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Original Article (short paper)

Relative age effect, skeletal maturation and aerobic running performance in youth soccer players

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Abstract — **Aims:** To investigate the presence of a relative age effect (RAE) and the influence of birth quarters (BQ), semesters (S) as well as skeletal maturation on anthropometric characteristics and aerobic peak speed (PS_{T-CAR}) in youth male soccer players. **Methods:** One hundred players were recruited to participate in this study. Players were allocated into 4 BQ's and 2 S. Skeletal maturity status was assessed using the Fels method. Assessments for players included determination of body size and composition and PS_{T-CAR}. **Results:** Overall, more players were born in BQ1 (38 %) and S1 (75%). The likelihood of players born in BQ1 and BQ2 being selected was 3.61 to 4.96 times higher than players in BQ3 and BQ4. Players in BQ4 maturing earlier were biologically older than their peers in BQ1. The players in BQ3 and S2 displayed higher PS_{T-CAR} compared with players in BQ2 and S1, respectively. However, players of contrasting skeletal maturity status did not differ in aerobic performance. **Conclusion:** Our findings indicate that coaches and talent scouts are systematically retaining average and early maturing players born in S1 and excluding late maturing players born in BQ4. However, aerobic performance appeared to be dependent on the relative age, but independent of skeletal maturation during puberty.

Keywords: talent selection; young athletes; biological maturity; field testing; birth date.

Introduction

Similar to other team sports, youth soccer competitions are organized according to chronological age groups with specific cut-off dates (in general 1st of January) [1]. Players are usually grouped and selected based on their birth dates considering a period of one year (12 months) or two consecutive years (24 months) [2], in order to provide equal competition, fair play, and age-specific training. However, players who are born close to the cut-off date (e.g. first birth quarter) are, on average, 10-12 months older than those players who are born far from the cut-off date (e.g. fourth birth quarter) of the year selection, creating an advantage during the selection process in favor of players born in the first quarter. These variations into chronological age within an annual age group have been referred to as relative age, and its consequences are known as the *relative age effect* (RAE) [3].

The presence of RAE in players of team sports such as soccer in different European countries have been well documented and debated in the context of talent identification and selection [1,2,4–7]. These studies showed an asymmetry in birth month distribution with overrepresentation of youth soccer players born in the first quarter (~ 35 to 50%) compared with players born in the fourth quarter (~ 10 to 17%) of the year selection. Similarly, boys who are advanced in maturation are more frequently represented on soccer teams with increasing chronological age and sports specialization as male soccer players pass through adolescence [8]. In light of this, the combination of early biological maturity, and an older age might be associated with increased likelihood of selection in youth athletes [1], mainly due to better performance of the youth players advanced in biological maturity and/or chronologically older on tasks requiring strength, power, speed and endurance. In contrast, recent studies with youth soccer players in different age groups found that the relatively older age of soccer players may not always be linked to an advantage in maturity, morphological parameters, and physical and physiological components during adolescence [1,4,5,9].

Longitudinal studies have shown that to compete at a professional level, talented youth players need to develop soccer-specific aerobic fitness (i.e. intermittent endurance running capacity) in order to support physical demands of the entire match [10,11]. Consequently, several running field tests are applied during pre-season as a strategy to assess components of soccer-specific fitness and to structure short- and long-term training programs [12]. The Carminatti running test has been designed to evaluate the ability to perform high-intensity intermittent efforts using a shuttle running model for team sports athletes [13,14]. These studies showed that the peak speed reached in this test (PS_{T-CAR}) is achieved requiring the maximal aerobic power and also anaerobic components, in soccer players [13,14]. Recently, Teixeira, Da Silva, Carminatti, Dittrich, Castagna, Guglielmo[15] reported an acceptable reproducibility and validity of PS_{T-CAR} for determining the maximal aerobic speed (MAS) in youth soccer players aged 10-15 years. However, there are still few available studies using Carminatti test in male youth soccer players, especially analyses considering the relationship between RAE, skeletal maturation, and performance in this test during pubertal years. From the knowledge of this relationship, it could provide useful information for coaches and professionals involved in talent identification and selection programs, particularly informing professionals whether performance on this field test is independent of maturational status. The application of aerobic running tests that are not related to maturity status during puberty period has been strongly recommended in order to prevent the deselection of late maturing players [16].

