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Reference Values of Specific Physical Performances of Elite Youth Male Soccer Players: Taking into Consideration the Maturity Status

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SUMMARY

Background. Recognizing the significance of maturity-related adaptations is imperative for specialists and coaches when designing training regimens to nurture long-term athlete development.

Objective. This study aims to explore how both chronological age and maturity status influence anthropometric measurements and physical performance in elite youth male soccer-players. Additionally, our goal is to establish percentile values for anthropometric variables and physical performance across different maturity groups.

Methods. Two-hundred-eighty-seven soccer-players aged between 12-17 years participated in this study. Anthropometric measurements, including leg-muscle-volume (LMV), along with soccer-specific-physical-performances (SPP) such as Squat-Jump (SJ), Countermovement-Jump (CMJ), sprinting performances, and intermittent-endurance tests were assessed. Players were categorized into age groups (U12 to U17) and six maturational groups based on their maturity offset, ranging from -2.5 to +2.5 years.

Results. Significant differences ($p < 0.05$) were observed in anthropometric variables and SPP among different maturity groups. Body mass, leg length, and leg muscle volume exhibited consistent changes across consecutive maturity groups. Notably, jumping performances, particularly CMJ/SJ, were significantly influenced by maturity status, showing a progression of changes from -0.5 to +0.5 maturity groups for CMJ and from -0.5 to +0.5 maturity groups for SJ. Similarly, sprinting performances were significantly affected by maturity status, particularly in the -1.5 maturity group.

Conclusions. Our findings highlight the significant role of growth and peak height velocity (PHV) in the anthropometric development and SPP potential of youth soccer players.

KEY WORDS

Adolescents; androgenic; growth; maturation; physical activity.

INTRODUCTION

Development in young soccer players is characterized by a non-linear progression marked by intricate interactions among technical skills (1-3), physical performance (4, 5), social influences (6), and environmental factors (7). Several studies have shed light through data and rigorous analysis on the complex interplay between maturity and physical performance. For example, João Valente-dos-Santos *et al*. (8) studied anthropometric variables and Nikolaidis and Shah (9) focused on isometric muscle strength (10), while Nikolaïdis (11) delved into the topic of muscle endurance. In another study (12), explored intermittent-endurance capacity (13). Collectively, these studies have advanced our understanding of traditional development and how these attributes change with chronological age in soccer players. Moreover, players are often identified as talents when they outperform their peers within their designated age group (14). However, this approach tends to overlook the inherent variability in the physical development of young soccer players. Hence, early developing soccer players have a higher biological age relative to their chronological age (15), which often leads to them being recognized as talented individuals. In contrast, late developers, whose biological age (16) lags their chronological age, frequently go unnoticed in talent identification processes. This stark contrast in recognition underscores a critical need to move beyond the conventional approach of comparing young soccer players solely based on their chronological age. It is not clear for coaches that physical player development can substantially vary between individuals, and it may be more appropriate to consider youth athletes by maturity status instead of traditional chronological annual-age group (17).

In contrast, the publication of longitudinal normative data and research analyzing various specific physical performances and skills according to maturity categories for young male (18, 19) and female (20) soccer player is progressing. Research has modelled and identified the development and time points of increased and subsiding physical qualities related to somatic maturation and peak height velocity (PHV) categories. Towlson *et al*. (19) identified development tempo of anthropometric parameters and specific soccer physical performances and the transition/change time points in these relationships using segmental regression for youth (age 8-18 years). Anthropometric parameter and sprint performances began to markedly increase from Pre-PHV and trajectories subsided in their rate of development around post 16 years (~PHV). By comparison, lower limb power (21), agility (22-28), and endurance performance (29) illustrated more linear progressive trajectories and their developmental tempo waned around post-PHV. Furthermore, coaches need to identify time points of increased and subsiding developmental trajectories of morphological and specific soccer performance like strength, lower-body power performance, change of direction time and sprinting. Regular monitoring is needed to take into account the influence of maturation on athletic performance until post-PHV (19).

There is evidence that maturity effect physical performance (vertical jump, sprinting and intermittent endurance). Understanding the factors that may influence the development of physical characteristics during this key development period is important. Previous studies have classified players into three global maturational groups: early, on-time, and late-maturing (8, 30). These studies have widely demonstrated the influence of maturity on many aspects of physical performance, and how possible changes take place within a single group. Therefore, there is a need for further research, coaches, and other practitioners to gain more knowledge and adapt the training according to these changes caused by growth and maturity. Yet, up to now, there has been little data those encompassing soccer-specific performances for young male soccer players analyzed by 6 maturational intervals. The findings will provide novel comparative data for this cohort relative to maturity status and can be used by strength and conditioning coaches to inform the design of training programs and identify talented young male soccer players according to their maturity status. In addition, recognizing the significance of maturity-related adaptations is imperative for specialists and coaches when designing training regimens to nurture long-term athlete development. Therefore, the aims of the current study were: 1) to evaluate the influence of chronological age and the PHV on anthropometric and physical performances in a large cross-sectional sample of elite youth male soccer players (age 12-17 years) grouped into maturational intervals according to their maturity offset and 2) to establish percentile values of anthropometric variables and physical performances according to maturity groups.

