

The association between biological maturation and motor performance in U13 and U15 youth football players

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Abstract

Purpose: Biological maturation plays a considerable role in the development and performance of youth football players, particularly during adolescence, when substantial interindividual differences in growth and physical development occur. This study aimed to examine the relationship between biological maturation and anthropometric characteristics, motor performance, and sport-specific ball skills in U13 and U15 youth soccer players. The secondary aim was to examine differences in these outcomes between biological maturity groups within each age category (U13 and U15). **Methods:** The sample consisted of 378 male youth football players from Dalmatia (U13: n = 214; U15: n = 164). Anthropometric measurements included body height, body mass, body mass index, and sitting height. Biological maturation was estimated using age at peak height velocity (APHV) according to the Mirwald method, and players were classified as less mature, average, or more mature. Motor performance was assessed using sprint tests (5 m, 20 m, 20 m with the ball), explosive power tests (standing long jump, medicine ball throw), and agility tests (slalom with and without the ball). Associations between maturation and performance were examined using Pearson correlation coefficients, while one-way ANOVA was used to analyze differences between maturity groups. **Results:** Biological maturation showed significantly large correlations with anthropometric variables in both age groups, including body height (U13: $r=0.65$; U15: $r=0.73$) and body mass (U13: $r=0.59$; U15: $r=0.83$; $p<0.001$). In the U13 group, a significant association with motor performance was observed only for the medicine ball throw ($r=0.56$), while other tests showed trivial or non-significant correlations. In contrast, in the U15 group significant correlations were found for standing long jump ($r=0.66$), medicine ball throw ($r=0.70$), 5 m sprint ($r=-0.34$), and 20 m sprint ($r=-0.52$). Significant relationships with ball-related tests were also observed in U15 players for the 20 m sprint with the ball ($r=-0.51$) and slalom with the ball ($r=-0.42$). Furthermore, more mature players showed dominance in motor performance tests in the U15 generation, whereas in the U13 generation differences were also found; however, they were less pronounced, and more mature players were not always the most successful. **Discussion:** The results indicate that biological maturation is more strongly related to performance with increasing age. In the U13 group, most players have not yet reached peak height velocity, which may explain the weaker associations between maturation and motor performance. In contrast, many U15 players are closer to or have already passed their growth spurt, resulting in greater body size, strength, and power that contribute to improved performance in both physical and ball-related tests. **Conclusions:** Biological maturation shows stronger associations with motor and sport-specific performance in U15 than in U13 football players, highlighting the importance of considering biological maturity in talent identification and selection processes.

Key words: maturation, motor performance, talent identification, growth spurt

Introduction

Adolescence is characterized by substantial variability, particularly in body size and morphological characteristics (Rađa, Erceg and Grgantov, 2013; Rađa, Erceg and Milić, 2016; da Costa et al., 2023). This variability is especially pronounced during the initial stage of the long-term training process of young football players (Unnithan et al., 2012). Large developmental differences among young players further complicate talent identification and progression, mainly due to the well-known role of biological maturation in youth football players (Coelho e Silva et al., 2010; Malina, 2014). Children with early, average, and late maturation are often grouped by the same chronological age (CA) in many sports organizations worldwide, including school activities and club teams (Itoh and Hirose, 2020). Biological maturation can lead to both anthropometric and physical variations among individuals within the same chronological age group (Gundersen et al., 2022). Previous research has shown that early-maturing players are, on average, taller and heavier (Figueiredo et al., 2009; Vandendriessche et al., 2012; Gouvea et al., 2016) and often outperform their less mature peers in football-specific tasks such as jumping, sprinting, and changing direction (Gonzalo-Skok and Bishop, 2025), as well as in strength, speed, and agility (Vandendriessche et al., 2012). Such results lead coaches to more frequently select early-maturing players in their clubs' talent identification and selection programs (Williams and Reilly, 2000; Malina et al., 2007). Interestingly, in sport-specific ball-related motor tests, early-maturing players did not

demonstrate the same dominance as they did in the previously listed non-ball-related motor abilities (Figueiredo et al., 2009; Figueiredo et al., 2010; Vandendriessche et al., 2012).