In addition, the variation in biological maturity could be considered a potential confounding factor when analyzing the relationship between RAE and anthropometric characteristics of young players born at the beginning of the year selection[17]. Indeed, body size and composition are considered factors that may explain the occurrence of RAE, however, the variation of these factors is directly related to variability in biological maturation. Thus, the maturity status of youth soccer players could influence on the interpretation of the RAE during talent identification and selection process [4].

Therefore, the purpose of this study were to investigate: 1) the occurrence of RAE and to analyze skeletal maturation in a sample of Brazilian soccer players aged 10 to 15 years; and 2) the influence of likely RAE (i.e. birth quarters and semesters) and skeletal maturation on anthropometric characteristics and Carminatti test performance, in these youth soccer players. Given the available information, it was hypothesized that the RAE would be evident in a sample of Brazilian youth soccer players.

Methods

All procedures were approved by the Ethics Committee of the Federal University of Santa Catarina, Brazil (protocol 2004/2011) prior to this study. The clubs, players and their parents or legal guardians provided informed written consent. Participants were informed about the nature of the study and that the participation was voluntary and they could withdraw from the study at any time.

Participants

The total sample included 100 male youth soccer players (13.3 ± 1.2; range 10.2 to 15.4 years). Players were recruited from two professional clubs (team 1 and 2) competing at national level. At the time of the study, all players performed 3-5 regular training sessions per week (each of about 90-120 min), participating in an official game at the weekend, usually on Saturday. Goalkeepers were excluded from analysis.

Experimental Procedures

The assessments were conducted during the pre-season phase. All players visited the laboratory of the Federal University of Santa Catarina in order to complete the anthropometric battery and were transported to the Santa Catarina University Hospital for the x-ray assessment of the hand-wrist. The soccer-specific aerobic performance was assessed using the Carminatti test within one week. Participants were familiar with the testing procedures as part of their usual fitness assessment program. This test was carried out on the football pitch where players undertake their daily training sessions. All tests were performed at the same time of day (14:00–16:00 h); participants were allowed to drink water 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.

Birthdate distribution

To examine birth date distribution, all participants were categorized into four birth quarters (BQ) and two semesters (S) according to their month of birth (BQ1: January-March, BQ2: April-June, BQ3: July-September, BQ4: October-December and S1: January-June, S2: July-December). The cut-off date, for the year selection for youth soccer players in Brazil, runs from January 1St up to December 31th.

Anthropometry

A single, experienced individual according to the standard procedures performed all anthropometry assessments[18]. Body mass (kg) 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 m with respectively 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. Two skinfolds (triceps and subscapular) were assessed with a scientific adipometer accurate to 0.1 mm (Cescorf, Porto Alegre, Brazil). Fat mass in kg and as a percentage of total body mass was calculated from skinfold thickness [19]. This system of equations has been suggested as accurate for estimation of fat mass percentage in adolescents [20].

Age and Biological Maturity Status

Chronological (decimal) age (CA) was calculated as the difference between the date of birth and date of the hand-wrist radiograph for the assessment of skeletal maturity. Posterior-anterior radiographs of the left hand-wrist were taken. The Fels method [21] was used to estimate skeletal age (SA). The Fels method utilizes specific criteria for each bone of the hand-wrist and ratios of linear measurements of epiphyseal and metaphyseal widths. More details of the method and applications were presented elsewhere [22]. Ratings were entered into a program (Felshw 1.0 Software) to calculate SA and its standard error of the estimate. A single observer assessed all radiographs.[23] The difference between SA and CA (SA minus CA) provides an estimate of relative skeletal age (RSA). The difference between SA and CA was used to classify players as late (delayed: SA younger than CA by >1.0 years), average (on time: SA ± 1.0 years CA), early (advanced: SA older than CA by >1.0 years); mature (skeletally mature, SA = 18.0 years). This classification was already adopted in previous studies [22,24].