MATERIALS AND METHODS

Study population

Two-hundred-eight-seven Tunisian soccer players aged between 12-17 years were enrolled in the study and grouped into age categories (U12, n = 39; U13, n = 43, U14, n = 42, U15, n = 55; U16, n = 51; U17, n = 50). Players were from four professional soccer clubs participating in the premier division of Tunisian championship. Clubs were informed and agreed to the participation in the evaluation and the nature of the study was explained according to a simple schedule prearranged in the middle of the week. Players and their parents were fully informed about the aims and procedures of the protocol and signed a written informed consent form. The study protocol was approved by the local Ethics Committee of the Faculty of Medicine "Ibn El Jazzar" of Sousse (Tunisia) (Protocol N. 213-2023 – date of approval: November 13, 2023). All participants were injury-free. Players aged under 14 years were training four times per week and those older had five training sessions per week. Specifically, players aged U13 and U14 participated in soccer training for four sessions per week, while players aged U15, U16, and U17 engage in five sessions per week. On average, each training session lasted approximately 70 minutes. Official and friendly games were typically scheduled on weekends, with each game day followed by a day of rest.

Experimental design

Evaluations were performed within three days. The first day consisted of anthropometric measurements. On the second day, the assessments commenced with vertical jump (including squat jump and countermovement jump), followed by sprint performances of 30 meters to assess time at intervals (every 10 meters). Third day was planned for the Yo-Yo intermittent recovery Test–level 1 (YYIRTL1). All physical tests were preceded by a standardized warm-up, including jogging, dynamic movements and technic skills for 10 minutes followed by jumps and sprints of progressive intensity for 5 minutes. Players were allowed to wear a sports outfit consisting of a football kit (jersey, shorts, socks, and football shoes).

Anthropometric measurement

Testing was carried out in a standardized order after calibration of the measuring instruments. All anthropometrics variables were measured with participants in underwear and by the same material by a single trained investigator. Body mass (kg), standing and sitting height, (cm) were assessed to the nearest 0.1 kg and 0.1 cm, and measured respectively (31) with a digital scale (Harpenden Balance Scale, Holtain Ltd., Crosswell, UK) and a stadiometer (Harpenden Portable Stadiometer, Holtain Ltd., Crosswell, UK). The measurements of skinfold thickness were performed on the left side of the body and mean values were used for further analysis after in triplicate measurement using Harpenden Skinfold Caliper (Holtain Ltd., Crosswell, United Kingdom). Fat-free mass (in kilogram) and percentage of fat mass (% fat) were calculated using Siri's equation (32). Leg muscle volume (in milliliters) was assessed using the anthropometric method of Jones and Pearson (33). The method is based on the summation of truncated cones and has been validated for youths (34).

Maturity status

Maturity was estimated using the non-invasive method proposed by Mirwald *et al.* (35) from anthropometric measurement applied in research study (18). This method was approved to predict years from PHV (YPHV) as a measure of maturity offset using anthropometric variables: *years from PHV = -9.236 + (0.0002708 × leg length × sitting height) + (-0.001663 × age × leg length) + (0.007216 × age × sitting height) + (0.02292 × weight by height ratio)*. Groups were determined by the predicted years from PHV. The maturity status and classification of groups followed the study by Meyers *et al.* (36). Player was categorized into one to six of maturity-offset groups: (-2.5 YPHV [≤ -2.0], -1.5 YPHV [-1.99 to -1.0], -0.5 YPHV [-0.99 to 0.0], 0.5 YPHV [0.01 to 1.0], 1.5 YPHV [1.01 to 2.0], and 2.5 YPHV [≥ 2.01]).

Vertical jump tests

The assessment of the explosive leg power performance (37-44) was conducted using an optical system (Optojump, Microgate, Bolzano, Italy). Vertical jump height was assessed by two different protocols (squat and counter movement jump (45)) using a software system (Optojump Next, Microgate, V1.12.21.0). Performance was assessed on indoor and stable flooring to minimize the influence of external factors using following the protocol of Bosco *et al.* (46). All subjects performed three maximal trials for each jump type, and the best of the two trials was retained for analysis. Subjects completed three maximal CMJ efforts before testing. During the SJ, the subjects started with squat position, knees flexed at 90°, torso in an upright position, and hands on hips. From this position and upon a verbal command, subjects were requested to jump as high as possible and land with their knees straight. For the CMJ, the subjects started from a standing position, squatted down and then extended their knees maximally in one continuous movement, aiming to jump vertically as high as possible. For the jumping tests, subjects were instructed to land in the same position and at the same place to avoid lateral or horizontal displacement. The coefficients of variation were 4.6 and 4.4%, for SJ and CMJ, respectively.

Sprint tests

Maximal sprint speed (22, 23, 26, 28, 47-49) was evaluated over distances of 10-m, 20-m, 30-m (T10m, T20m, T30m). The photocell gates (Witty system, photocells witty gate, Microgate) were at placed 0.7 m above the ground and positioned at the starting line and at 10, 20 and 30 m marks. Times were recorded to the nearest 0.01 seconds. The best time was recorded as best score after 3 attempts, separated by a 3-minute rest period. The coefficients of variation of recorded times for 10 m, 20 m and 30 m sprints in our study were 4.7%; 4.3%; 4.6%, respectively.

