Skeletal Maturation and Aerobic Performance in Young Soccer Players from Professional Academies

Article *in* International Journal of Sports Medicine · August 2015

DOI: 10.1055/s-0035-1549922

9 authors, including:

Anderson Santiago Teixeira
Federal University of Santa Catarina
13 PUBLICATIONS **37** CITATIONS
SEE PROFILE

João Valente-Dos-Santos
University of Coimbra
82 PUBLICATIONS **246** CITATIONS
SEE PROFILE

Manuel J Coelho-e-Silva
University of Coimbra
213 PUBLICATIONS **2,053** CITATIONS
SEE PROFILE

Juliano Fernandes da Silva
Federal University of Santa Catarina
48 PUBLICATIONS **259** CITATIONS
SEE PROFILE

Skeletal Maturation and Aerobic Performance in Young Soccer Players from Professional Academies

Authors
A. S. Teixeira[1], J. Valente-dos-Santos[2], M. J. Coelho-e-Silva[3], R. M. Malina[4], J. Fernandes-da-Silva[1], P. Cesar do Nascimento Salvador[1], R. D. De Lucas[1], M. C. Wayhs[1], L. G. A. Guglielmo[1]

Affiliations
Affiliation addresses are listed at the end of the article

Key word
- adolescence
- field testing
- intermittent exercise
- skeletal age
- young athletes

Abstract

The contribution of chronological age, skeletal age (Fels method) and body size to variance in peak velocity derived from the Carminatti Test was examined in 3 competitive age groups of Brazilian male soccer players: 10–11 years (U-12, n = 15), 12–13 years (U-14, n = 54) and 14–15 years (U-16, n = 23). Body size and soccer-specific aerobic fitness were measured. Body composition was predicted from skinfolds. Analysis of variance and covariance (controlling for chronological age) were used to compare soccer players by age group and by skeletal maturity status within of each age group, respectively. Relative skeletal age (skeletal age minus chronological age), body size, estimated fat-free mass and performance on the Carminatti Test increased significantly with age. Carminatti Test performance did not differ among players of contrasting skeletal maturity status in the 3 age groups. Results of multiple linear regressions indicated fat mass (negative) and chronological age (positive) were significant predictors of peak velocity derived from the Carminatti Test, whereas skeletal age was not a significant predictor. In conclusion, the Carminatti Test appears to be a potentially interesting field protocol to assess intermittent endurance running capacity in youth soccer programs since it is independent of biological maturity status.

Introduction

The characteristics of young athletes in several team sports and specifically in soccer are reasonably well documented [2, 11, 16, 21, 22]. Statures of adolescent soccer players, on average, fluctuate above and below reference medians for the general population of youth, while body masses, on average, tend to fluctuate above and below the 75th percentile [21]. Mean skeletal ages (SA) tend to approximate mean chronological ages (CA) among youth soccer players 11–12 years old, but SAs tend to be in advance of CAs in players 13–14 and 15–16 years old [21]. The findings suggest selective preference for players advanced in skeletal maturation with increasing age as male soccer players pass through adolescence [2, 11, 21, 22]. Advanced maturation is associated with larger body size and greater strength and power. These observations are mainly derived from youth soccer players of European ancestry [3, 9, 11]. Corresponding data for Brazilian youth soccer players are limited, especially for studies which include SA as the indicator of maturity status. This is somewhat surprising given the popularity of soccer in Brazil.

Soccer includes periods of high-intensity interspersed with periods of lower-intensity effort. Players need to attain high levels of several aspects of physical fitness, including intermittent endurance to support the demands of a game and to recover from repeated bouts of high-intensity effort [30, 36]. Aerobic running performance also appears to be an important discriminating factor between elite and sub-elite players [35], whereas tactical and technical skills are considered as determinants for successful participation at elite levels [32] (▶ **Fig. 1**).

Field tests with different activity patterns (e.g., continuous or intermittent) have been regularly used in the evaluation of aerobic running performance in the context of talent identification and development [33]. Some studies have also suggested a need for field tests that are not related to maturity status in youth soccer in order to prevent the deselection of late maturing players [37]. In this context, there is a need for systematic evaluation of the relationship between per-

accepted after revision
April 05, 2015

Bibliography
DOI http://dx.doi.org/10.1055/s-0035-1549922

Int J Sports Med 2015; 36: 1069–1075
ISSN 0172-4622

Correspondence
Prof. Manuel J Coelho-e-Silva, PhD
Estadio Universitario de Coimbra
University of Coimbra
3040-156 Coimbra
Portugal
Tel.: + 351/239/802 770
Fax: + 351/239/802 779
mjcesilva@fcdef.uc.pt

