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Original Article

Peak height velocity in soccer: anthropometric, functional, motor and cognitive implications

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Abstract:
Body size variability due to hormonal changes arising from different maturational development speeds can represent advantages to players who are early in this process. The present study aimed to analyze anthropometric, physical, and technical-tactical indicators according to the somatic maturity status of young soccer players. Thirty-seven subjects (14.57 ± 1.26 years) of a regional soccer project took part in the study. Anthropometric measurements of weight, height, trunk-cephalic height, and triceps and subscapular skinfolds were verified. Based on this information, peak height velocity was estimated. To evaluate functional capacities, the sit-and-reach test, Yo-Yo Intermittent Recovery Test level 1, handgrip, and 30m speed test were performed. In addition, a soccer specific motor skills protocol and declarative tactical knowledge test were applied. Results show significant differences between groups in body weight, height, trunk-head height, body mass index, and handgrip ($P \leq 0.05$). When analyzing the relationship between anthropometric variables, specific motor skills, and declarative tactical knowledge no significant correlations were verified. Although anthropometric indicators increase with advances in maturational classification, in this study tactical-technical skills were demonstrated not to be related to body size.
Key-Words*:* physical fitness, somatic maturity, sports training, tactical knowledge.

Introduction

Adolescence is characterized as a period of intense corporal modifications due to hormonal and metabolic alterations broadly related to maturational status. During pre-pubertal and pubertal stages, biological maturation may differ considerably for individuals of the same age, since the development of this process occurs at different speeds and due to different influences, among other factors (Linhares et al. 2009).

When analyzing soccer context, it is noticed that talent selection and recruitment situations generally occur between 13 and 17 years, ages more sensitive to body changes derived from maturation. Rabelo et al. (2016), report the effect of relative age on detecting and selecting talent in Brazilian soccer, that is, players born in the first months of the year tend to predominate and remain in soccer teams, which possibly occurs due to physical and maturational attributes. However, when selecting players based on physical and morphological aspects, observers can commit prognostic errors, since maturational indicators have been shown to be weakly associated with technical-tactical performance (Borges, Avelar & Rinaldi, 2015).

Thus, there is a need to follow and evaluate the maturational development of young players so that sports education and training programs can opt for simple and easy to apply practical instruments, taking into account a low operational cost, accuracy of the measures, and close relationship with motor performance (Machado, Bonfim & Costa, 2009). In this sense, a commonly used alternative is peak height velocity (PHV), which refers to the age of maximum growth in stature during the spurt of growth in adolescence (Malina, 2009). Based on this evidence, Mirwald, Baxter-Jones, Bailey and Beunen (2002) developed a noninvasive technique to predict the distance that the individual is from PHV, which considers the interactions between measures of leg length, trunk-cephalic height, age, body mass, and height.

Several studies have adopted PHV aiming to evaluate the level of somatic maturity linked to functional, anthropometric, and physiological components (Figueiredo, Coelho-e-Silva & Malina, 2011; Menegassi et al., 2017; Buchheit & Mendez-Villanueva, 2013). However, it is noted in these studies that the assessment of

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specific motor skills (SMS) and tactical knowledge (DTK) is rarely included. Thus, in order to clarify which performance conditioning variables are linked to maturity status in soccer, this study aimed to evaluate anthropometric, functional, motor, and cognitive indicators according to the PHV stage of young soccer players.

Material & Methods

Participants

70 players between the ages of 13 and 17, belonging to a regional soccer project, were pre-selected to participate in the study. The following inclusion criteria were adopted: I - participation in systematized training for at least one year; II – not presenting muscle or skeletal lesions; III - participation in regional competitions. Thus, the final sample consisted of 37 soccer players aged 14.57 (±1.26 years). The study was approved by the local ethics committee (opinion nº 653.698).

Test protocols

Anthropometric measurements of body mass, height, and trunk-cephalic height were obtained using a calibrated digital reading scale (0.1 kg) and a wooden stadiometer (0.1 cm). Based on this information, the body mass index (BMI) was calculated. To evaluate body composition, a scientific measure of skinfold thickness was taken by a Cescorf adipometer (0.1 mm). The subscapular (SE) and tricipital (TR) skinfolds were measured according to the standardization of Harrison et al. (1988). Evaluation of somatic maturity was performed based on peak height velocity (PHV).

