**	.553**
3	Body mass – BM (kg)	.559**	.842**	1	.011	.962**	.700**	.507**	.504**	.343*	.430**	.525**
4	Body fat percentage – BF (%)	-.208	-.386**	.011	1	-.255	-.390**	-.335*	-.325*	-.301*	-.369*	-.244
5	Muscle mass – MM (kg)	.588**	.909**	.962**	-.255	1	.764**	.578**	.569**	.404**	.514**	.566**
6	Leg length – LL (cm)	.632**	.897**	.700**	-.390**	.764**	1	.452**	.486**	.348*	.411**	.477**
7	Squat jump – SJ (cm)	.469**	.531**	.507**	-.335*	.578**	.452**	1	.919**	.765**	.658**	.630**
8	Countermovement jump – CMJ (cm)	.452**	.547**	.504**	-.325*	.569**	.486**	.919**	1	.809**	.562**	.613**
9	Drop jump - DJ (cm)	.376*	.405**	.343*	-.301*	.404**	.348*	.765**	.809**	1	.570**	.628**
10	Stiffness test - ST (s)	.524**	.465**	.430**	-.369*	.514**	.411**	.658**	.562**	.570**	1	.611**
11	Standing long jump – SLJ (cm)	.673**	.553**	.525**	-.244	.566**	.477**	.630**	.613**	.628**	.611**	1

Note: $p < 0.05$ indicated with (*), $p < 0.01$ indicated with (**); significant correlations determined using Pearson's correlation coefficient.

The results of the one-way ANOVA (Table 3) showed statistically significant differences between the age groups of soccer players (13, 14, and 15 years) in almost all analysed variables ($p < 0.001$), except for body fat percentage ($p = 0.056$). The largest differences were observed in body height ($F = 18.27$), leg length ($F = 17.08$), and standing long jump performance ($F = 22.66$), clearly indicating a strong influence of biological maturation on morphological and motor performance. The findings show that the oldest group (15-year-olds) achieved superior results in explosive strength tests, which can be attributed to increased muscle mass and biomechanical advantages associated with growth.

Significant differences were also identified in the squat jump ($F = 15.94$; $p < 0.001$), countermovement jump ($F = 19.24$; $p < 0.001$), drop jump ($F = 17.83$; $p < 0.001$), and stiffness test ($F = 13.39$; $p < 0.001$). These results confirm that the development of explosive strength and reactive abilities shows a clear relationship with age. This can be explained by greater muscle mass and improved intermuscular coordination, which enables more efficient execution of movements requiring rapid direction changes and high force production in a short time.

On the other hand, the absence of significant differences in body fat percentage ($p = 0.056$) may indicate a similar training regimen and controlled body composition across all three age groups.

DISCUSSION

This study identified significant associations between anthropometric characteristics and explosive strength, as well as clear differences between age groups. The results confirm that muscle mass and leg length have a dominant influence on explosive performance in young soccer players (Franca et al., 2023).

The negative correlation between body fat percentage and jump performance indicates that a higher proportion of fat reduces jump take-off efficiency, which is consistent with previous findings by Marković (2007) and Starzak et al. (2015). These results also support the conclusion that a greater proportion of muscle mass enhances the ability to generate force within a short time frame, whereas an increased amount of body fat has the opposite effect. According to Marković and Mikulić (2010), optimal body composition and neuromuscular coordination play a crucial role in the development of explosive strength in youth football players.

Similarly, findings from Čović et al. (2017) showed that body composition parameters measured using bioelectrical impedance analysis (BIA) significantly correlate with sprint speed and other forms of explosive movements in young soccer players. The authors indicate that a higher muscle mass and lower body fat percentage contribute to more efficient force production and faster movement execution, directly influencing performance in explosive strength tests.

The ANOVA results further confirm that age has a significant impact on most variables, which is expected given growth-related changes, increases in muscle mass, and accumulated training effects.

The overall findings reveal a clear pattern of relationships between morphological and motor abilities in players aged 13–15. For most variables, growth and maturation appear to directly influence improvements in lower-limb explosive strength. The older age groups demonstrated superior performance across all explosive strength tests, indicating that increases in muscle mass and leg length contribute to more efficient jump take-off mechanics and greater force production in short time intervals. Lehnert et al. (2024) also reported that biologically more mature soccer players achieve better sprint and explosive strength performance, primarily due to their ability to recruit a higher percentage of motor units, exhibit better coordination, and utilise more effective muscle pre-activation.

A particularly pronounced difference between the youngest and oldest groups was observed in both vertical and horizontal jump tests, indicating that biological maturity and muscular development play a crucial role in achieving better performance outcomes. This study confirms that the greatest improvement in explosive strength occurs during late puberty, a period characterised by increases in muscle mass and enhanced neuromuscular coordination. Similar results were reported by Yapıcı et al. (2022), who confirmed that the level of biological maturity is significantly associated with vertical jump height and muscle strength in adolescents. The authors emphasised that, as biological maturation progresses, neuromuscular function and force-generation capacity improve, resulting in better performances in explosive strength tests. Their findings support the results of the present study, suggesting that the differences between younger and older players in vertical and horizontal jumps are primarily due to muscular development and increases in muscle mass.

The negative relationship between body fat percentage and explosive strength test performance indicates that an increased proportion of fat has a limiting effect on speed and explosive power. This study confirms the importance of continuous monitoring of body composition and nutritional regulation in young soccer players, especially during periods of rapid growth when changes in body mass are most pronounced. The absence of significant differences in body fat percentage between age groups may reflect similar training regimens and well-regulated body composition across the sample. These results align with the findings of Malina, Bouchard, and Bar-Or (2004), who emphasised that the greatest differences in explosive abilities among adolescents emerge during periods of accelerated growth.

Finally, Cossio-Bolaños et al. (2021) found that speed and explosive strength represent key performance indicators in youth soccer players and can be significantly improved through targeted, structured training interventions. Supporting this, Aloui et al. (2021) demonstrated that an additional eight-month program combining plyometric training and short sprints has a positive effect on improving speed and explosive strength in youth football players, further confirming the importance of targeted interventions in the development of motor abilities.

CONCLUSION

The results of this study indicate a strong association between anthropometric characteristics and lower-limb explosive strength, as well as significant differences between age groups. Older players (15 years) achieved better performance in explosive strength tests, which is related to greater body height, higher muscle mass, and longer leg length.

The observed differences between age groups, together with the significant correlations between anthropometric and motor indicators, suggest that the training process should be adapted to each player's developmental stage, particularly in terms of training and competition periodisation. Based on the findings, it is recommended that younger players be gradually introduced to explosive-type exercises through football-specific games and simple plyometric drills, while more complex exercises with external load may be implemented in older players.

Overall, the results confirm that success in explosive strength tests is not solely a reflection of training experience but rather a combination of biological maturity, optimal body composition, and well-structured training. This study may serve as a basis for developing normative values and designing individualised training programs within youth football selections.

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Conflict of Interest

The authors do not have any conflicts of interest to disclose. All co-authors have reviewed and concurred with the manuscript's content, and no financial interests need to be reported.