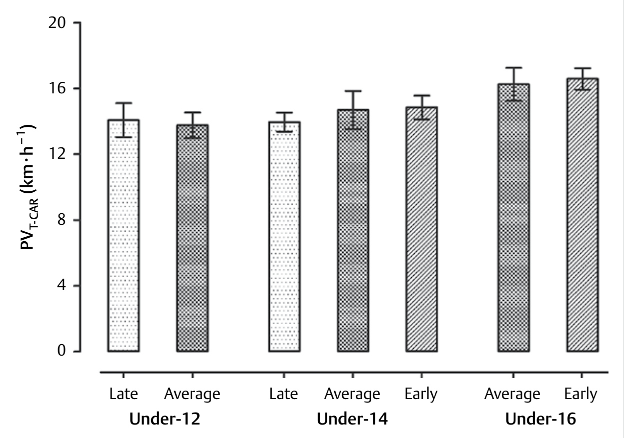

Fig. 1 Peak velocity derived from *Carminatti Test* among soccer players of contrasting skeletal maturity status within each competitive age group.

formance outputs and biological maturation in youth soccer players, in addition to evaluation of the properties of field tests (i.e., reproducibility, validity and sensitivity) [7,25,26].

Although several field testing protocols are available, they have not been extensively examined in the context of maturity-associated variation. The interrelationship between skeletal maturation and aerobic running performance derived from the yo-yo intermittent endurance test and 20-m multistage fitness test has been studied in youth soccer players [11,20,36]. Cross-sectional and longitudinal analyses have indicated a potentially important role for CA, biological maturity status, body size and training volume in the development of aerobic running performance [20,30,36]. An additional aerobic field protocol, the *Carminatti Test*, for the assessment of high-intensity intermittent running capacity has been proposed; it uses peak velocity reached at the end of the test ($PV_{T\text{-}CAR}$) as a parameter to individualize the covered distance during the testing session [6]. The test has acceptable reproducibility and validity in adult [8] and youth soccer players [34]. $PV_{T\text{-}CAR}$ was consistently correlated with aerobic parameters obtained with an incremental treadmill protocol (maximal aerobic velocity: $r=0.81$; VO_2peak: $r=0.57$; anaerobic threshold: $r=0.69$) and also with anaerobic outputs derived from repeated sprints (fastest sprint time: $r=-0.81$; mean sprint time: $r=-0.71$) [6,8,34]. Information is lacking regarding age- and maturity-associated variation in *Carminatti Test* outputs in youth soccer players during adolescence.

The present study examines age- and maturity-associated variation in body size and proportions, estimated body composition and aerobic running performance assessed as $PV_{T\text{-}CAR}$ in Brazilian youth soccer players 10–15 years of age. It was hypothesized that older age groups are larger in body size and perform better in $PV_{T\text{-}CAR}$ compared to younger players, and that players of contrasting maturity status within an age group would not differ substantially in $PV_{T\text{-}CAR}$.

Methods

▼

The study was approved by the Ethics Committee of the Federal University of Santa Catarina, Brazil (protocol 2004/2011) and was conducted in accordance with the ethical standards of the International Journal of Sports Medicine [12]. The clubs, players and their parents or legal guardians provided informed written consent. Participants were informed about the nature of the study; participation was voluntary and players could withdraw at any time.

Participants

This cross-sectional sample included 92 male youth soccer players ages 10.2–15.4 years old who were recruited from professional club academies competing at the Brazilian national level. Players were classified as under-12 (U-12, 10.0–11.9 years), under-14 (U-14, 12.0–13.9 years) and under-16 (U-16, 14.0–15.9 years) by the Soccer Federation of Santa Catarina (member of the Brazilian Soccer Confederation). At the time of study, all players had at least 3 years of experience in soccer training and took part in regional and national championships. Players performed 3–5 regular training sessions per week (about 90-120 min per session) and participated in official games usually on Saturdays. Training sessions consisted mainly of technical and tactical skill development (70% of the training time), soccer-specific coordination and agility (15%) and physical conditioning (15%). Physical conditioning was performed once a week in the under-12 and under-14 groups (aerobic fitness was developed using small-sided games) and twice a week in the under-16 group (aerobic and anaerobic training consisted of short or long-interval running and plyometrics or sprint training drills, respectively). Goalkeepers were excluded from analysis.

Experimental procedures

The assessments were conducted in 2 sessions during the pre-competitive period of the season. All players visited the laboratory of the Federal University of Santa Catarina in order to complete the anthropometric battery and were transported to Santa Catarina University Hospital for an X-ray of the left hand-wrist. Aerobic running performance was assessed with the *Carminatti Test* within one week of the anthropometry and hand-wrist X-ray. Participants were familiar with the testing procedures as part of their usual fitness assessment program. All tests were performed at the same time of day (16:00–18:00 h); participants were allowed to drink water "ad libitum" during the field test. In order to avoid undue fatigue before testing, participants were instructed to avoid heavy training during the 48 h preceding each test. Diet at the sport academies was standardized on the day before testing (~50–60%, 30–25% and 20–15% of total energy intake composed of carbohydrates, fat and protein, respectively). Participants were also instructed to avoid caffeinated drinks [8].