Understanding the relationship between biological maturation and performance in football is particularly important, as the onset of puberty often coincides with the selection of players for youth academies, elite teams, and national squads (Gundersen et al., 2022). Evidence consistently shows that biological maturation is associated with youth physical performance. In a review of multiple sports including football, Malina (1994) summarized the impact of biological maturation on strength, power, and speed, while Vandendriessche et al. (2012) reported similar associations across strength, speed, agility, and flexibility assessments in youth football players. Furthermore, the development of aerobic capacity in young football players is significantly related to biological maturity (Valente-dos-Santos et al., 2012). More recent research (Gundersen et al., 2022; Hermassi et al., 2024; Konarski et al., 2024; Hironaga et al., 2025) corroborates most of these findings, emphasizing the strong impact of biological maturity on speed and explosive power abilities. However, technical skills involving the ball demonstrated markedly weaker associations with biological maturation compared to physical abilities. No significant relationships were observed between biological maturation and various technical skills, including dribbling, ball control, shooting accuracy, and the wall pass test (Figueiredo et al., 2009; Vandendriessche et al., 2012; Gouvea et al., 2016). Furthermore, although Malina et al. (2005) identified some significant associations between biological maturation and ball control with the body (explaining 13% of the variance), ball control with the head (14% of the variance), and dribbling with a pass (21% of the variance), the relatively small proportion of explained variance suggests that maturation plays a minor role even in the technical skills where associations exist. While a substantial body of evidence exists on biological maturation in youth football, relatively few studies have directly compared maturation effects across two distinct age categories within the same sample and testing battery. This is particularly relevant given that abilities such as speed, agility, power, and aerobic endurance are well known to depend on biological maturation during youth development, and that selection processes remain strongly biased toward more mature players despite growing awareness of this phenomenon and its negative consequences for talent development. By contrast, associations between maturation and technical, ball-specific skills have generally been small or inconsistent, raising the question of whether the influence of maturation is uniform across physical and technical performance domains, or whether it becomes more or less pronounced at different developmental stages. Clarifying this issue is particularly relevant in club and national-team settings, where selection decisions for U13 and U15 squads are made annually and directly shape players' access to higher levels of competition, coaching, and developmental resources, yet practical, age-specific guidance for talent identification protocols remains scarce. To address this gap, biological maturation was estimated using the Mirwald method, given its non-invasive and widely validated application in youth athletic populations, and its associations with anthropometric, motor, and technical ball-specific performance variables were examined separately in U13 and U15 players using correlation and group-comparison analyses. The main aim of this study was to examine the relationship between biological maturation and both motor performance and sport-specific ball skills in U13 and U15 youth soccer players. The secondary aim was to examine differences in these outcomes between biological maturity groups within each age category.

Material and Methods

Participants

The study sample comprised 214 U13 and 164 U15 football players from Dalmatia. The Ethical Committee of the Faculty of Kinesiology (approval number 2181-205-02-05-26-026, Split, Croatia) approved the research. The U13 players had a mean chronological age of 12.31 years, average height of 157.15 cm, body mass of 46.64 kg, and training age of 4.81 years. In the U15 group, mean chronological age was 14.21 years, with a height of 170.48 cm, body mass of 58.03 kg, and training age of 6.50 years. Participants were recruited from football clubs competing at different levels, including the 1st and 2nd Croatian Football Leagues – South Division and the 1st County League for U13 and U15 categories. Players in the 1st and 2nd Leagues trained four to five times per week and competed in official weekend matches across the Dalmatian region, whereas County League players trained three to four times per week and played weekly matches within the Split-Dalmatia County. All participants were tested under uniform environmental conditions (8:00–10:00 a.m.; 25.6 ± 0.8 °C; $36.3 \pm 2.5\%$ relative humidity), with each session beginning with a questionnaire on date of birth, dominant leg, and training experience, while testing was conducted over two consecutive days due to the study's scope.