To evaluate young boys, Mirwald et al. (2002) proposed an equation which allows estimation of the distance in years that the child or adolescent is from peak height velocity: *PHV = -9.236 + 0.0002708 (leg length * trunk-cephalic height) - 0.001663 (age * leg length) + 0.007216 (age * trunk-cephalic height) + 0.02292 (weight / height)*100*. The classification according to maturational groups followed specifications indicated in the study of Machado, Bonfim and Costa (2009), adopting as cutoff points: Pre-PHV = lower than -0.50 years; Age-PHV = between -0.50 and 0.50 years; Post-PHV = over 0.50 years.

In order to evaluate the aerobic performance of the players, the Yo-Yo Intermittent Recovery Test Level 1 was used. The test requires the subjects to perform a series of 20m runs with a cadence pre-established by an audiometer and 10-second intervals between each run (Krustrup et al., 2003). Upper limb muscle strength was determined by means of the handgrip test performed with a dynamometer. Three repetitions were performed for each hand, with a one minute interval between repetitions, aiming to achieve the highest possible handgrip. The highest grip value for each hand was computed (Barbosa, Santarém, Jacob Filho & Marucci, 2012). As an indicator of velocity, the 30m speed test was applied. For this evaluation, a FusionSport- Smartspeed photocell system was used. Subjects performed the sprint twice, with a five-minute interval between attempts. The lowest time was adopted for analysis (Marins & Giannichi, 1998). Flexibility was assessed using the sit-and-reach test. The procedure was repeated three times and the greatest distance reached was considered for analysis (Wells & Dillon 1952).

The specific motor skills (SMS) of the players were evaluated through the battery of tests proposed by Mor and Christian (1979). This battery includes the evaluation of three skills: passing, kicking, and dribbling. To evaluate passing, a small goal of 91 cm was demarcated with a rope limiting the height. Three other cones were placed at a distance of 14m from the goal at different angles. In order to hit "inside" the area, subjects performed four passes in each of these three places. For each hit a point was computed. The maximum score of the test is 12 points. In the kicking evaluation, a regular soccer goal was used, divided into four result areas by two ropes suspended from the top bar of the goal, 1.22m from each side post. A 14.5m goal line was scored for kicking a stationary ball with the preferred foot. Four kicks were executed at each of the angles, totaling 16 attempts. Each kick that hit the intended target received 10 points and, if the ball entered a target adjacent to the target, 4 points were awarded. The maximum score of this test is 160 points. To evaluate dribbling, a circular path with a diameter of 18.5m was demarcated. The start/finish line was marked with a cone. Cones were placed at intervals of 4.5m around the circle. The player dribbled the ball around the course running sinuously through the cones until returning to the starting point. Three attempts were allowed: the first in a clockwise direction, the second in a counterclockwise direction, and the third in the direction chosen by the player. The two best results obtained were adopted for the final score of the test.

Finally, to evaluate declarative tactical knowledge (DTK) of the players, the instrument validated by Mangas (1999) was used. This consists of 11 offensive soccer scenes, where each presents 4 alternative "solutions" for the situation. Therefore, players are evaluated according to the number of right and wrong answers for each situation. In this study, however, we chose to follow the scoring model proposed by Giacomini, Soares, Santos, Matias and Greco (2011), where, best solution = 1.0 point; 2nd best solution = 0.75 points; 3rd best solution = 0.50 points; and worst solution = 0.25 points. The maximum score in this test is 11 points.

Statistical analysis

Seven days after the first collection, a retest was performed with 14 randomly selected subjects to evaluate the intra-rater reproducibility of the anthropometric measures. According to criteria proposed by Perini, Oliveira, Ornellas and Oliveira (2005), the following technical errors of measurement were found for

anthropometric variables: body mass 0.78%; height 0.25%; trunk-cephalic height 1.03%; triceps skinfold 4.49%; and subscapular skinfold 5.61%. The statistical package IBM SPSS 20.0 was used to perform the statistical tests. To verify the normality of the data, the Shapiro-Wilk test was applied. To group players into three different levels of somatic maturity, the Non-hierarchical cluster k-means method was applied, after which the Kruskal-Wallis test was used to identify significant differences between the groups of pre-PHV, age-PHV, and post-PHV. Subsequently, the Mann-Whitney U test was used. The Spearman Correlation Coefficient was selected to correlate anthropometric variables, body composition, specific motor skills, and tactical knowledge. The significance level adopted was P≤0.05.