Anthropometry

Anthropometry was assessed by a single, experienced individual following standard procedures [15]. Body mass was measured to the nearest 0.1 kg using a calibrated scale (Soehnle, Murrhardt, Germany). Stature and sitting height were measured to the nearest 0.1 cm with a stadiometer (Sanny, American Medical do Brazil, São Paulo, Brazil) and sitting height table (Harpenden model 98 607, Holtain Ltd, Crosswell, UK), respectively. Leg length (subischial) was estimated as stature minus sitting height. 2 skinfolds (triceps and subscapular) were measured with an adipometer accurate to 0.1 mm (Cescorf, Porto Alegre, Brazil). Fat mass (FM) in kg and as a percentage of total body mass (%Fat) were predicted from skinfolds [29,31]. Intra-observer technical errors of measurement were 0.2 cm for stature, 0.4 cm for sitting height, 0.3 mm for the triceps and 0.3 mm for the subscapular skinfolds.

Biological maturity

Posterior-anterior X-rays of the left hand-wrist were taken. The Fels method [28] was used to estimate SA. The method utilizes specific criteria for each bone of the hand-wrist and ratios of linear measurements of epiphyseal and metaphyseal widths [22]. Ratings and ratios were entered into a program (Felshw 1.0 Software, Lifespan Health Research Center, Departments of Community Health and Pediatrics, Boonshoft School of Medicine, Wright State University, Dayton, Ohio) to calculate SA and its standard error of estimate. The protocol considers 18 years as the age of the mature state, in contrast to TW3 method that considers mature state at an age of 16.5 years [19]. X-rays were assessed by a single observer [5] trained by an experienced assessor and based on 14 films from basketball players 14.52–16.95 years of age, the intra-individual differences were calculated (-0.12 ± 0.34) and inter-observer error of measurements was 0.25 years (%CV = 1.41). The 2 assessors performed 391 observations with an agreement rate of 93.1%. Chronological age (CA) was calculated as the difference between the date of birth and date of the X-ray. The difference between SA and CA, an estimate of relative skeletal age, was used to classify players as late (SA younger than CA by > 1.0 years), average or on time (SA within ± 1.0 year of CA), early (SA older than CA by > 1.0 years), or skeletally mature. This classification has been regularly used in previous studies with youth soccer players [5, 11, 22].

Carminatti test

The test consisted of intermittent shuttle runs of 12 s performed between 2 lines set at progressive distances with a 6-s recovery between each run and a total stage time of 90 s. The protocol had a starting velocity of 9 $km \cdot h^{-1}$ over a running distance of 30 m (15 m out and back). The length in a single direction was increased progressively by 1 m at every level. Each stage consisted of 5 repetitions with a 6-sec walking period between 2 lines set 2.5 m from the starting line. 8–10 athletes were evaluated simultaneously with the running pace dictated by a pre-recorded audio system [6, 34]. The test ended when participants failed to follow the audio cues on the front line for 2 successive repetitions (objective criteria observed by observers). $PV_{T\text{-}CAR}$ was calculated from the distance of the last set completed by the athlete divided by the time to complete the stage repetition. In the case of an incomplete set, peak velocity was interpolated using the equation: $PV = v + (ns/10) * 0.6$, where "v" is the velocity of the last fully completed stage and "ns" = number of repetitions completed in the partially completed stage. Reproducibility of $PV_{T\text{-}CAR}$ was estimated with replicate tests within a period of 1 week among 34 youth players 10.2–13.0 years of age. The intra-class correlation coefficient and measurement error expressed as coefficient of variation for $PV_{T\text{-}CAR}$ were, respectively, 0.89 and 2.30% (0.3 $km \cdot h^{-1}$). Additionally, based on exploratory data obtained from motion analysis recordings, performed according to procedures described elsewhere [27], of adolescent soccer players from the current study (n = 40, 14.5 ± 0.6 years), suggested promising correlations between $PV_{T\text{-}CAR}$ and high intensity activity ($r = 0.76$, $p < 0.001$), high-intensity running ($r = 0.66$, $p < 0.01$), sprinting ($r = 0.58$, $p < 0.01$) and total distance covered ($r = 0.50$, $p < 0.01$).

Statistical analyses

Descriptive statistics (mean ± SD) were calculated for the total sample and for specific age groups. Normality was checked using the Kolmogorov-Smirnov test. Between-age group differences were tested using univariate analysis of variance (ANOVA), while univariate analysis of covariance (ANCOVA) with chronological age as the covariate was used to compare players of contrasting maturity status. The magnitude of the differences was assessed using standardized mean differences (Cohen effect size, ES) with thresholds of 0.20, 0.60, 1.20, 2.0 and 4.0 for small, moderate, large, very large and extremely large [1]. Multiple linear regressions (backward method) were used to estimate the contribution of CA, SA, stature and estimated FFM and FM to inter-individual variation in $PV_{T\text{-}CAR}$. Statistical significance was set at 5%. Analyses were done using SPSS (SPSS 13.5 version, Chicago, Illinois, USA).