Anthropometric variables and biological maturation

Anthropometric variables, including body mass (BM), body height (BH), body mass index (BMI), and sitting height (SH), were assessed according to international protocols (Gordon, Chumlea and Roche, 1988), with each measurement performed twice and the mean of the two values recorded. Chronological age (CA) was calculated in decimal form by comparing the participants' date of birth with the date of data collection (Ross and Marfell Jones et al., 1991). The percentage of predicted adult height (PAH%) was calculated using the formula proposed by Mirwald et al. (2002). The estimated biological age (BA) was calculated using age at peak height velocity (APHV) according to Mirwald et al. (2002) with each participant's individual APHV compared to the reference value for boys of 13.8 years. The difference between the reference value (13.8 years) and the

individual APHV was then added to the player's chronological age to obtain the estimated biological age (BA). The formula used was:

$$\text{Estimated biological age (BA)} = \text{Chronological age (CA)} + (13.8 - \text{Individual APHV})$$

Following the calculation of estimated biological age for each participant, the mean of estimated biological age was computed separately for the U13 and U15 groups. Participants were subsequently categorized into three maturity groups based on their deviation from their group's mean biological age (Ostojić et al., 2014): LESS MATURE: participants whose estimated biological age was more than 0.5 years below the group mean, AVERAGE: participants within ± 0.5 years of the group mean, MORE MATURE: participants whose estimated biological age exceeded the group mean by more than 0.5 years.

Motor performance with and without the ball

Participants performed several sprint performance tests, each recorded in seconds. Sprint performance was assessed using a 5-meter sprint (S5m), a 20-meter sprint (S20m), and a 20-meter sprint with the ball (S20m B). Explosiveness of the lower and upper body was measured using two tests recorded in centimeters: the standing long jump (SLJ) (Marković et al., 2004) and the medicine ball throw with a 3 kg ball (MBT) (González-Devesa et al., 2025). Agility (measured in seconds) was evaluated through a slalom test both with and without the ball (SLAL B / SLAL). The slalom test involved weaving between six cones spaced 2 meters apart along an 11-meter straight line (Sporiš et al., 2010). Participants were instructed to navigate the cones at maximum speed, moving in both directions, and turning around the last cone. All timed tests were recorded using a photocell timing system (Brower Timing Systems, Draper, USA), with participants starting 50 cm behind the starting line to prevent premature sensor activation and being allowed a 3-minute recovery period between attempts.

Statistical analysis

Basic descriptive statistics are presented as means and standard deviations ($M \pm SD$) along with the range (minimum–maximum). Pearson correlations were applied to examine the relationship between estimated biological age and performance. Correlation coefficients (r) of < 0.1 , 0.1 – 0.3 , 0.3 – 0.5 , 0.5 – 0.7 , 0.7 – 0.9 , and > 0.9 were interpreted as trivial, small, moderate, large, very large, and nearly perfect correlations, respectively (Vincent, 1995). Differences among the three groups ($p < 0.05$) were assessed using one-way analysis of variance (ANOVA) with a Bonferroni post-hoc test for pairwise comparisons. Partial eta squared (η^2) was used to estimate effect size in the ANOVA, with the following thresholds: 0.01 – 0.05 indicating a small effect, 0.06 – 0.13 a medium effect, and ≥ 0.14 a large effect (Cohen, 1988). Data were analyzed using the Statistica software package, version 13.0 (Dell Inc., Round Rock, TX, USA).

Results

Table 1. Pearson correlation coefficients between estimated biological age with anthropometric variables and motor performance with and without the ball

Variables	U13			U15		
	r (maturity)	STRENGTH	p	r (maturity)	STRENGTH	p
BH (cm)	0.65*	LARGE	<0.001	0.73*	LARGE	<0.001
BM (kg)	0.59*	LARGE	<0.001	0.83*	LARGE	<0.001
BMI (kg/m ²)	0.37*	MODERATE	<0.001	0.55*	LARGE	<0.001
SLJ (cm)	-0.09	TRIVIAL	0.375	0.66*	LARGE	<0.001
MBT (cm)	0.56*	LARGE	<0.001	0.70*	LARGE	<0.001
S5m (s)	0.01	TRIVIAL	0.962	-0.34*	MODERATE	0.014
S20m (s)	-0.05	TRIVIAL	0.629	-0.52*	LARGE	<0.001
SLAL (s)	0.07	TRIVIAL	0.499	-0.25	SMALL	0.071
S20m B (s)	-0.12	SMALL	0.265	-0.51*	LARGE	<0.002
SLAL B (s)	-0.04	TRIVIAL	0.713	-0.42*	MODERATE	0.002

Legend: r : Pearson coefficient of correlation, * denotes significant correlation, r^2 : coefficient of determination, p : p -value

