Relationship among explosive power, body fat, fat free mass and pubertal development in youth soccer players: a preliminary study

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Abstract

Purpose Changes in body size and functional capacities are highly individual during puberty, and the performance of a soccer player is often closely related to their maturity status. The aim of the study was to evaluate the relationships among explosive power, body fat, fat free mass and pubertal development in young soccer players.

Methods Explosive power (countermovement jump—CMJ), body mass index (BMI), percentage of body fat (%BF), fat free mass (FFM) and a Self-Administered Rating Scale for pubertal development (PDS) values of 11 “Giovanissimi” (age 13 year), 13 “Allievi” (age 15 year) and 10 “Juniores” (age >17 year) male soccer players were compared. The statistical analysis was performed using an analysis of variance among categories with Fisher’s post hoc as appropriate. Furthermore, Pearson correlations among variables were calculated considering all subjects and also within categories.

Results Statistical differences emerged among categories in CMJ ($F_{2,30} = 28.3, p < 0.01$), body fat weight ($F_{2,31} = 29.2, p < 0.01$) and PDS ($F_{2,29} = 18.5, p < 0.01$), while %BF values showed statistical differences only for “Giovanissimi” and “Juniores” ($F_{2,31} = 3.4, p = 0.01$). CMJ showed significant correlations with FFM ($r = 0.68$) and PDS ($r = 0.63$), PDS with FFM ($r = 0.71$) and BMI with %BF ($r = 0.71$). A high correlation was found within categories.

Conclusion Since we found differences between categories and no correlation between chronological age and pubertal status, this study highlights the importance of assessing of puberty in youth soccer team.

Keywords Soccer · Body fat · Development · Performance

Introduction

Soccer is the most popular sport in the world, with about 200 million participants at every levels (amateur and professional), gender (male and female) and age (child, adult and elderly) [1]. Similar to other field-based team sport, soccer is characterized by alternation of high- and low-intensity movements and other intense actions such as jumps, turns, tackles, kicking and dribbling [2–4].

Given that in youth sport competitions children are divided according to their chronological age, the physical performance required youth soccer match are different from youth to youth and compared to adults. Harley et al. [5] showed that the distances covered by youth English
soccer players ranged from \(~6,000\) m (Under 12) to \(~7,600\) m (Under 16), with high-intensity running ranged from \(~1,700\) to \(~2,500\) m (Under 12 and Under 16, respectively), whereas other studies \([6, 7]\) have shown a total distance covered during a match of \(~700\) m by high-intensity running and \(~250\) m by sprinting in Italian Under 14 soccer players. In addition, Vaeyens et al. \([8]\) have demonstrated better performances of sprint and vertical jump in elite youth soccer players (Under 13–Under 14) when compared with sub-elite and non-elite youth soccer players.

Puberty is the period of transition from childhood to adulthood with sexual maturation and includes changes in the nervous and endocrine systems and the corresponding anthropometric, physiological and psychological changes \([9–11]\). During and after puberty, a marked increase in physical performance occurs as a result of muscular, neuronal, hormonal and biomechanical factors \([12]\). Various studies \([8, 13, 14]\) have shown that an advanced biological maturity, within single year chronological age groups of males, is associated with advantages in body size, fat free mass and several components of physical fitness, including aerobic power, muscular strength and speed. In particular, the development of muscle strength in children is related to factors such as age, body size and sexual maturation \([12, 15]\). In terms of psychological profile, puberty shows changes in motivation, cognitive and socio-emotional characteristics \([16, 17]\). In addition, various studies \([18, 19]\) have shown that boys and girls responded differently to puberty and that post-pubertal boys have a better psychological adjustment than pre-pubertal boys.

Although various studies \([20–22]\) showed that age, biological maturity, number of years of training, morphology and anthropometry affect the physical and physiological profile of players, few studies have investigated on the relationship among these variables in youth soccer players. Understanding the correlation between physical and physiological demands of youth soccer players could have practical implications for training prescription, talent identification and the quantification of training loads.

For this reason, the aims of this preliminary study were (1) to assess anthropometric, performance and pubertal characteristics and (2) to describe the association among variables in male youth soccer players. For this purpose, in the same testing session the tests were always performed in the same sequence (pubertal development, anthropometric and jumping evaluations) with 10 min of rest among them. Physical performance test was performed following a standard 15-min warm up, which consisted of jogging (40–60 % of maximal heart rate), strolling locomotion and stretching of the lower limb muscles.