Results

Descriptive statistics for the total sample are summarized in **Table 1**. The examination of chronological age group as a significant source of inter-individual variation on body size, estimated body composition and $PV_{T\text{-}CAR}$ is presented in **Table 2**. Magnitude effects ranged from moderate to very large for comparisons between U-12 and U-14, from small to very large for the contrast of U-14 and U-16, and between large and extremely large for the comparison U-12 and U-16.

CAs ranged from 10.2 to 15.4 years, while SAs ranged from 8.3 to 17.2 years (was not normally distributed). For the sample as a whole, 12 players were delayed, 44 players were on time, and 36 players were advanced in SA relative to CA. Comparisons by age group are summarized in **Table 2**. All variables differed significantly across age groups except estimated FM. The magnitude effects for all dependent variables, with the exception of $PV_{T\text{-}CAR}$, were always larger between U-12 and U-14 compared to the effect size between U-14 and U-16 groups.

Characteristics of players of contrasting maturity status within each competitive age group are presented in **Table 3**. Peak velocity derived from the *Carminatti Test* and FM did not differ among maturity groups within each competitive age group. Effect size ranged between trivial (late vs. average in U-12, aver-

Table 1 Descriptive statistics for the total sample (n = 92).

		Mean		Standard deviation	Kolmogorov-Smirnov	
	value	SEM	(95%CI)		value	p
chronological age (years)	13.3	0.1	(13.1 to 13.6)	1.2		
skeletal age (years)	13.9	0.2	(13.4 to 14.3)	2.2		
stature (cm)	160.1	1.3	(157.6 to 162.7)	12.4	0.090	0.07
body mass (kg)	49.6	1.2	(47.1 to 52.1)	12.0	0.117	<0.01
fat-free mass (kg)	42.2	1.1	(40.1 to 44.3)	10.3	0.125	<0.01
fat mass (kg)	7.4	0.3	(6.8 to 8.0)	3.1	0.089	0.07
$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)	15.0	0.1	(14.7 to 15.3)	01.3	0.067	0.20

$PV_{T\text{-}CAR}$ (peak velocity determined by the *Carminatti Test*); SEM (standard error of the mean); 95%CI (95% confidence interval) age and early in U-14 and U-16) and moderate (late vs. average in U-14). Players of contrasting maturity status within the U-12 and U-16 groups did not differ in stature, sitting height and estimated leg length, but differed significantly in estimated FFM (◉ **Table 3**). Within the U-14 group, players advanced in skeletal maturation were significantly heavier and taller and had a greater sitting height than average (on time) and late maturing players, who did not differ from each other.

Results of the multiple linear regressions are summarized for each age group in ◉ **Table 4**. Estimated FM and CA were significant predictors of performance on the Carminatti test. Estimated FM accounted for about 71 % of the variance in $PV_{T\text{-}CAR}$ in U-12 players. Among U-14 players, FM and CA accounted for 16 % of the variance in $PV_{T\text{-}CAR}$, while CA was the single significant predictor of $PV_{T\text{-}CAR}$ among U-16 players and accounted for 32 % of the variance.

Discussion

Chronological age- and maturity-associated variation in body size, estimated body composition and aerobic running performance using a new protocol in Brazilian youth soccer players were considered. The results were generally consistent with the hypothesis that intermittent endurance running capacity assessed by the $PV_{T\text{-}CAR}$ did not differ among players of contrasting skeletal maturity status within of each competitive age group. Estimated FM and CA were the unique contributors to inter-individual variability in $PV_{T\text{-}CAR}$, but contributions of each varied by age group.

Relative to US age-specific percentiles for males [14], U-12 soccer players had a mean stature and body mass between the 25th and 50th percentiles, whereas U-14 and U-16 players had, respectively, a mean stature and body mass between the 50th and 75th percentiles at each age. Observations on the body size of this sample of Brazilian youth soccer players, especially in the 2 older age groups, were consistent with previous studies of Portuguese youth soccer players [21] and data for the majority of samples of young soccer players [16,17]. Variation in body size and estimated body composition associated with contrasting maturity status in this sample of U-14 soccer players was similar to that for adolescent males in general, i. e., boys advanced in SA are taller and heavier than those on time and late in SA [19]. Among the 3 competitive age groups compared in the present study, maturity-associated variation in body size and composition was more apparent among U-14 players (mid-puberty) compared to corresponding variation among U-12 and U-16 players. Note, however, the small sample of U-12 players only included one early maturing player, while the sample of U-16 players did not have any of late maturing players. Sample size may be a limitation of the current study. Data dealing with biological maturity status, specifically SA, of Brazilian youth soccer players are scarce. The present study determined SA with the Fels method. The results were generally consistent with previous studies of Portuguese [11,21], Italian [2], French [3] and Japanese [13] players. In late childhood-early adolescence (U-12), the full spectrum of skeletal maturity from late through early was apparent, although the small sample of U-12 players in the present study did not include early maturing boys. However, among U-14 players, largely mid-adolescence, SA was advanced relative to CA and the majority of players was average (on time) and early, with only few late maturing players [17].