Table 1 shows significant associations between biological maturation and anthropometric measures, including body height ($r=0.65$, $r^2=0.42$; U13 and $r=0.73$, $r^2=0.53$; U15), body mass ($r=0.59$, $r^2=0.35$; U13 and $r=0.83$, $r^2=0.69$; U15), and body mass index ($r=0.37$, $r^2=0.13$; U13 and $r=0.55$, $r^2=0.30$; U15). Regarding motor performance without the ball, a significant relationship with biological maturation was observed only for the medicine ball throw in the U13 category ($r=0.56$, $r^2=0.32$), while no significant association was found for the standing long jump ($r=-0.09$, $r^2=0.01$) or sprint performance (5m: $r=0.01$, $r^2 < 0.01$; 20m: $r=-0.05$, $r^2=0.01$) and slalom test ($r=0.07$, $r^2=0.004$). In the U15 category, biological maturation showed significant associations with almost all motor variables without the ball, including the standing long jump ($r=0.66$, $r^2=0.44$), medicine ball throw ($r=0.70$, $r^2=0.49$), 5m sprint ($r=-0.34$, $r^2=0.11$), and 20m sprint ($r=-0.52$, $r^2=0.27$). A weaker and non-significant correlation was observed for the slalom test ($r=-0.25$, $r^2=0.06$). Additionally, biological maturation was not significantly associated with sport-specific performance with the ball in the U13 category (20m sprint with ball: $r=-0.12$, $r^2=0.02$; slalom with ball: $r=-0.04$, $r^2=0.001$). However, in the U15 category significant associations were observed for both the 20m sprint with the ball ($r=-0.51$, $r^2=0.26$) and the slalom with the ball ($r=-0.42$, $r^2=0.18$).

Table 2. Differences in biological and morphological indicators among U13 and U15 football players with different levels of biological maturation

	Variables	LESS MATURE (n=70)	AVERAGE (n=87)	MORE MATURE (n=57)	p	η^2
U13	CA (years)*	11.76±0.54 ^{bc}	12.41±0.47 ^c	12.84±0.39	<0.001	LARGE
	APHV (years)*	13.97±0.56 ^{bc}	13.75±0.43 ^c	13.08±0.57	<0.001	LARGE
	BA (years)*	11.50±0.45 ^{bc}	12.46±0.27 ^c	13.58±0.47	<0.001	LARGE
	PAH (%)	82.99±1.64 ^{bc}	85.33±1.16 ^c	89.68±3.43	<0.001	LARGE
	BH (cm)*	150.89±6.96 ^{bc}	156.36±5.82 ^c	166.04±7.31	<0.001	LARGE
	BM (kg)*	40.54±6.43 ^c	44.71±7.94 ^c	56.34±11.41	<0.001	LARGE
	BMI (kg/m ²)*	17.76±2.18 ^c	18.56±4.21 ^c	20.31±3.20	<0.001	MEDIUM
	Variables	LESS MATURE (n=54)	AVERAGE (n=50)	MORE MATURE (n=60)	p	η^2
U15	CA (years)*	13.49±0.47 ^{bc}	14.27±0.64 ^c	14.82±0.49	<0.001	LARGE
	APHV (years)*	14.32±0.48 ^{bc}	13.91±0.65 ^c	13.41±0.61	<0.001	LARGE
	BA (years)*	12.92±0.53 ^{bc}	14.11±0.29 ^c	15.27±0.48	<0.001	LARGE
	PAH (%)	85.25±2.10 ^{bc}	89.80±1.28 ^c	94.73±0.89	<0.001	LARGE
	BH (cm)*	162.97±9.95 ^{bc}	170.87±6.38 ^c	178.79±6.28	<0.001	LARGE
	BM (kg)*	50.39±9.33 ^{bc}	57.06±7.80 ^c	65.69±10.53	<0.001	LARGE
	BMI (kg/m ²)*	18.67±2.17 ^c	19.37±2.27 ^c	20.65±2.52	<0.001	MEDIUM

Legend: p: p-value, *denotes significant differences, η^2 : Partial eta squared, a: denotes significant differences from "LESS MATURE", b: denotes significant differences from "AVERAGE", c: denotes significant differences from "MORE MATURE"