Aerobic Performance (Carminatti's Test)

The test consisted of intermittent shuttle runs of 12 s performed between two lines set at progressive distances with a 6-s recovery between each run and a total stage time of 90 s. The test protocol had a starting velocity of 9 km·h^{-1} over a corresponding running distance of 30 m (15 m out and back). The stage length in a single direction was increased progressively by 1 m every set. Each stage consisted of five repetitions; between each repetition, there was a 6 s walk that was performed between two lines set 2.5 m from the start line. During the test 8-10 athletes were evaluated simultaneously with the running pace dictated by pre-recorded audio cues (beeps) that determined the running velocity to be performed between the start and finish lines [14,15]. The test ended when evaluators observed that the participants failed to keep in time with the audio cues on the front line for two successive repetitions (objective criteria). The $PS_{T\text{-}CAR}$ was calculated from the distance of the last set completed by the athlete divided by the time to complete the stage repetition.

Statistical Analyses

Descriptive statistics were calculated and Kolmogorov-Smirnov test was used to check data normality. First, differences between the observed and the expected birth date distributions were tested with chi-square statistics. Expected birth date distributions were calculated in accordance with the live births rate in State of Santa Catarina between 1997 and 2001 (Departamento de informática do Sistema Único de Saúde do Brasil - DATASUS), following previous studies[2]. Odds ratios (OR) and 95% confidence intervals (95% CI) were calculated for the relative age quarter distribution of the total sample. Second, factorial ANCOVA (controlling for chronological age [CA]) were used to test the effect of birth quarters, birth semesters, skeletal maturity status and respective interaction terms on body size and composition, and Carminatti test performance. Statistical significance was set at $p \leq 0.05$ for all analyses. Effect sizes (ES) were calculated using partial eta squared (η^2_p), which were defined as trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5) and large (>0.5)[25]. Calculations were performed with the statistical packages SPSS (SPSS 17.0 version, Chicago, Illinois, USA).

Results

Table 1 shows the birth date distribution by quarter and semester for the current sample of adolescent soccer players. The birth date distribution of the youth soccer players differed significantly from the theoretical distribution expected by the birth quarters ($\chi^2_{(3)}$= 21.174; P<0.001) and semesters ($\chi^2_{(1)}$=21.073; P<0.001). Overall, 38% of the players were born in the first quarter, while only 11% of the players were born in the fourth (i.e. last) quarter. Furthermore, the distribution of players between semesters also demonstrated that a greater proportion of players were born in the first semester of the selected year (75%). The odds ratios calculations revealed that the likelihood of a player born in BQ1 being selected was 4.96 (95%CI: 2.35 to 10.45) and 3.77 (95%CI: 1.88 to 7.54) times higher compared to players born in BQ4 and BQ3, respectively. Similarly, players born in BQ2 also had a 4.75 (95%CI: 2.25 to 10.02) and 3.61 (95%CI: 1.80 to 7.23) times greater selection chance than their peers born in BQ4 and BQ3, respectively. Note that all odds ratios calculations were significant since the 95% confidence interval did not include 1.

Table 1. Birth date distribution per quarter (BQ) and semester (S) for youth soccer players of the current sample compared to the number of live births in the State of Santa Catarina between 1997 and 2001, and frequency distribution (f) of skeletal maturity status by birth quarter and semester.