Table 2 Descriptive statistics (mean ± SD) for chronological age, skeletal age, body size descriptors and peak velocity determined by the *Carminatti Test* by competitive age group (U-12, U-14 and U-16), and results of univariate ANOVA with respective magnitude effects.

Dependent variables (Yi)	Age groups					U12 vs. U14		U12 vs. U-16		U14 vs. U16	
	U-12 (n = 15)	U-14 (n = 54)	U-16 (n = 23)	F	p	ES	(qualitative)	ES	(qualitative)	ES	(qualitative)
Age (years)				217.784	<0.001						
Skeletal age (years)	10.6 ± 1.3 ^{a}	13.8 ± 1.5 ^{b}	16.0 ± 0.9 ^{c}	72.974	<0.001						
SA minus CA (years)	− 0.8 ± 1.2 ^{a}	0.6 ± 1.3 ^{b}	1.3 ± 0.9 ^{b}	14.032	<0.001	1.14	(moderate)	2.00	(large)	0.60	(small)
Stature (cm)	143.0 ± 4.1 ^{a}	159.8 ± 9.7 ^{b}	172.1 ± 7.1 ^{c}	54.454	<0.001	2.30	(very large)	5.09	(extremely large)	1.61	(large)
Body mass (kg)	34.6 ± 4.4 ^{a}	48.8 ± 9.6 ^{b}	61.4 ± 7.7 ^{c}	45.458	<0.001	2.01	(very large)	4.74	(extremely large)	1.61	(large)
Fat mass (kg)	5.9 ± 2.1 ^{a}	7.5 ± 3.6 ^{a}	8.1 ± 2.3 ^{a}	2.426	0.094	0.78	(moderate)	1.50	(large)	0.39	(small)
Fat-free mass (kg)	28.7 ± 3.1 ^{a}	41.3 ± 7.6 ^{b}	53.3 ± 5.9 ^{c}	62.290	<0.001	2.41	(very large)	6.06	(extremely large)	1.97	(large)
$PV_{T\text{-}CAR}$ (km · h^{-1})	13.9 ± 0.9 ^{a}	14.7 ± 1.0 ^{b}	16.5 ± 0.7 ^{c}	48.620	<0.001	1.09	(moderate)	3.85	(very large)	2.35	(very large)

SA minus CA (skeletal age minus chronological age); $PV_{T\text{-}CAR}$ (peak velocity determined by the *Carminatti Test*)

Means in the same row having the same superscript are not significantly different

Table 3 Age-adjusted means (standard errors) by skeletal maturity groups separately for U-12, U-14 and U-16 adolescent soccer players, and results of univariate ANCOVA (controlling for chronological age) with magnitude effects for comparisons between groups.

Age	Y_i: Dependent	Xi: Skeletal Maturity Groups					Late vs. Average		Late vs. Early		Average vs. Early	
group	variables	Late	Average	Early	F	p	ES	(qualitative)	ES	(qualitative)	ES	(qualitative)
U-12[a]		(n = 6)	(n = 8)	(d)								
	stature (cm)	140.9 (1.6)	144.9 (1.4)		3.712	0.080	1.17	(moderate)				
	body mass (kg)	32.6 (1.8)	36.2 (1.6)		2.171	0.169	0.90	(moderate)				
	fat mass (kg)	5.9 (0.9)	5.8 (0.8)		0.012	0.916	0.05	(trivial)				
	fat-free mass (kg)	26.7 (1.1)	30.4 (0.9)		6.520	0.027	1.47	(very large)				
	$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)	14.1 (0.4)	13.8 (0.3)		0.401	0.539	0.36	(small)				
U-14[b]		(n = 6)	(n = 27)	(n = 21)								
	stature (cm)	153.4 (3.1)	158.0 (1.4)	164.0 (1.7)	6.133	0.004	0.55	(small)	1.22	(large)	0.71	(moderate)
	body mass (kg)	44.2 (3.2)	46.7 (1.5)	52.8 ± 1.7)	4.571	0.015	0.28	(small)	1.02	(moderate)	0.60	(moderate)
	fat mass (kg)	8.3 (1.4)	7.6 (0.7)	7.2 (0.8)	0.219	0.804	0.18	(trivial)	0.34	(small)	0.12	(trivial)
	fat-free mass (kg)	35.9 (2.4)	39.1 (1.1)	45.5 (1.3)	9.818	< 0.001	0.50	(small)	1.48	(large)	1.02	(moderate)
	$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)	14.0 (0.4)	14.7 (0.2)	14.8 (0.2)	1.671	0.198	0.64	(moderate)	1.22	(large)	0.10	(trivial)
U-16[c]		(e)	(n = 9)	(n = 14)								
	stature (cm)		168.9 (2.4)	172.6 (2.1)	1.260	0.275					0.54	(small)
	body mass (kg)		56.1 (2.1)	63.4 (1.9)	6.470	0.019					1.10	(moderate)
	fat mass (kg)		7.1 (0.7)	8.6 (0.6)	2.531	0.127					0.72	(moderate)
	fat-free mass (kg)		49.0 (1.7)	54.8 (1.5)	6.320	0.021					1.11	(moderate)
	$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)		16.4 (0.2)	16.5 (0.2)	0.225	0.640					0.15	(trivial)