Results

Table 1 presents the descriptive characteristics of the young soccer players according to their maturational status. A significant difference was observed in anthropometric variables, a trend for increasing values being observed as the level of somatic maturity of the players increased.

Table 1. Comparison of anthropometric, functional, tactical, and technical variables between maturational stages.

Variables	pre-PHV (n=9)	age-PHV (n=13)	post-PHV (n=15)
	Md (Q1-Q3)	Md (Q1-Q3)	Md (Q1-Q3)
Age (years)	13.52 (13.12 – 14.25)	13.74 (13.39 – 14.10)	15.62 (15.17 – 16.78)[a,b]
Time of Practice (months)	60.00 (48.00 – 72.00)	36.00 (30.00 – 90.00)	60.00 (36.00 – 120.00)
Weight (kg)	46.30 (44.35 – 47.65)	58.80 (54.90 – 64.95) [a]	63.40 (60.30 – 69.60) [a]
Height (cm)	162.30 (155.90 – 164.50)	171.40 (168.55 – 173.80)[a]	174.20 (168.00 – 177.90)[a]
TCH (cm)	81.50 (78.25 – 82.55)	89.40 (87.75 – 90.35)[a]	90.00 (88.50 – 92.60)[a]
BMI (kg/m^2)	17.59 (17.01 – 18.70)	20.06 (18.87 – 22.25)[a]	20.96 (20.47 – 22.84)[a]
SR (cm)	26.80 (28.40 – 30.00)	24.80 (20.00 – 31.45)	25.00 (21.30 – 31.90)
HG_R (kgf)	18.00 (15.25 – 22.75)	30.00 (21.00 – 35.00)[a]	37.00 (28.00 – 45.00)[a,b]
HG_L (kgf)	15.00 (13.00 – 20.50)	25.00 (18.50 – 32.00)[a]	32.00 (27.00 – 37.00)[a]
Yo-Yo Test (m)	520.00 (340.00 – 800.00)	680.00 (420.00 - 980.00)	600.00 (480.00 – 880.00)
Sprint 30m (km/h)	25.96 (23.56 – 26.64)	25.34 (24.50 – 26.28)	25.78 (24.80 – 26.82)
DTK (score)	9.00 (8.62 – 9.62)	8.50 (8.25 – 9.62)	8.50 (8.00 – 9.00)[a]
Dribbling (seconds)	32.59 (30.48 – 34.37)	31.69 (31.02 – 35.06)	30.85 (29.82 – 34.36)
Passing (score)	5.00 (4.00 – 6.00)	4.00 (3.50 – 6.00)	4.00 (4.00 – 7.00)
Kicking (score)	54.00 (34.00 – 62.00)	50.00 (32.00 – 58.00)	44.00 (24.00 – 68.00)

NOTE: PHV = peak height velocity; TCH = trunk-cephalic height; BMI = body mass index; SR = sit-and-reach; HGR = right handgrip; HGL = left handgrip; Yo-Yo Test = Yo-Yo Intermittent Recovery Test level 1; DTK = declarative tactical knowledge; a = significant difference to pre-PHV (P≤0.05); b = significant difference to age-PHV (P≤0.05). In an attempt to verify whether body size and PHV are related to specific motor skills and tactical knowledge, table 2 presents correlations between anthropometric and body composition variables with specific motor skills and tactical knowledge.

Table 2 – Correlation between anthropometric variables, peak height velocity, body composition, and technical skills of young soccer players.

	Weight (kg)	Height (cm)	TCH (cm)	PHV (years)
DTK (score)	-0.27	0.12	-0.17	-0.36*
Dribbling (seconds)	-0.01	0.04	0.11	-0.15
Passing (score)	-0.02	0.06	-0.01	-0.03
Kicking (score)	0.06	0.05	0.02	-0.06

NOTE: * = (P≤0.05); PHV = peak height velocity; TCH = trunk-cephalic height; DTK = declarative tactical knowledge.

As described in Table 1, the sample demonstrated homogeneity in relation to time of practice of the modality (P> 0.05). Regarding specific motor skills, there was a significant difference only in handgrip indicators in favor of the post-PHV group. In the SMS and DTK, the groups presented similar performances and only the DTK presented a significant difference in favor of the pre-PHV group compared to the post-PHV group. Regarding Table 2, the results show a negative correlation between PHV and DTK, indicating that individuals in this sample who had not reached PHV had greater tactical knowledge when compared to the other groups.