Soccer Players	Birth Quarters (BQ) and Semesters (S): BQ1	BQ2	BQ3	BQ4	Total	χ^2_3 (BQ)	P	χ^2_1 (S)	P
	S1		S2						
Number (%)	38 (38.0%)	37 (37%)	14 (14%)	11 (11%)	100	21.174	<0.001		
	75 (75%)		25 (25%)					21.073	<0.001
Expected	25.8%	26.3%	25.4%	22.5%					
	52.1%		47.9%						
State of Santa Catarina									
Number (%)	122.662 (25.8%)	124.966 (26.3%)	120.956 (25.4%)	107.035 (22.5%)	475.619				
Skeletal Maturity Status	f	f	f	f					
	f		f						
Late (Delayed)	2	7	3	0					
	9		3						
Average (On-time)	17	19	4	5					
	36		9						
Early (Advanced)	19	11	7	6					
	30		13						

Table 2. Age-adjusted means ± standard errors by birth quarters (BQ), birth semesters (S) and skeletal maturity groups for the total sample of youth soccer players (n=100).

	Birth Quarters (BQ) [a]				Birth Semesters (S) [a]		Skeletal Maturity Groups [a]		
	BQ1 (n=38)	BQ2 (n= 37)	BQ3 (n=14)	BQ4 (n=11)	S1 (n=75)	S2 (n=25)	Late (n=12)	Average (n=45)	Early (n=43)
SA (years)	13.5 ± 0.1	13.4 ± 0.1	13.4 ± 0.1	14.5 ± 0.1	13.4 ± 0.1	13.4 ± 0.1	-	-	-
Weight (kg)	48.5 ± 1.8	49.8 ± 1.3	48.6 ± 2.0	51.1 ± 2.1	49.5 ± 1.0	49.1 ± 1.7	44.3 ± 2.6	46.9 ± 1.3	55.7 ± 1.3
Fat mass (kg)	7.4 ± 0.8	7.5 ± 0.6	5.7 ± 0.9	6.9 ± 0.9	7.7 ± 0.4	6.2 ± 0.8	6.6 ± 1.1	6.6 ± 0.6	7.3 ± 0.6
FFM (kg)	41.1 ± 1.4	42.3 ± 1.0	42.9 ± 1.5	44.3 ± 1.6	41.7 ± 0.7	42.9 ± 1.3	37.6 ± 1.9	40.3 ± 1.0	48.4 ± 1.0
Height (cm)	159.7 ± 1.8	159.9 ± 1.3	158.7 ± 2.0	160.9 ± 2.1	159.8 ± 1.0	158.8 ± 1.7	154.4 ± 2.6	157.8 ± 1.4	165.6 ± 1.3
Sitting height (cm)	82.6 ± 1.0	82.9 ± 0.7	82.3 ± 1.1	83.2 ± 1.1	82.7 ± 0.5	82.4 ± 0.9	80.4 ± 1.4	81.8 ± 0.7	85.4 ± 0.7
Leg Length (cm)	77.1 ± 1.1	77.0 ± 0.8	76.4 ± 1.2	77.7 ± 1.3	77.0 ± 0.6	76.4 ± 1.0	74.1 ± 1.6	76.0 ± 0.8	80.2 ± 0.8
$PS_{T\text{-}CAR}$ (km.h^{-1})	15.3 ± 0.2	14.9 ± 0.2	15.8 ± 0.3#	15.1 ± 0.3	14.9 ± 0.1	15.6 ± 0.2‡‡	15.5 ± 0.3	15.3 ± 0.2	15.1 ± 0.2

CA (chronological age); SA (skeletal age); FFM (fat free mass); $PS_{T\text{-}CAR}$ (peak velocity derived from Carminatti test); [a] Covariate (chronological age = 13.44 years); # denotes significant differences in relation to BQ2 (p<0.05); ‡‡ denotes significant differences in relation to S1 (p<0.05)

Table 3. Factorial analyses of variance (ANOVA) to examine birth quarter (BQ), birth semester (S), skeletal maturity and the interaction term as significant source of inter-individual variability for the total sample of young soccer players (n=100).