$PV_{T\text{-}CAR}$ (peak velocity determined by *Carminatti Test*); [a] Covariate (chronological age = 11.36 years); [b] Covariate (chronological age = 13.23 years); [c] Covariate (chronological age = 14.68 years); (d) This category had only one U-12 participant classified as early maturing; (e) This category was empty because any U-16 participant was classified as late maturing

Table 4 Results of multiple linear regressions (backward extraction) to predict $PV_{T\text{-}CAR}$ in youth soccer players by age group.

Sub-samples		Significant Predictors	Standardized beta Coefficients			R^2	Adjusted R^2
Age-group	n		value	(95 %CI)	p		
U-12	15	fat mass	− 0.856	(− 1.166 to − 0.546)	< 0.001	0.733	0.712
U-14	54	fat mass	− 0.407	(− 0.674 to − 0.140)	0.004	0.190	0.158
		chronological age	+ 0.334	(0.067 to 0.602)	0.015		
U-16	23	chronological age	+ 0.593	(0.228 to 0.959)	0.003	0.352	0.321

$PV_{T\text{-}CAR}$ (peak velocity derived from the *Carminatti Test*)

The current data were consistent with other studies of youth soccer players in supporting the hypothesis that average and early maturing boys are more likely to be retained and promoted by coaches, clubs and soccer organizations, while late maturing players may be more likely to drop out or to be excluded [11, 17, 21]. This change in the proportion of late- and early-maturing players across adolescence has practical implications regarding strategies and criteria used by coaches and scouts. On the other hand, it raises the issue of how can the skilled later maturing boy be encouraged to remain in the sport.

Results of this study using the *Carminatti Test* were generally similar to studies using the Yo-Yo Intermittent Endurance (Yo-Yo IE1) test in adolescent players [7, 9, 11]. Performance on the Yo-Yo test did not differ among 13–14 year-old youth soccer players of contrasting skeletal maturity status, whereas better performance was noted in later maturing 11–12 year-old players compared to average and early maturing players who do not differ from each other [9, 11]. The lack of consistent differences in intermittent endurance capacity assessed by Carminatti test and Yo-Yo IE1 among soccer players of contrasting maturity status might be partially explained by longitudinal studies that noted a direct relationship between intermittent endurance capacity and time spent in soccer-specific activities (training plus independent practice) during adolescence [30, 36].

High-intensity intermittent endurance capacity is an important functional capacity in both the prediction of soccer match performance [4] and also in the selection of youth players [23, 35]. Specific performance protocols used in talent identification and selection programs may, however, be differentially affected by inter-individual variation in skeletal maturity status. Coaches and trainers use a variety of field tests to assess and monitor the development of sport-specific aerobic running performance in youth soccer players [4, 24, 34]. Multilevel modeling has been used to evaluate developmental changes on a progressive aerobic 20-m continuous shuttle run test during adolescence; aerobic running performance was substantially related to CA and its quadratic power function, and to annual volume of training [36]. However, when SA was considered, estimated FFM and annual volume of training in conjunction with biological maturation significantly influenced annual gains in the aerobic running performance of adolescent soccer players. The current study used the *Carminatti Test* protocol in male soccer players in 3 competitive age groups spanning adolescence. As expected, significant age-related variation in $PV_{T\text{-}CAR}$ was noted. Previous studies have also reported age-related variation in Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) and VAMEVAL Test performances in Croatian (12.0–18.9 years) and Arab (11.5–17.8 years) youth soccer players, respectively [23, 24]. Although the comparisons are limited due to differences in protocols or performance output, observations in the present study indicated that the *Carminatti Test* adequately discriminated age-related changes in intermittent endurance running capacity between 10 and 15 years of age, consistent with other field tests used in youth soccer. Differences in *Carminatti Test* performance ($PV_{T\text{-}CAR}$) were more pronounced between U-14 and U-16 players (ES = 2.35; very large) compared to the magnitude of the effect between U-12 and U-14 players (ES = 1.09; moderate). The sample of U-16 players in the present study had 2 more training sessions per week than their younger peers.