Table 2 reveals significant differences, with *MORE MATURE* players exhibiting higher values in both age categories for chronological age (F=85.7, η^2 =0.448; U13 and F=89.1, η^2 =0.525; U15) and biological age (F=447.1, η^2 =0.806; U13 and F=390.9, η^2 =0.829; U15). Furthermore, *MORE MATURE* players showed significantly earlier attainment of peak height velocity (APHV) (F=50.4, η^2 =0.323; U13 and F=34.83, η^2 =0.305; U15) and a higher percentage of predicted adult height achieved (F=67.1, η^2 =0.576; U13 and F=150.6, η^2 =0.795; U15). Anthropometric variables, including body height (F=83.3, η^2 =0.441; U13 and F=47.90, η^2 =0.413; U15), body mass (F=54.07, η^2 =0.347; U13 and F=38.18, η^2 =0.323; U15) and body mass index (F=9.04, η^2 =0.080; U13 and F=10.57, η^2 =0.117; U15), were also significantly greater for the more mature players.

Table 3. Differences in motor tests with and without the ball among U13 and U15 football players with different levels of biological maturation

	Variables	LESS MATURE (n=70)	AVERAGE (n=87)	MORE MATURE (n=57)	p	η^2
U13	SLJ (cm)	164.66±19.94 ^c	175.69±25.74	177.37±34.07	0.022	SMALL
	MBT (cm)*	472.42±105.34 ^{bc}	552.35±93.13 ^c	653.07±157.36	<0.001	LARGE
	S5m (s)*	1.13±0.11 ^c	1.12±0.08 ^c	1.01±0.35	0.006	MEDIUM
	S20m (s)*	3.60±0.23 ^c	3.49±0.22	3.41±0.53	0.005	SMALL
	SLAL (s)	8.07±0.53	7.91±0.58	7.71±1.64	0.135	SMALL
	S20m B (s)*	3.94±0.36 ^b	3.76±0.28	3.77±0.54	0.016	MEDIUM
	SLAL B (s)*	12.37±1.67 ^b	11.48±1.88	11.86±1.82	0.001	SMALL
	Variables	LESS MATURE (n=54)	AVERAGE (n=50)	MORE MATURE (n=60)	p	η^2
U15	SLJ (cm)*	176.40±24.81 ^{bc}	197.10±20.52 ^c	211.23±18.12	<0.001	LARGE
	MBT (cm)*	588.97±129.77 ^{bc}	696.47±160.60 ^c	828.57±171.37	<0.001	LARGE
	S5m (s)*	1.09±0.09 ^c	1.07±0.11	1.02±0.08	0.008	MEDIUM
	S20m (s)*	3.43±0.25 ^{bc}	3.29±0.25 ^c	3.10±0.19	<0.001	LARGE
	SLAL (s)*	7.98±0.70 ^c	7.95±0.63	7.68±0.64	0.028	SMALL
	S20m B (s)*	3.79±0.34 ^{bc}	3.51±0.25 ^c	3.29±0.26	<0.001	LARGE
	SLAL B (s)*	11.56±1.66 ^c	11.19±1.56	10.80±1.30	0.028	SMALL

Legend: p: p-value, *denotes significant differences, η^2 : Partial eta squared, a: denotes significant differences from "LESS MATURE", b: denotes significant differences from "AVERAGE", c: denotes significant differences from "MORE MATURE"

Table 3 shows a higher proportion of more mature players achieving better results in the motor performance tests compared with the other groups (less and average), particularly in the standing long jump (U13: F=3.91, η^2 =0.046; U15: F=28.96, η^2 =0.318) and the medicine ball throw (U13: F=17.57, η^2 =0.246; U15: F=23.51, η^2 =0.304). Furthermore, sprint performance over 5 meters (F=5.28, η^2 =0.061; U13 and F=5.07,

$\eta^2=0.090$; U15) and 20 meters ($F=5.52$, $\eta^2=0.050$; U13 and $F=29.30$, $\eta^2=0.268$; U15) also significantly differed between groups, favoring the biologically more mature players. In the U13 group, the slalom test did not show significant differences between groups ($F=2.02$, $\eta^2=0.019$), whereas in the U15 group, *MORE MATURE* players performed significantly better than other groups ($F=3.64$, $\eta^2=0.044$). On the other hand, players with *AVERAGE* maturation showed significantly better results than *LESS MATURE* players in ball handling tests (S20mB, $F=4.28$, $\eta^2=0.060$ and SLAL B, $F=4.72$, $\eta^2=0.046$). In contrast, within the U15 group, biologically more mature players achieved significantly better results in both sprint with the ball over 20 meters ($F=30.09$, $\eta^2=0.358$) and slalom with the ball ($F=3.66$, $\eta^2=0.044$).