	Factorial ANCOVA (controlling for CA)[a]														
	Effect of Birth Quarter			Effect of Birth Semester			Effect of Maturity			Interaction BQ x Maturity			Interaction Semester x Maturity		
	F	p-value	η^2_p	F	p-value	η^2_p	F	p-value	η^2_p	F	p-value	η^2_p	F	p-value	η^2_p
SA (years)	0.054	0.983	0.002	0.020	0.888	0.001	-	-	-	2.574	0.032	0.128	2.373	0.099	0.049
Weight (kg)	0.162	0.922	0.005	0.036	0.850	0.001	11.199	<0.001	0.203	1.819	0.117	0.094	1.975	0.144	0.041
Fat mass (kg)	1.077	0.363	0.035	2.798	0.098	0.029	0.310	0.734	0.007	1.468	0.208	0.077	0.016	0.984	0.001
FFM (kg)	0.291	0.832	0.010	0.589	0.445	0.006	16.716	<0.001	0.275	1.689	0.1.46	0.088	3.230	0.044	0.065
Height (cm)	0.188	0.905	0.006	0.253	0.616	0.003	9.410	<0.001	0.176	1.711	0.140	0.089	3.204	0.045	0.064
Sitting height (cm)	0.178	0.911	0.006	0.100	0.753	0.001	7.091	0.001	0.139	1.282	0.279	0.068	1.148	0.322	0.024
Leg Length (cm)	0.143	0.934	0.005	0.309	0.580	0.003	7.559	0.001	0.147	1.854	0.111	0.095	4.443	0.014	0.087
$PS_{T\text{-}CAR}$ (km.h^{-1})	2.833	0.043	0.088	6.849	0.010	0.069	0.457	0.635	0.010	2.208	0.060	0.111	2.042	0.136	0.042

CA (chronological age); SA (skeletal age); FFM (fat free mass); $PS_{T\text{-}CAR}$ (peak velocity derived from Carminatti test); [a] Covariate (chronological age = 13.44 years)

For the sample as a whole, 43 were classified as early maturing (43%), 45 were average (45%) and 12 were identified as delayed (12%). Players classified as average and early in skeletal maturation are represented in all quarters of birth, while none of the 12 players classified as late maturing were born in the last quarter of the year. It is also remarkable that average and early maturing players are more represented when compared with late maturing players in all birth quarters (Table 1).

Descriptive statistics by birth quarters, semesters and skeletal maturity status are summarized in Table 2. Birth quarters and semesters were a consistent source of variation for $PS_{T\text{-}CAR}$. Players born in BQ3 and S2 displayed higher $PS_{T\text{-}CAR}$ values than those born in BQ2 and S1, respectively. Effect sizes (η^2_p) were rated as trivial (Table 3). Players advanced in skeletal maturation were, on average, heavier (F=32.752, p<0.001), taller (F=30.073, p<0.001) and had a greater fat free mass (F=39.560, p<0.001), sitting height (F=25.132, p<0.001) and estimated leg length (F=26.233, p<0.001) than average (on time) and late maturing players. Small effect sizes (η^2_p) ranging from 0.139 to 0.275 were noted among skeletal maturity status (Table 3). In contrast, skeletal maturity status was not a significant source of variation for estimated fat mass (F=0.721, p=0.490; trivial ES) and $PS_{T\text{-}CAR}$ (F=0.512, p=0.601; trivial ES). Significant "birth quarters*skeletal maturity" interaction (F=2.574, p=0.032) was found for skeletal age (Table 3). Early maturing players born in BQ4 (15.75 ± 0.19 years) were biologically older than their peers in the same skeletal maturity status born in BQ1 (15.11 ± 0.11 years) (Figure 1). This difference was reported as small (Table 3). There was also a significant "birth semesters*skeletal maturity" interaction for fat-free mass, height and leg length (Table 3). Post-hoc Bonferroni test indicated that early maturing players born in S2 had higher fat-free mass (50.05 ± 1.62 vs. 46.10 ± 0.96 kg; p=0.032) than those players born in S1 who mature earlier (Figure 2a). In contrast, players born in S1 classified as "on-time" in skeletal maturation were significantly taller (160.95 ± 1.15 vs. 154.55 ± 2.36; p=0.016) and had greater leg length (78.05 ± 0.69 vs. 73.92 ± 1.41; p=0.009) than their average maturing peers born in S2 (Figure 2b and 2c). The magnitude of effect was trivial for all comparisons made (Table 3).