Estimated FM is negatively related with performance, especially in tests that require the movement or projection of the body [18]. In the context of youth soccer, CA (positive) and adiposity (negative) accounted for 24 % of the variance in the Yo-Yo IE1 in 11–12 year-old players [10], while among soccer players 13–14 years old, training history, CA, sitting height to stature ratio (positive) and body mass (negative) accounted for 43 % of the variance in the Yo-Yo IE1 [10]. The explained variance at older ages may reflect the years of training in the sport and experience with the test.

Although the *Carminatti Test* and Yo-Yo IE1 performance output are not directly comparable, the results of several studies have consistently shown that a large proportion of the variation in intermittent endurance capacity was not explained by age, biological maturity status (SA or stage of puberty), body size and years of training [10]. Further research is needed to examine interrelationships among developmental changes in $PV_{T\text{-}CAR}$ and growth, biological maturation and training over years of specialization in soccer and also other sports. There is also a need to evaluate relationships between the *Carminatti Test* and other field tests of aerobic endurance capacity in youth athletes.

Practical Application

▼

Performance on the *Carminatti Test* appeared to be independent of variation in skeletal maturity within each age group of adolescent soccer players. By inference, the *Carminatti Test* seems to be a potentially useful tool for the assessment of intermittent endurance running capacity under field conditions and perhaps in talent identification, selection and developmental programs, as it is independent from biological maturation during puberty.

Conflict of interest: The authors have no conflict of interest to declare.

Affiliations
[1] Physical Effort Laboratory, Sports Center, Federal University of Santa Catarina, Florianópolis, Brazil
[2] Faculty of Sport Sciences and Physical Education, University of Coimbra, Coimbra, Portugal
[3] Estadio Universitario de Coimbra, University of Coimbra, Coimbra, Portugal
[4] Department of Kinesiology and Health Education, University of Texas at Austin, Texas, United States