Discussion

The primary objective of this study was to examine the relationship between biological maturation and anthropometric characteristics, motor performance, and sport-specific skills in U13 and U15 youth football players. A secondary objective of this study was to examine differences in motor performance and ball-related skills between biological maturity groups within each age category. Significant associations (moderate to very large) were observed between biological maturation and anthropometric measures. In the U15 group, maturation was related to all speed and explosiveness tests (small to large), with no significant relationship for the agility test (small). In the U13 group, a significant association was evident only for lower-body explosiveness (large). Significant associations with sport-specific ball tests were observed only in the U15 group (moderate to large). Among U13 players, more mature players performed better in sprint and explosive power tests, whereas agility showed no significant differences between groups. In ball-related tests, differences were observed between maturity groups, where *AVERAGE* mature players performed better than *LESS* mature players. In the U15 category, more mature players outperformed their peers across nearly all tests, including sprinting, explosive power, agility, and ball-related skills.

A very high percentage of explained variance ($>30\%$) indicates a pronounced association between biological maturation and anthropometric variables (body height and body mass). These findings corroborate the well-documented role of maturation-related growth and somatic development during adolescence (Vandendriessche et al., 2012; Itoh and Hirose, 2020; Yang and Chen, 2022; Čaušević et al., 2023). In the U15 group, the SLJ and MBT explained 44% and 49% of the variance, respectively, which aligns with studies showing that increases in muscle mass (Moran et al., 2017; Almeida Neto et al., 2021), neuromuscular changes (Radnor et al., 2018), and strength contribute to enhanced explosive performance during puberty (Vandendriessche et al., 2012; Wilczyński et al., 2022; Gundersen et al., 2022; Hermassi et al., 2024). In the U13 group, the SLJ explained only 1% of the variance, whereas the MBT explained 32%, suggesting that the early association of maturation with performance is more evident in tasks that depend on trunk and upper-body strength. This may also be related to absolute strength, as greater muscle mass resulting from more pronounced developmental differences in U15 players may contribute to better performance. Additionally, Philippaerts et al., 2006 reported significantly greater improvements in the standing long jump after the age of peak height velocity (APHV) compared with the period preceding it. Generally, stronger correlations (Table 3) observed in older players (U15) suggest that the connection with biological maturation increases as players approach or surpass peak height velocity, which is consistent with some previous findings. For example, Figueiredo et al., 2009 reported significant relationships between maturity and vertical jump performance in 13–14-year-olds, but not in 11–12-year-olds, football players. Additionally, Radnor et al., 2021, found that maturation was not associated with 5-m sprint performance in the U13 group (trivial correlation, $<1\%$ explained variance), whereas a significant moderate association was observed in the U15 group. The results suggest that in younger players (U13), acceleration over very short distances is less associated with maturation and more closely associated with technique and coordination. In contrast, during mid-adolescence (U15), maturation-related increases in strength and power become progressively more important. Additionally, the 20-m sprint showed a significant association with biological maturation in the U15 age group (27% explained variance), but not in the U13 group (1% explained variance). This finding contrasts with previous research (Rommers et al., 2019; Itoh and Hirose, 2020; Radnor et al., 2021; Gundersen et al., 2022; Wenger and Csapo, 2025), which suggested that maximal or near-maximal sprinting speed is sensitive to maturational differences even at earlier stages of development. The slalom test demonstrated only trivial-to-small correlations ($p > 0.05$), accounting for 1% and 6% of the variance in U13 and U15 players, respectively. In contrast, Valente-dos-Santos et al., 2014 reported that maturity-related variability influenced change-of-direction performance in young football players aged 12–14, while Rommers et al. (2019) found significant age-by-maturity interaction effects within the agility for U14 and U15. Significant associations and higher explained variance in ball-related skills were observed in the U15 group compared with the U13 group for both ball tests (Table 3). In the U13 group, most players had not yet experienced their peak growth spurt, allowing technical skills to develop relatively independently of maturation, which is in line with previous research (Malina et al., 2005; Gouvea et al., 2016; Vandendriessche et al., 2012). In the U15 group, the relationship between biological maturation and motor performance also extended to ball-related skills, likely reflecting the combined association with body size and general motor performance. Previous research also emphasized the cumulative effects of long-term training, showing that years of practice contribute to ball control