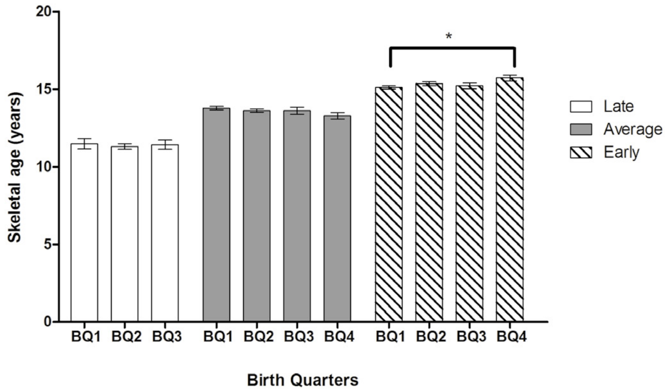

Figure 1. Age-adjusted mean ± standard error for skeletal age (SA) within each skeletal maturity status by birth quarters in young soccer players.

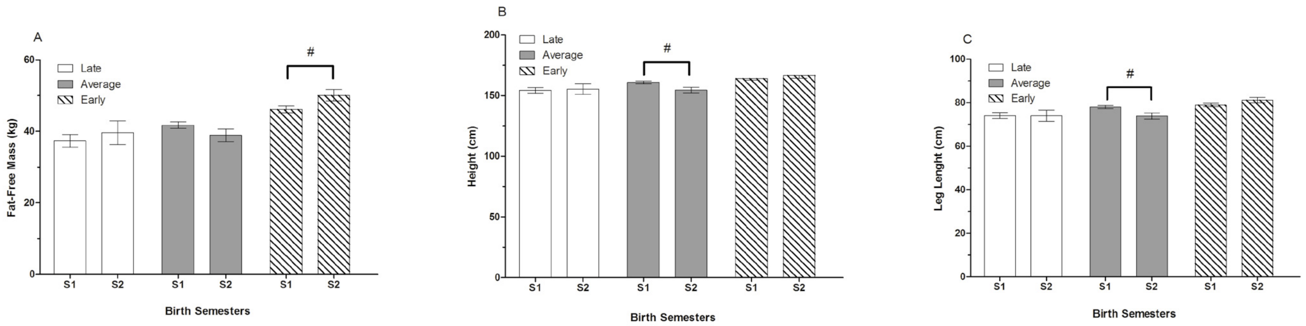

Figure 2. Age-adjusted mean ± standard error for fat-free mass (panel A), height (panel B) and leg length (panel C) within each skeletal maturity status by birth semesters in young soccer players.

Discussion

The present study investigated the occurrence of a RAE and the influence of skeletal maturation and birth quarters/semesters on anthropometric characteristics and aerobic performance assessed by the Carminatti field test in a sample of Brazilian youth soccer players. The results were consistent with our hypothesis showing an asymmetry in birth period distribution, with 38% and 75% of players born in the first quarter and semester, respectively, and less than 12% of players born in the fourth quarter of the selected year (Table 1). However, our major original findings were: (i) players born in BQ4 who mature earlier were biologically older than their early maturing peers born in BQ1; (ii) players born in S2 had greater fat-free mass than their peers born in S1; (iii) a coaches' bias toward average and early maturing players through the selection process was confirmed in Brazilian soccer professional academies; (iv) birth quarters and semesters were identified as a significant source of variation for aerobic performance (i.e., PS_{T-CAR}), but not for body size descriptors; (v) players of contrasting skeletal maturity status differed significantly in body size and composition (except fat mass), but not on aerobic performance.