References

1 *Batterham AM, Hopkins WG.* Making meaningful inferences about magnitudes. Int J Sports Physiol Perform 2006; 1: 50–57
2 *Cacciari E, Mazzanti L, Tassinari D, Bergamaschi R, Magnani C, Zappulla F, Nanni G, Cobianchi C, Ghini T, Pini R, Tani G.* Effects of sport (football) on growth: auxological, anthropometric and hormonal aspects. Eur J Appl Physiol 1990; 61: 149–158
3 *Carling C, Le Gall F, Malina RM.* Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003. J Sports Sci 2012; 30: 1683–1693
4 *Castagna C, Manzi V, Impellizzeri F, Weston M, Barbero Alvarez JC.* Relationship between endurance field tests and match performance in young soccer players. J Strength Cond Res 2010; 24: 3227–3233
5 *Coelho-e-Silva MJ, Figueiredo AJ, Simoes F, Seabra A, Natal A, Vaeyens R, Philippaerts R, Cumming SP, Malina RM.* Discrimination of u-14 soccer players by level and position. Int J Sports Med 2010; 31: 790–796
6 *Da Silva JF, Guglielmo LG, Carminatti LJ, De Oliveira FR, Dittrich N, Paton CD.* Validity and reliability of a new field test (Carminatti's test) for soccer players compared with laboratory-based measures. J Sports Sci 2011; 29: 1621–1628
7 *Deprez D, Vaeyens R, Coutts AJ, Lenoir M, Philippaerts R.* Relative age effect and Yo-Yo IR1 in youth soccer. Int J Sports Med 2012; 33: 987–993
8 *Dittrich N, da Silva JF, Castagna C, de Lucas RD, Guglielmo LG.* Validity of Carminatti's test to determine physiological indices of aerobic power and capacity in soccer and futsal players. J Strength Cond Res 2011; 25: 3099–3106
9 *Figueiredo AJ, Coelho-e-Silva MJ, Cumming SP, Malina RM.* Size and maturity mismatch in youth soccer players 11- to 14-years-old. Pediatr Exerc Sci 2010; 22: 596–612
10 *Figueiredo AJ, Coelho-e-Silva MJ, Malina RM.* Predictors of functional capacity and skill in youth soccer players. Scand J Med Sci Sports 2011; 21: 446–454
11 *Figueiredo AJ, Goncalves CE, Coelho-e-Silva MJ, Malina RM.* Youth soccer players, 11–14 years: maturity, size, function, skill and goal orientation. Ann Hum Biol 2009; 36: 60–73
12 *Harriss DJ, Atkinson G.* Ethical standards in sport and exercise science research: 2014 Update. Int J Sports Med 2013; 34: 1025–1028
13 *Hirose N.* Relationships among birth-month distribution, skeletal age and anthropometric characteristics in adolescent elite soccer players. J Sports Sci 2009; 27: 1159–1166
14 *Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL.* 2000; 2000 CDC Growth Charts for the United States: methods and development: Vital Health Stat 11. 2002; 246: 1–190
15 *Lohman TG, Roche AF, Martorell R.* Anthropometric standardization reference manual. Champaign, IL: Human Kinetics, 1988
16 *Malina RM.* Physical growth and biological maturation of young athletes. Exerc Sport Sci Rev 1994; 22: 389–433
17 *Malina RM.* Growth and maturity status of young soccer (football) players. In: Reilly T, Williams AM (eds.). Science and Soccer. London: Science and soccer, 2003; 287–306
18 *Malina RM.* Body composition in athletes: assessment and estimated fatness. Clin Sports Med 2007; 26: 37–68
19 *Malina RM, Bouchard C, Bar-Or O.* Growth, maturation, and physical activity. 2nd ed. Champaign, IL: Human Kinetics, 2004
20 *Malina RM, Eisenmann JC, Cumming SP, Ribeiro B, Aroso J.* Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13–15 years. Eur J Appl Physiol 2004; 91: 555–562
21 *Malina RM, Pena Reyes ME, Eisenmann JC, Horta L, Rodrigues J, Miller R.* Height, mass and skeletal maturity of elite Portuguese soccer players aged 11–16 years. J Sports Sci 2000; 18: 685–693
22 *Malina RM, Pena Reyes ME, Figueiredo AJJ, Coelho-e-Silva MJ, Horta L, Miller R, Chamorro M, Serratosa L, Morate F.* Skeletal age in youth soccer players: implication for age verification. Clin J Sport Med 2010; 20: 469–474
23 *Markovic G, Mikulic P.* Discriminative ability of the Yo-Yo intermittent recovery test (level 1) in prospective young soccer players. J Strength Cond Res 2011; 25: 2931–2934
24 *Mendez-Villanueva A, Buchheit M, Kuitunen S, Poon TK, Simpson B, Peltola E.* Is the relationship between sprinting and maximal aerobic speeds in young soccer players affected by maturation? Pediatr Exerc Sci 2010; 22: 497–510
25 *Meylan C, Cronin J, Oliver J, Hughes M.* Reviews: Talent Identification in Soccer: The Role of Maturity Status on Physical, Physiological and Technical Characteristics. Int J Sport Sci Coach 2010; 5: 571–592
26 *Pearson DT, Naughton GA, Torode M.* Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. J Sci Med Sport 2006; 9: 277–287
27 *Rebelo A, Brito J, Seabra A, Oliveira J, Krustrup P.* Physical match performance of youth football players in relation to physical capacity. Eur J Sport Sci 2014; 14 (Suppl 1): S148–156
28 *Roche AF, Chumlea CW, Thissen D.* Assessing the Skeletal Maturity of the Hand-Wrist: Fels Method. Springfield, IL: CC Thomas, 1988
29 *Rodriguez G, Moreno LA, Blay MG, Blay VA, Fleta J, Sarria A, Bueno M.* Body fat measurement in adolescents: comparison of skinfold thickness equations with dual-energy X-ray absorptiometry. Eur J Clin Nutr 2005; 59: 1158–1166

30 *Roescher CR*, *Elferink-Gemser MT*, *Huijgen BC*, *Visscher C*. Soccer endurance development in professionals. Int J Sports Med 2010; 31: 174–179

31 *Slaughter MH*, *Lohman TG*, *Boileau RA*, *Horswill CA*, *Stillman RJ*, *Van Loan MD*, *Bemben DA*. Skinfold equations for estimation of body fatness in children and youth. Hum Biol 1988; 60: 709–723

32 *Stølen T*, *Chamari K*, *Castagna C*, *Wisløff U*. Physiology of soccer: an update. Sports Med 2005; 35: 501–536

33 *Svensson M*, *Drust B*. Testing soccer players. J Sports Sci 2005; 23: 601–618

34 *Teixeira AS*, *Da Silva JF*, *Carminatti LJ*, *Dittrich N*, *Castagna C*, *Guglielmo LG*. Reliability and validity of the Carminatti's test for aerobic fitness in youth soccer players. J Strength Cond Res 2014; 28: 3264–3273

35 *Vaeyens R*, *Malina RM*, *Janssens M*, *Van Renterghem B*, *Bourgois J*, *Vrijens J*, *Philippaerts RM*. A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. Br J Sports Med 2006; 40: 928–934

36 *Valente-dos-Santos J*, *Coelho-e-Silva MJ*, *Duarte J*, *Figueiredo AJ*, *Liparotti JR*, *Sherar LB*, *Elferink-Gemser MT*, *Malina RM*. Longitudinal predictors of aerobic performance in adolescent soccer players. Medicina (Kaunas) 2012; 48: 410–416

37 *Vandendriessche JB*, *Vaeyens R*, *Vandorpe B*, *Lenoir M*, *Lefevre J*, *Philippaerts RM*. Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15–16 years). J Sports Sci 2012; 30: 1695–1703