Yo-Yo test

The Yo-Yo Intermittent Recovery Test Level 1 (YYIRTL1) was conducted according to the method of Krustrup *et al.* (50). The test aims to estimate the participant's intermittent endurance capacity. For the single trial, subjects had to perform as many shuttles as possible with the maximum distance covered expressed in meters. The test consisted of repeated 20-m shuttle runs at progressively increasing speeds, with each shuttle followed by a recovery period of 10 seconds around a marker placed 5 m behind the finishing line. Speed was dictated by an audio metronome from a calibrated CD player. When a subject failed twice to reach the finish line in time, the total running distance covered was recorded as the test result.

Statistical analysis

Descriptive statistical analysis for anthropometric and physical performance was completed using SPSS for Windows (version 26.0). The normality of all variables was tested by Jarque-Bera tests. Data were presented as arithmetic means and standard deviation (SD) and were calculated for each variable. One-way ANOVA with a *post-hoc* analysis (Bonferroni) was used to determine differences between age groups and maturity groups. The upper limit for statistical significance was set at $p < 0.05$. Effect size (ES) was calculated using the method proposed by Cohen (2013) considering that the use of the P-value alone provides no information about the size or direction of the effect or the range of feasible values (51). ES lower than 0.2, between 0.2 and 0.49, between 0.5 and 0.79 and equal to or higher than 0.8 were considered trivial, small, moderate, and large, respectively.

The smallest worthwhile difference (SWD) was set at 0.2 × between subject standard deviation (SD) for the comparison groups. The probability that the magnitude of difference was greater than the SWD was rated as follows: < 0.5%, almost certainly not; 0.5-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; and > 99.5%, almost certainly (17). If the 90% confidence interval (CI) crossed both the upper and lower boundaries of the SWD, it was considered that unclear.

RESULTS

Results of anthropometric variables and physical performances according to age and maturity groups are presented in **table I**. According to chronological age, significant differences ($p < 0.05$) were found for YPHV for all groups. The U-14 and U-15 age groups corresponded to the period of peak growth for Tunisian youth soccer players. The negative values of YPHV from the age groups U-12, U-13 indicates they are early-maturing players. The positive values ($-1 < \text{YPHV} < 1$) for maturing players were from U-14 and U-15. From U-16 and older groups, players had ($\text{YPHV} > 1$) late-maturing players.

Anthropometric changes were mostly evident for U-13 and younger groups. Except for the BMI and percentage of body fat, anthropometric measurements increased according to age groups and showed significant differences ($p < 0.05$). For leg muscle volume, data increased gradually up to the U-16 age group and significant differences were noted between each age group. Concerning physical performances, changes were observed from U-13 for the SJ, CMJ, T30m and YYIRTL1 and from U-14 for T10m and T20m.

Data of anthropometric variables and physical performances by maturity groups were presented in **table II**. Significant differences ($p < 0.05$) were noted for YPHV across all groups. Changes in anthropometric variables were shown from -1.5 *vs* 2.5 maturity groups except for the percentage of body fat. As for physical performances, the major significant differences were between -1.5 *vs* -0.5 and -0.5 *vs* 0.5 maturity groups. The standardized differences and effect size of anthropometric and physical characteristics between consecutive maturation groups for youth soccer players are shown in **table III**.

The SWD of body mass, leg length and leg muscle volume were almost likely between consecutive maturity groups. BMI and percentage of fat were possibly between consecutive maturity groups. Sitting height was almost certainly to less possibly for the more mature group. Concerning jumping performances, SWD for CMJ was almost different from -0.5 *vs* 0.5 maturity groups and almost certainly to likely for SJ. Regarding sprinting performances (T10m, T20m, T30m) they were almost certainly different from the -1.5-maturity group. Except for the -1.5 *vs* -0.5 maturity group, YYIRTL1 was unclear. The 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles of anthropometrics and physical performances according to maturity group were presented in **tables IV** and **V**.

Table I. Anthropometric variables and physical performances according to the age.

Variables	U12 (n = 39)	U13 (n = 43)	U14 (n = 42)	U15 (n = 55)	U16 (n = 51)	U17 (n = 50)
YPHV (years)	-2.01 ± 0.71	-1.54 ± 0.52	-0.43 ± 0.61	0.84 ± 0.89	1.52 ± 0.58	2.28 ± 0.55
Height (cm)	153.15 ± 6.84	158.70 ± 7.03*	163.62 ± 7.24	170.5 ± 6.32*	175.15 ± 6.82	176.15 ± 6.26
Body mass (kg)	40.56 ± 4.50	39.16 ± 5.77*	49.85 ± 7.82*	59.11 ± 5.78*	68.7 ± 7.49	69.43 ± 6.86
Sitting height (cm)	72.19 ± 7.60	57.97 ± 3.72*	79.89 ± 5.32*	85.82 ± 4.68*	87.85 ± 3.69	88.98 ± 3.16
Leg length (cm)	93.55 ± 4.30	90.73 ± 4.94*	99.32 ± 4.58	103.2 ± 4.85*	106.39 ± 5.56	106.98 ± 5.12
BMI ($kg \cdot m^{-2}$)	17.18 ± 1.20	17.16 ± 1.62	18.55 ± 2.26	20.28 ± 1.46	22.34 ± 1.75	22.34 ± 1.50
Percentage of fat (%)	12.92 ± 2.87	12.98 ± 3.57	16.54 ± 3.78	13.75 ± 2.22	16.52 ± 4.55	16.4 ± 3.29
Leg muscle volume (mL)	4,011.44 ± 756.54	4,039.88 ± 810.12*	5,021.62 ± 741.23*	6,255.25 ± 944.13*	7,206.14 ± 1,075.9*	7,091.64 ± 1,169.52*
SJ (cm)	21.21 ± 3.09	21.71 ± 2.95*	25.26 ± 4.61	31.26 ± 4.94	30.41 ± 5.64	30.18 ± 4.42
CMJ (cm)	23.61 ± 2.63	23.56 ± 2.62*	26.4 ± 4.70*	33.17 ± 5.38	32.61 ± 4.95	31.34 ± 5.91
T_{10m} (s)	2.08 ± 0.05	2.06 ± 0.05	2 ± 0.08*	1.97 ± 0.09*	1.95 ± 0.12*	1.92 ± 0.08
T_{20m} (s)	3.65 ± 0.12	3.65 ± 0.13	3.52 ± 0.07*	3.24 ± 0.14*	3.2 ± 0.17	3.07 ± 0.24
T_{30m} (s)	5.05 ± 0.12	5.06 ± 0.11*	5.01 ± 0.11*	4.76 ± 0.23	4.68 ± 0.19	4.52 ± 0.11
YYIR TL1 (m)	1,055.38 ± 248.85	1,147.44 ± 212.34*	1,295.24 ± 223.88*	1,795.27 ± 189.46*	2,101.57 ± 301.59	2,262.8 ± 466.9