performance (Malina et al., 2005), while annual training volume has been identified as a significant longitudinal predictor of dribbling speed (Valente-dos-Santos et al., 2014).

Significant differences in favor of more mature players were observed across multiple tests, consistent with previous research by Itoh and Hirose (2020), Morris et al. (2020) and Negra et al. (2022). In the U13 category, more mature players didn't achieve the best results in ball-related tests which is in accordance with previous research (Figueiredo et al., 2009; Figueiredo et al., 2010; Vandendriessche et al., 2012). Slalom performance (U13) did not differ between maturity groups, suggesting that early-maturing players may face temporary coordination challenges due to rapid body changes, consistent with findings that maturation affects morphology and physical fitness more than motor coordination (Vandendriessche et al., 2012).

Practical applications and limitations

The findings of this study provide additional insight into the relationship between biological maturation and specific dimensions of anthropological status. The expected association between biological maturity and anthropometric characteristics in both groups highlights the importance of regular monitoring and evaluation of athletes. Furthermore, in the U13 age group, a significant association with motor performance was observed only in the medicine ball throw (MBT) test, whereas in the U15 group, associations were found in all tests except the slalom test. This pattern may suggest that the transition between these two age categories represents a sensitive developmental period, which could also be related to the average age at peak height velocity (APHV) of 13.8 years, a stage that most U15 players have likely already reached or passed. In addition, the observed differences in morphological variables between biological maturity groups highlight the need to adapt the training process, particularly in contact sports. The more pronounced differences in motor performance variables among U15 players, likely related to the growth spurt and the increase in body height, further emphasize the importance of a holistic approach to the selection process, including the consideration of a larger number of relevant variables when making selection decisions. The main limitation of this study is the cross-sectional design, which limits conclusions about long-term effects. Therefore, future research should include multiple time points and longitudinal monitoring of young players, as well as more direct methods of assessing biological maturity, such as radiographic wrist assessment or similar approaches.

Conclusions

In summary, this study showed that biological maturation is more strongly correlated with performance in U15 than in U13 players. Many U15 players have already reached or passed their PHV, displaying more pronounced anthropometric characteristics that, together with accumulated training experience, contribute to superior physical capacities, particularly under controlled testing conditions. In contrast, most U13 players have not yet reached PHV. Although anthropometric characteristics significantly differed between groups of varying biological maturity in this age category, these differences were transferred less consistently into motor and sport-specific performance, resulting in weaker correlations with biological maturity compared to U15. Overall, the advantages of advanced biological maturity are evident to varying degrees across both age groups, and the variability among players of the same chronological age highlights that selection should favor long-term potential rather than current performance alone.

These findings indicate that the association between biological maturation and performance appears to depend on both age and performance domain, being more evident for physical and motor outcomes than for technical, ball-specific skills, and more pronounced among U15 than U13 players. These results have direct implications for talent identification practices in youth football. For U15 players, coaches should incorporate players' status of biological maturity for identification and selection purposes, rather than solely physical and/or technical testing. Superior performance of more mature players may reflect their maturational advantage rather than superior long-term potential. For U13 players, where maturation showed limited association with most performance measures, talent selection decisions may benefit from relying more heavily on technical indicators rather than physical test outcomes alone. Practically, the integration of maturity status assessment (e.g., via the non-invasive Mirwald method) into routine testing protocols could help clubs avoid systematically favoring more mature players and instead support a more equitable, long-term-oriented selection process. Future studies should adopt longitudinal designs that track players through and beyond peak height velocity, incorporate maturity assessment methods, and examine whether maturity-related performance advantages persist into late adolescence and senior-level competition.

Conflicts of interests

The authors have no conflict of interest to declare.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT 5.1 (OpenAI) in order to support minor linguistic editing and refinement of the English language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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