The current findings revealed a skewed birth dates distribution of selected players, which was in contrast to the similar distribution of birth dates observed in the population of south Brazil, specifically in the State of Santa Catarina. In agreement with several previous studies in European youth soccer players[1,4,5], the most players in our sample were born in the first half of the year (75%). Still, the percentage of players born in the last quarter of the year in the present study (11%) is similar to that previously reported by Carling, le Gall, Reilly, Williams[5]. In the present study, the OR calculations clearly showed that the likelihood of a soccer player born in BQ1 and BQ2 being selected by soccer professional academies can be 3.61 to 4.96 times greater compared to the players who are born in the last two birth quarters. These findings are in agreement with previous studies in team sports such as soccer, and individual sports like alpine sky racing [26–29]. For instance, Müller, Gonaus, Perner C, Müller E, Raschner, Gonaus, Perner, Müller, Raschner[28] found a significant selection bias in a sample of 423 male young soccer players (mean chronological age: 11.1 ± 0.6 years), with players born in the first relative age quarter showing a likelihood of 5.74 (95%CI: 3.72 to 8.86) times higher of being selected by soccer professional academies than players born in BQ4.

The possible reasons that may contribute to the existence of RAE might be of interest for coaches and scouts involved in the talent identification and selection process during the adolescence years. It has been suggested that the organization of youth soccer competition in addition to psychological aspects and the differences in training experience and game involvement across birth quarters are the factors responsible for large RAE observed in team sports [28,29]. However, some studies have reported that biological maturation may influence the chance of players born in different birth quarters being selected and retained by coaches in soccer academies [1,27]. Consistent with these findings, a previous study showed that skeletal maturity status has a much stronger influence – approximately 10-fold – on talent selection process in professional soccer academies than RAE[31]; it was demonstrated that early maturing players are preferentially selected as male soccer players pass through adolescence[1,8,9].

In the current sample, 43 players were classified as early maturing (43%), 45 were average (45%) and only 12 were identified as delayed (12%). Thus, the players born in the fourth quarter of the year and classified as late in skeletal maturation are notably absent, while those on time and early maturing players are represented in all birth quarters. The distribution of skeletal maturity status by birth quarters (Table 1) is in accordance to that reported by Figueiredo and colleagues [16] showing that none of the players born in the last birth quarter of the selection year acting in soccer professional academies (i.e. elite level) from Portugal were classified as late in skeletal maturation. Collectively, these findings seem to indicate that the combination of being born later in a selection year and also having later maturing provide a significant disadvantage for being selected into elite youth soccer teams [4]. It has been suggested that the more plausible explanation for these players being underrepresented at elite youth level and receive fewer opportunities to participate in competitive games during the talent identification and selection process is probably due to their momentary physical disadvantage [9,29]. In the current study, it was found a significant "birth quarters*maturity status" interaction for SA, showing that early maturing players born in the last birth quarter were biologically older than their peers at the same maturity status born in the first relative age quarter (Figure 1). This finding are consistent with the argument that players born later in a given year successfully selected for elite teams are able to counteract the RAE if they are more mature (i.e. biologically older) than their chronologically older counterparts[1,4,9]. Of interest, the current study used skeletal age as biological maturity indicator, while previous studies have used estimated peak height velocity, a less accurate and limited measure of biological maturity [32].

Coaches and talents scouts should be aware that these players more mature inappropriately identified as being the most talented during adolescence may fail to meet adult expectations, and if lateborn and late maturing players avoid early dropout and remain engaged in their sport until late adolescence/early adulthood, they often outperform their early born or early mature counterparts [33]. In a longitudinal follow-up study with Serbian youth soccer players [34], it was demonstrated that the proportion of late maturing players at age 14 who achieved the elite level of adult soccer competence was significantly higher than the proportion of players classified as "on-time" and "advanced" in skeletal maturation. In other words, elite soccer competence seems to be achieved more often by the boys who late matured at age 14, while early-maturing boys less frequently attain top-level soccer.