YPHV: years from peak height velocity; BMI: Body Mass Index; SJ: squat jump; CMJ: countermovement jump; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{30m}: time 30-m sprint; YYIR TL1: Yo-Yo Intermittent Recovery Test (level-1). *Significant difference age *vs* previous age ($p < 0.05$).

Table II. Anthropometric and physical characteristics of youth soccer players by maturity offset group.

Variables	Maturity offset groups (YPHV)					
	-2.5 (n = 33)	-1.5 (n = 57)	-0.5 (n = 32)	0.5 (n = 43)	1.5 (n = 62)	2.5 (n = 53)
YPHV (years)	-2.21 ± 0.62	-1.67 ± 0.51*	-0.46 ± 2.55*	0.50 ± 0.27*	1.51 ± 0.29*	2.40 ± 0.36*
Height (cm)	149.18 ± 9.49	153.12 ± 5.99*	164.78 ± 7.66*	167.74 ± 5.55*	173.15 ± 5.92*	178.94 ± 5.07*
Body mass (kg)	38.78 ± 5.58	40.78 ± 4.97	51.39 ± 7.81*	58.47 ± 5.67*	64.53 ± 6.25*	72.11 ± 6.59*
Sitting height (cm)	64.67 ± 9.43	66.41 ± 9.11	78.72 ± 6.06*	84.14 ± 1.79*	87.56 ± 2.40*	91.09 ± 2.48*
Leg length (cm)	90.36 ± 5.73	93.76 ± 3.83*	99.44 ± 5.23*	101.95 ± 3.87*	104.98 ± 5.04*	108.89 ± 4.44*
BMI ($kg \cdot m^{-2}$)	17.09 ± 1.26	17.12 ± 1.57	18.81 ± 1.84*	20.73 ± 1.79*	21.49 ± 1.62*	22.51 ± 1.83*
Percentage of fat (%)	12.84 ± 2.75	13.56 ± 3.42	15.79 ± 4.33*	15.20 ± 4.22	14.77 ± 3.53	17.06 ± 3.11*
Leg muscle volume (mL)	3,851.76 ± 862.7	4,153.67 ± 667.48	5,245.5 ± 847.64*	6,165.23 ± 917.77*	6,655.18 ± 1,045.58*	7,504.79 ± 1,039.08*
SJ (cm)	21.50 ± 3.48	21.83 ± 3.36	26.57 ± 4.86*	29.60 ± 6.31*	30.53 ± 5.25	30.77 ± 3.79
CMJ (cm)	23.86 ± 2.63	23.82 ± 3.47	27.51 ± 5.18*	31.82 ± 5.92*	32.17 ± 6.03	32.25 ± 4.65
T_{10m} (s)	2.07 ± 0.05	2.05 ± 0.05*	2.00 ± 0.09*	1.98 ± 0.09*	1.95 ± 0.11	1.92 ± 0.08
T_{20m} (s)	3.66 ± 0.11	3.62 ± 0.13*	3.46 ± 0.15*	3.31 ± 0.19*	3.15 ± 0.21	3.13 ± 0.20
T_{30m} (s)	5.05 ± 0.11	5.05 ± 0.11	4.92 ± 0.21*	4.84 ± 0.24*	4.66 ± 0.21*	4.57 ± 0.14*
YYIR (m)	1,135.15 ± 231.93	1,111.4 ± 242.19	1,509.38 ± 383.16*	1,689.77 ± 362.46*	2,058.06 ± 351.37*	2,156.23 ± 468.67

BMI: Body Mass Index; SJ: squat jump; CMJ: countermovement jump; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{30m}: time 30-m sprint; YYIR: Yo-Yo Intermittent Recovery Test (Level-1). *Significant difference group *vs* previous group ($p < 0.05$)

Table III. Standardized differences and effect sizes between consecutive maturity offset group in youth soccer players.