Discussion

The present study aimed to analyze the anthropometric, functional, motor, and cognitive indicators according to the level of somatic maturity of young soccer players. The main results were: significant differences between the pre-PHV, age-PHV, and post-PHV groups in body mass, height, trunk-cephalic height, BMI, and handgrip strength. No significant correlation was found between specific motor skills, declarative tactical knowledge, or anthropometric variables.

Differences found in body mass, height, trunk-cephalic height, and BMI (Table 1) indicate that post-PHV players present higher anthropometric indicators when compared to the pre-PHV and age-PHV groups. Mortatti, Honorato, Moreira and Arruda (2013), in a study with under-12 and under-13 soccer players also verified an increase in anthropometric variables as maturational status increased. It is important to note that in the present study, the median ages for the pre-PHV and age-PHV groups did not differ statistically, but significant differences were observed in weight, height, trunk-cephalic height, and BMI between these groups. This suggests that the maturational stage and not the age is the variable that best explains the growth and development of the investigated subjects.

Regarding specific motor skills, there were significant differences in handgrip between the groups, with an increase in strength concomitantly with the increase in maturational level. According to Silva and Oliveira (2002), strength of the upper limbs undergoes dramatic changes with advancing age, especially in the second decade of life, and the maturational level of the adolescent influences this. The constant interaction between genes, hormones, nutrients, and environmental factors causes the production of strength, which increases according to maturational status (Malina, 2009). Corroborating with this, Ulbrich et al. (2007) verified a gradual increase in handgrip strength as the maturational stage increased, and Lloyd et al. (2014) when evaluating lower limbs strength in young soccer players, found that maturation status is a significant predictor of performance outcomes. These findings reveal that the data presented in this study are in line with others performed with similar populations. In relation to tactical knowledge, pre-PHV players demonstrated greater DTK when compared to post-PHV. A study by Matias and Greco (2010) found that more experienced players have a superior DTK to less experienced athletes. However, although the players of the present study differed in age ($P < 0.05$), the training time (experience) in the modality was not different between them. In this sense, we can infer that other variables in the training context, such as the quantity and quality of the training may have influenced the results of the players' DTK. Although the purpose of this study is not to verify the impact of the training process on cognitive variables, a study by Silva and Greco (2009) concluded that players who underwent training that values the tactical dimension proved to be more effective for the construction of tactical knowledge. Therefore, age and maturational level should not be the only indicators capable of explaining the DTK.

Similarly, in specific motor skills, performance was homogeneous among the three maturational groups (Table 1). Other studies are in agreement with these results and indicate that SMS are not influenced by maturation (Figueiredo, Silva, Cumming & Malina, 2010; Matta, Figueiredo, Garcia & Seabra, 2014). However, Borges et al. (2017) evidenced that when adopting Mor and Christian's battery tests, physical variables such as aerobic power, strength, and velocity might interfere with technical performance. Therefore, one of the reasons that may explain the equity in technical performance found in this study is the variable time of practice, which did not present significant differences between the three groups. According to Greco and Matta (1996), for the player to improve the SMS domain and increase their motor capacity, it is necessary to train to acquire new experiences. It is also important to mention that the protocol used, although recurrent in studies related to soccer (Praça, Soares, Matias, Costa & Greco, 2015) does not assess the technical qualities of the players in a real game situation, which compromises the ecological validity of the tests and could influence the final scores.

Finally, Table 2 shows that no significant correlation was found between SMS and DTK and anthropometric variables. These results suggest that SMS and the DTK of the modality are not related to body size, agreeing with the study by Figueiredo et al. (2010) that verified differences in body mass and height, but equity in performance of specific motor skills between different maturational stages of young players. However, during the process of detecting and selecting sports talent, many clubs overestimate body size and physical fitness to the detriment of technical and tactical quality. Some studies in Physical Education have shown that the excessive valorization of anthropometric and physical variables can turn into an exclusion process of players with quality but late maturation status.

Conclusions

It is concluded that the players advanced in the maturation process (post-PHV) did not present better performance in SMS or DTK when compared to pre-PHV and age-PHV players. Therefore, tactical and technical qualities were not shown to be related to body size. In this scenario, it is suggested that the process to select and recruit sports talents should not choose players only because of their biotype and physical performance, especially during adolescence, since these maturational advantages may not accompany the tactical and technical performance of the individual, which can lead to prognostic errors.

Conflicts of interest - The authors declare that there are no conflicts of interest.

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