Some studies have attributed the occurrence of the RAE to variations in body size and composition [2,29]. Although it has been reported as one of the factors explaining the occurrence of RAE, caution is required in interpreting these findings, because variations in body size and proportion may actually be directly linked to inter-individual variability in biological maturation. Our findings showed that players contrasting in maturity status differed significantly in body size and composition. Early maturing players are heavier and taller with more fat-free mass and longer segment lengths than average and late maturing boys, who did not differ from each other (Table 2). On the other hand, birth quarters and semesters were not a consistent source of variation for body size and composition variables in this study. Malina, Ribeiro, Aroso, Cumming[35] and Carling, le Gall, Reilly, Williams[5] have reported similar results for anthropometric parameters in 39 elite Portuguese soccer players aged 14 years and 160 elite French youth soccer players aged 14–16 years, respectively. This similarity in anthropometric characteristics among birth quarters and semesters might be attributed to the overrepresentation of average and early maturing players within each relative age quarter.

In addition, the novel finding of the current study was that early maturing players born in S2 selected by coaches had greater fat-free mass than their peers born in S1 (Figure 2a). This result suggests that the current talent identification and development programs from which these players were recruited are focused on the formation of strong physically homogenous groups [1,5]. Meantime, our results are consistent with the argument of a recent study reporting that the coaches and talent scouts automatically associate large players with positive performance attributes and small players with negative performance attributes, even when no apparent performance advantage is evident [36]. Note that those players who mature earlier, despite being heavier and taller, display similar $PS_{T\text{-}CAR}$ values compared to their late maturing peers who are thinner and shorter.

Currently, the ability to perform intermittent high-intensity running has been considered as one of the most important physical performance determinants in youth soccer players[4]. Carminatti test is a soccer-specific field test designed to evaluate the maximal aerobic speed through intermittent running including changes of direction, accelerations, and decelerations [13–15]. Previous studies using Yo-Yo Intermittent Recovery test [2,4] have demonstrated similar performances between players born across 4 birth quarters. In opposition, it was observed that players born in BQ3 and S2 reached greater $PS_{T\text{-}CAR}$ values compared to their peers born in BQ2 and S1. This finding is of practical interest to coaches and scouts involved in the talent identification and selection process. Considering that biological maturity was not a significant source of variation for $PS_{T\text{-}CAR}$, our data suggest that laterborn players who are engaged in a highly structured soccer training program can achieve aerobic performance levels to the same extent or even greater than their peers born earlier in the year selection. Thus, it is recommended that more opportunities need to be provided during adolescence for those smaller and later maturing talented boys who are born at the end of the year selection (i.e. relatively younger) due to the overrepresentation of early maturing players (bigger and stronger) demonstrated in the current and prior studies [8,17,31].

Finally, there are some limitations to the current study that should be acknowledged. First, other potential predictors of talent, such as training history, psychological and sociological characteristics in addition to technical and tactical skills were not included in the analysis. Second, the sample size is relatively small, in particular, the number of players born in the second semester, resulting also in a small number of players among skeletal maturity groups within the last two birth quarters.

Conclusions

In summary, the current study clearly identified an overrepresentation of players born during the beginning of the year, confirming the occurrence of RAE in this sample of Brazilian youth soccer players. Those players who are advanced in skeletal maturation and born in the last birth quarter are biologically older (i.e. skeletal age) than their early maturing peers born in the first relative age quarter, highlighting that the coaches and talent scouts' selection decisions are biased towards physically more mature players. In addition, intermittent endurance running capacity assessed by the Carminatti's test was significantly influenced by birth quarters and semesters but not for variation in skeletal maturity status during pubescence. In a practical setting, maturity status and aerobic field tests not related to maturation should be taken into account when selecting young soccer players.

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