Variables	Maturity offset groups comparison				
	-2.5 *vs* -1.5	**-1.5 *vs* -0.5**	**-0.5 *vs* 0.5**	**0.5 *vs* 1.5**	**1.5 *vs* 2.5**
YPHV (years)	Unlikely (0.93 ± 0.10)	Possibly (0.79 ± 0.12)	Possibly (0.68 ± 0.10)	Unlikely (3.60 ± 0.09)	Unlikely (2.73 ± 0.08)
Height (cm)	Unclear (-0.04 ± 1.34)	Almost certainly (-0.33 ± 1.54)	Unclear (-0.12 ± 1.29)	Unclear (-0.33 ± 1.03)	Almost certainly (-0.46 ± 0.97)
Body mass (kg)	Almost certainly (0.24 ± 0.92)	Unclear (-0.46 ± 1.42)	Almost certainly (0.13 ± 1.45)	Almost certainly (-0.34 ± 1.09)	Almost certainly (-0.41 ± 1.16)
Sitting height (cm)	Almost certainly (-0.13 ± 1.61)	Almost certainly (-0.27 ± 1.79)	Very likely (-0.14 ± 0.96)	Possibly (-0.30 ± 0.44)	Possibly (-0.38 ± 0.47)
Leg length (cm)	Unclear (0.01 ± 0.85)	Unclear (-0.37 ± 0.92)	Unclear (-0.07 ± 0.90)	Unclear (-0.32 ± 0.79)	Almost certainly (-0.48 ± 0.80)
BMI ($kg \cdot m^{-2}$)	Unclear (0.12 ± 0.26)	Possibly (-0.40 ± 0.33)	Possibly (-0.03 ± 0.39)	Possibly (-0.25 ± 0.28)	Possibly (-0.29 ± 0.28)
Percentage of fat (%)	Unclear (0.13 ± 0.56)	Possibly (-0.33 ± 0.69)	Unclear (0.18 ± 0.82)	Unclear (-0.30 ± 0.62)	Possibly (-0.52 ± 0.55)
Leg muscle volume (mL)	Almost certainly (0.32 ± 132)	Almost certainly (-0.39 ± 161)	Almost certainly (0.19 ± 193)	Almost certainly (-0.30 ± 167)	Almost certainly (-0.42 ± 175)
SJ (cm)	Possibly (0.07 ± 0.59)	Unclear (-0.19 ± 0.81)	Almost certainly (-0.31 ± 1.14)	Almost certainly (-0.03 ± 0.93)	Likely (-0.33 ± 0.72)
CMJ (cm)	Unclear (0.12 ± 0.56)	Possibly (-0.08 ± 0.80)	Almost certainly (-0.40 ± 1.16)	Almost certainly (-0.17 ± 0.97)	Almost certainly (-0.25 ± 0.84)
T_{10m} (s)	Unclear (0.02 ± 0.01)	Almost certainly not (-0.02 ± 0.02)	Almost certainly not (-0.07 ± 0.02)	Almost certainly not (-0.09 ± 0.02)	Unclear (-0.22 ± 0.02)
T_{20m} (s)	Almost certainly not (0.06 ± 0.02)	Almost certainly not (0.02 ± 0.03)	Almost certainly not (-0.11 ± 0.04)	Almost certainly not (0.01 ± 0.03)	Almost certainly not (-0.04 ± 0.03)
T_{30m} (s)	Almost certainly not (0.02 ± 0.02)	Almost certainly not (0.02 ± 0.03)	Very Unlikely (-0.11 ± 0.04)	Very Unlikely (-0.08 ± 0.04)	Almost certainly not (-0.10 ± 0.03)
YYIR TL1 (m)	Unclear (0.41 ± 42.31)	Almost certainly (-0.77 ± 66.15)	Unclear (0.08 ± 72.51)	Unclear (0.14 ± 64.53)	Unclear (-0.46 ± 64.04)

Magnitude based inferences and effect sizes (ES ± 90 CIs). BMI: Body Mass Index; SJ: squat jump; CMJ: Countermovement jump; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{30m}: time 30-m sprint; YYIR: Yo-Yo Intermittent Recovery Test (Level-1).

Table IV. Percentiles values of anthropometric variables according to maturity offset groups.

		Maturity offset groups (YPHV								Maturity offset groups (YPHV)					
		-2.5 (n = 33)	-1.5 (n = 57)	-0.5 (n = 32)	0.5 (n = 43)	1.5 (n = 62)	2.5 (n = 53)			-2.5 (n = 33)	-1.5 (n = 57)	-0.5 (n = 32)	0.5 (n = 43)	1.5 (n = 62)	2.5 (n = 53)
Body height (cm)	5th	133.00	144.00	152.00	157.2.00	161.50	171.00	Body mass (kg)	5th	30.10	35.10	39.40	50.10	54.70	57.40
	10th	138.00	146.00	154.60	158.50	166.30	171.00		10th	34.00	35.80	41.00	51.00	56.20	60.90
	25th	142.50	149.50	159.30	163.00	169.00	174.50		25th	35.50	37.30	46.10	54.40	60.80	68.50
	50th	147.00	151.00	165.00	169.00	173.00	180.00		50th	37.60	39.40	50.50	57.20	64.10	74.20
	75th	154.00	156.00	168.00	171.00	175.30	181.00		75th	39.80	43.60	55.10	63.80	67.20	77.00
	90th	164.00	163.00	176.00	174.60	181.70	187.60		90th	50.20	48.20	63.70	67.30	73.00	79.40
	95th	169.00	163.20	182.00	177.00	184.90	189.00		95th	51.70	50.20	67.50	67.30	74.60	81.50
Sitting height (cm)	5th	50.50	55.40	56.50	81.00	84.00	86.70	Leg length (cm)	5th	80.50	87.50	92.00	95.00	98.20	101.70
	10th	52.50	55.50	76.00	82.00	84.00	88.00		10th	81.50	88.50	93.00	96.00	99.00	103.00
	25th	57.00	57.50	79.00	83.00	85.00	90.00		25th	87.50	91.00	95.30	99.00	101.00	105.50
	50th	61.50	62.50	80.00	84.00	87.00	91.00		50th	90.50	94.00	99.00	102.00	104.50	109.00
	75th	72.50	75.00	82.00	85.00	90.00	92.50		75th	93.00	97.00	101.80	105.00	108.00	112.00
	90th	78.40	77.20	82.00	86.60	91.00	94.00		90th	98.80	99.20	110.00	106.00	113.40	116.20
	95th	82.30	78.00	82.00	88.00	91.90	96.00		95th	101.00	100.00	110.00	108.00	114.00	117.00
BMI (kg/m^2)	5th	14.60	14.50	15.90	17.80	19.30	19.40	Percentage of fat (%)	5th	7.80	7.10	9.40	9.90	10.30	11.30
	10th	15.80	15.30	16.00	18.20	19.50	20.20		10th	9.10	9.30	9.60	10.40	10.90	12.60
	25th	16.00	16.20	17.80	19.30	20.20	21.00		25th	11.80	11.50	11.70	11.90	12.10	14.60
	50th	17.20	17.10	18.50	21.00	21.30	22.40		50th	12.20	13.30	16.00	14.00	13.90	17.40
	75th	18.30	17.60	20.00	21.70	22.60	24.30		75th	14.90	15.40	19.50	18.40	16.50	19.70
	90th	18.60	19.60	20.90	23.00	23.70	24.80		90th	15.80	18.50	21.40	20.50	19.90	21.40
	95th	18.60	20.70	23.20	24.00	24.60	25.20		95th	17.30	20.20	22.60	25.60	21.90	22.00

BMI: Body Mass Index.

Table V. Percentiles values of leg muscle volumes and physical performances according to maturity offset groups.

		Maturity offset groups								Maturity offset groups					
		-2.5 (n = 33)	-1.5 (n = 57)	-0.5 (n = 32)	0.5 (n = 43)	1.5 (n = 62)	2.5 (n = 53)			-2.5 (n = 33)	-1.5 (n = 57)	-0.5 (n = 32)	0.5 (n = 43)	1.5 (n = 62)	2.5 (n = 53)
Leg muscle volume (mL)	5th	2,809	2,809	3,839	5,023	4,995	5,600	SJ (cm)	5th	17.10	17.10	17.10	20.00	20.27	25.56
	10th	2,809	3,297	4,244	5,066	5,386	5,815		10th	17.10	17.10	20.00	21.30	23.80	25.80
	25th	3,257	3,772	4,701	5,412	5,971	6,689		25th	17.10	19.40	23.20	24.60	26.60	28.35
	50th	3,945	4,115	5,162	6,193	6,684	7,629		50th	23.20	21.80	26.50	28.50	29.40	29.40
	75th	4,106	4,681	5,867	6,817	7,118	8,173		75th	24.50	23.20	30.00	34.10	34.33	33.05
	90th	5,650	4,963	6,529	7,577	7,943	8,584		90th	25.80	25.80	33.52	37.16	37.96	37.00
	95th	5,650	5,507	6,966	7,648	8,250	9,316		95th	25.80	29.48	36.16	39.16	39.67	39.92
CMJ (cm)	5th	16.90	17.10	17.90	20.30	20.00	25.10	T_{10m} (s)	5th	2.00	1.98	1.80	1.82	1.76	1.74
	10th	17.00	17.80	20.07	21.30	23.30	26.00		10th	2.00	1.98	1.86	1.87	1.79	1.81
	25th	17.20	18.30	22.52	25.30	26.10	28.00		25th	2.05	2.03	1.95	1.91	1.86	1.88
	50th	17.30	21.30	25.40	28.50	29.20	30.70		50th	2.05	2.06	2.00	1.99	1.95	1.92
	75th	19.65	23.70	28.70	32.60	33.30	35.30		75th	2.13	2.09	2.07	2.05	2.03	1.98
	90th	23.52	25.80	31.35	35.30	36.20	38.20		90th	2.15	2.11	2.10	2.10	2.08	2.01
	95th	24.00	29.50	34.24	37.10	38.80	39.02		95th	2.16	2.12	2.15	2.15	2.09	2.06
T_{20m} (s)	5th	3.45	3.43	3.10	2.96	2.64	2.74	T_{30m} (s)	5th	4.85	4.81	4.42	4.42	4.37	4.34
	10th	3.45	3.47	3.15	3.03	2.90	2.83		10th	4.85	4.89	4.49	4.44	4.40	4.39
	25th	3.58	3.50	3.42	3.17	3.05	3.01		25th	4.95	4.98	4.84	4.65	4.45	4.47
	50th	3.66	3.60	3.50	3.35	3.15	3.16		50th	5.10	5.10	4.98	4.84	4.65	4.57
	75th	3.76	3.76	3.55	3.48	3.32	3.26		75th	5.15	5.13	5.07	5.02	4.85	4.63
	90th	3.79	3.81	3.64	3.55	3.37	3.37		90th	5.15	5.18	5.13	5.18	4.94	4.74
	95th	3.80	3.82	3.64	3.59	3.42	3.45		95th	5.17	5.18	5.16	5.27	5.04	4.82
YYIR TL1 (m)	5th	720	716	960	1,028	1,446	1,360								
	10th	840	720	972	1,164	1,596	1,496								
	25th	920	840	1,170	1,420	1,830	1,800								
	50th	1,160	1,000	1,540	1,720	2,040	2,120								
	75th	1,320	1,200	1,780	1,920	2,330	2,520								
	90th	1,520	1,360	2,028	2,168	2,600	2,800								
	95th	1,520	1,416	2,206	2,384	2,674	2,960								

DISCUSSION

The aim of this study was to examine the influence of age and maturity status on anthropometric and several physical performances parameters in a large cross-sectional sample of elite youth male soccer players (aged 12-17 years) and to establish normative data using percentile according to maturity status. The strength of this study lies in the analysis of data according to age and maturity status with approach used for sprinting performances for youth male (36) and specific physical performances for female soccer players (20). This method allowed us to identify the differences between consecutive age and maturity groups. Data was aligned by age categories (U12 to U17) and six maturational intervals according to their maturity offset from -2.5 to 2.5 year around PHV including soccer-specific physical performances. Our study revealed several key findings. Firstly, sprinting performances showed an early development, occurring between -2.5 years before PHV and 0.5 YPHV, compared to other physical attributes we examined. Secondly, as players mature, starting at approximately -0.5 years before PHV and continuing throughout PHV, we observed significant enhancements in leg muscle volume, leading to remarkable improvements in vertical jump performance.

Concerning the Yoyo test, we observed a significant performance increase from -1.5 YPHV to 1.5 YPHV. Lastly, we established normative data of anthropometric and physical performances according to maturity status in a large cross-sectional sample of elite youth male soccer players aged 12 to 17 years. Our data showed that anthropometric and physical performances changes and development during growth and maturation were nonlinear between consecutive age and maturation groups. Our finding supports previous research which confirm that age-related anthropometry and physical performance increase significantly with age (52). Notably, within our sample, anthropometric changes occurred around the PHV between the ages of 14-15 which was slightly later compared to the study by Philippaerts *et al*. (53). Previous study showed that the average age associated with PHV is (13.8 ± 0.8 years) compared to Tunisian soccer players, who demonstrate a PHV (14.29 ± 0.59 years). Concerning the onset of the growth spurt, some researchers have demonstrated an earlier onset at around 10.7 years old (52).

In general, the onset of the stature growth spurt is around 12 years old (54). For our study, the rate of development of height, body mass, sitting height leg length and leg muscle volume increased markedly and asynchronously from 12 to 16 years. Height increases significantly with an average of 4.38 cm / year between 12-17 years with peak 6.88 cm at age between 14-15 years. Notably, previous study indicated that the average of growth is around 7 cm/ year (55).

Compared with previous studies, the 14-year-old players were taller to Belgium soccer player and have the same stature as English soccer players (52), French professional soccer (56) and Eastern European soccer player (55). Also, body mass increased significantly from 13 to 16 years with an average 9.85 kg/year peaking at 10.7 kg at 13-14-year age range. Leg muscle volume increased significantly with age, especially between the U13, U14 and U15 age groups with an average of 1,055.42 mL/year.

According to maturity groups, all anthropometric variables were significant different between groups (-0.5 and 0.5 YPHV). From -0.5 maturity group and after YPHV, significant differences were recorded for all anthropometrics variables between maturity groups are recorded excepting the percentage of fat. Leg muscle volume demonstrate almost certainly difference between different maturity groups. Moreover, the spurt in muscle mass for youth player occurs shortly after PHV (54). Such findings could be related to the nature of the cross-sectional sample and this evolution might suggest important implications for success in soccer and directly effect to the selection criteria established by coaches of young players. However, multiple physical modifications are caused by hormonal changes and the influence of testosterone between mid and late puberty, which is a potent anabolic hormone. Youth soccer players experience a significant increase in muscle volume and lean body mass, associated with loss of adipose tissue and gain in weight (57). The tempo of development influenced by age and maturation involve changes in physical characteristics and performances both before and after PHV (19). The development of anthropometric characteristics could be the key for several observed changes in physical characteristics and performances between consecutive maturity groups (54).

The explosive power of the lower limbs was tested in the present study by the SJ and the CMJ which are considered as indices of explosive leg power (58). Performance increased significantly with age according to various studies (52, 59) and somewhat contrasts with youth soccer studies demonstrating that jump ability improves but does not follow the same trend as the anthropometric gains (60). The most significant increase in vertical jump was identified at the age of 12, whereas 13- and 14-year-old players. According to maturity groups, the greatest significant change was recorded between -1.5 and .5 YPH. From -.5 YPH, almost certain difference was observed for more mature players for SJ and CMJ. Changes may be related to hormonal and morphological changes reported to occur around PHV (61). Increases in leg length and muscle mass were associated with increased vertical jump heights. Growth evolution and structural changes were deemed to override any negative effects of the concomitant increase in body mass. After

PHV, performances tend to increase or achieve a plateau which may impact player's lower-body power. It is recommended to improve neuromuscular strength and fundamental movement skills in players before PHV working on correct running mechanics, multiplane jumping and landing tasks (62).

Maximum sprinting speed was the best talent indicator for predicting selection for professional academies (63). The time around PHV is a key point in the improvement in speed (36). Our results revealed that sprint times improved with age and maturity. Performance differences were significant from 13 to 16 for the T10m and from 13 to 15 for the T20m. According to maturity groups, significant differences were recorded from -2.5 YPHV to 0.5 YPHV. Yagüe and De La Fuente (64) reported improvements in speed in the 12 months post-PHV that were not observed in this study; however, they also noted improvement in speed 16 months before PHV. The Spanish sample was largely composed of average and early mature boys (13.0 ± 0.63). Old soccer players were faster in sprinting (T30m) and significant differences were shown only between 13 and 14 years. According to maturity groups, significant differences were noted from -1.5 YPHV. These performances appeared earlier and were in advance compared to the study by Meyers *et al.* (36) who mentioned an improvement in sprint times for the 30m dash after PHV. Performances are closely related to body mass and contact times, because players spend more time on the ground when sprinting. The stride frequency decreases during the pre-PHV period, and stride length increases with maturation. Performances are likely due to increased limb length and improved relative force production (36). Moreover, there is a greater increase in lean muscle mass, which results in improved expression of both concentric strength and power (65). The Yo-Yo Intermittent Recovery Test Level 1 YRIRTL1 was confirmed as a valid resource for coaches, fitness trainers, and sport scientists interested in assessing endurance capacity in young football players (66).

Our results showed that the total distance covered in the specific intermittent endurance test increases steadily between the ages of 12 and 17 years, with significant differences shown between age groups. However, a decrease in the rate of increase was observed between 12 and 13 years, in agreement with the study by Carvalho *et al.* (67). A previous study (67) demonstrated higher distance covered for 14-year-old players from a Spanish first division (La Liga) club (1,658.5 ± 408.5 m) and at the start of an experimental study (1,488 ± 345 m) and (1,764 ± 256 m) for the control group (68). Current U17 players had a considerably greater performance in distance covered during the YYIRTL1 to the studies of (69) with Belgium soccer players and (70) with the Croatian population who reported distances of 1,910 ± 428 m and 1,581 ± 390 m respectively in 17-year-old elites. Performance increased significantly according to maturity groups from -1.5 to 1.5 years YPHV occurring around the timing of PHV when players moved from pre- to post-PHV. Philippaerts *et al.* (53) reported that the highest increase in cardiorespiratory endurance coincides with the timing of PHV. Previous research has reported that growth-related changes to the central and peripheral cardiovascular system, including increases in stroke volume and cardiac output, as well as changes in muscular function and metabolic capability occur around the onset of PHV (61). Furthermore, the study of Bailey *et al.* (71) indicated that maximal gains in peak oxygen occurred around the timing of PHV, with continued improvement observed during late adolescence. Percentile values of anthropometric variables and specific physical performances according to maturity groups were provided. These percentile values are of interest to estimate the proportion of youth soccer players with high or low specific physical performance levels according to PHV. Consequently, the present data could serve as reference values or standards for other youth soccer samples from the north of Africa in high-level soccer development programs.

This study has some limitation that need to be considered. Players did not join clubs and training session and competition at the same time; therefore, it was not possible to obtain information on the soccer experience and training age of the players. The longitudinal data focused on natural development without determining the effect of training on the development of jumping, sprinting, and total distance. From this sample, no data were available on some physical performances to compare with maturity groups. We cannot compare youth female players' performances (20). Our study's data suggest that, during the pre-PHV period, the primary focus should be on developing technical competency and assisting players in coping with the growth-related anthropometric changes they undergo during this stage. Training and learning tasks should be centered around correcting running mechanics, addressing specific multiplanar jumping and landing tasks, and improving sprinting techniques (62). Coaches should prioritize the improvement of fundamental movement skills before players reach PHV. Furthermore, it is essential to complement the effects of androgens and muscle growth with neural training to maximize the benefits of maturity-related changes.

We strongly recommend conducting regular physical assessments and comparing the results to identify periods of rapid growth and maturation, as well as to monitor performance improvements or setbacks. Moving into the post-PHV phase, coaches should emphasize the development of the aerobic system in players. This can be achieved through a variety of exercises, including small-sided games combined with short-duration, intermittent, high-intensity training. It is crucial to incorporate specific movements into training sessions to foster the development of technical and tactical skills.

CONCLUSIONS

By chronological order, sprinting performances demonstrated early development alongside leg muscle volume, leading to remarkable improvements in vertical jump performance. Intermittent endurance performance increases occurred around the timing of peak height velocity (PHV). Percentiles and normative data of anthropometric and physical performances according to maturity status were established to help specialists and coaches estimate the levels of youth soccer players with high or low soccer-specific physical performances.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

MT, TW, GR, JP: methodology, investigation, formal analysis, writing – original draft. JCS: methodology, investigation, formal analysis, writing – original draft. MG, AF, GMM, JP, YT: writing – original draft. JP, YT: conceptualization, methodology, supervision, writing – reviewing & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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