The club agreed to the participation of the soccer players in the evaluation as part of a routine exam performed by the club. All participants were tested during the 2012–2013 Italian competitive soccer season at the middle of the annual competitive soccer season. All participants and their parents were adequately informed about the study and gave their written informed consent. The study was approved by the University Scientific Commission.

Participants

Thirty-four young male soccer players (age 15 ± 2 year, height 168 ± 0.1 cm, weight 61.9 ± 12.4 kg, BMI 21.8 ± 3.1 kg m\(^{-2}\)) recruited from a Youth Soccer Team of “Pol. Albalonga” (League “D”), with training volume of at least 3 days and a match per week, volunteered to participate in this study. The participants were homogeneous with regard to their training status, as none of the participants underwent any strenuous activity and training outside of their normal training schedule. Given that youth soccer competitions are organized into annual age groups according to chronological age, all soccer players in the Youth Soccer Team are grouped on the basis of chronological age: “Giovanissimi A” (14 years) and “B” (13 years), “Allievi A” (16 years) and “B” (15 years) and “Juniores” (17–18 years together). In this study, we evaluated the subjects that participate at the first year (B) of “Giovanissimi” \((n = 11,\) age 13 year, height 156 ± 9 cm, weight 54.3 ± 16.6 kg) and “Allievi” \((n = 13,\) age 15 year, height 172 ± 6 cm, weight 62.9 ± 8.9 kg) categories and all “Juniores” \((n = 10,\) age >17 year, height 186 ± 6 cm, weight 90.3 ± 8.9 kg) soccer players.

Measurements

**Anthropometric characteristics**

Anthropometric values (weight and height) were measured. Body mass index (BMI) was used to assess weight relative to height and calculated by dividing body mass in kilograms by height in squared meters.

Body adiposity was estimated by the measurement of skinfold thickness to the nearest 0.1 mm using a Harpenden caliper. Three skinfold measurements (triceps, subscapula and anterior suprailiac) were taken on the right side
of the body. To reduce measurement variation, the same experienced investigator examined all subjects. Each measurement was taken in triplicate and the average value was taken for calculation. To estimate the percent body fat (%BF) we used the skinfold equations of Slaughter et al. [23]:

\[
\text{Pre-pubescent} = 1.21 \times (\text{triceps} + \text{subscapular}) - 0.008 \times (\text{triceps} + \text{subscapular})^2 - 1.7 \\
\text{Pubescent} = 1.21 \times (\text{triceps} + \text{subscapular}) - 0.008 \times (\text{triceps} + \text{subscapular})^2 - 3.4 \\
\text{Post-pubescent} = 1.21 \times (\text{triceps} + \text{subscapular}) - 0.008 \times (\text{triceps} + \text{subscapular})^2 - 5.5 \\
\]

Fat free mass (FFM) was calculated as follows:

\[
\text{FFM (kg)} = \text{weight} \times (100 - \%\text{BF})/100
\]

**Pubertal development**

The measure of pubertal development was obtained by a reliable and valid brief Self-Administered Rating Scale for pubertal development (PDS) [24, 25]. Given that there is not an Italian version of PDS questionnaire, we have translated a questionnaire reported by Carskadon and Acebo [26] and we have got a good Cronbach’s alpha (0.85) for internal consistency.

In the questionnaire, soccer players were asked to rate the amount of change or development they had experienced with respect to several physical characteristics (body hair growth, facial hair growth, skin changes, voice deepening and growth spurt) associated with pubertal maturation. Ratings on each characteristic were made along a 4-point scale ranging from “1” (no development) to “4” (development completed). Pubertal status scores were derived by summing the ratings made on the five characteristics and then dividing by five to retain the original metric from “1” to “4”.

In addition to computing a pubertal status score, PDS enable us to classify an individual’s level of development in five pubertal status categories: pre-pubertal, beginning pubertal, mid-pubertal, advanced pubertal and post-pubertal. The assignment was made on the basis of reported body hair growth, facial hair growth and voice change. Subjects were considered pre-pubertal if they reported no development on any of three characteristics (a combined score of “3”), beginning pubertal if they reported a combined score of “4” or “5”, mid-pubertal if they reported a combined score of “6”, “7” or “8”, advanced pubertal if they reported a combined score of “9”, “10” or “11”, post-pubertal if they reported completed development of all three characteristics (a combined score of “12”).

**Countermovement jump**

To measure the explosive power of the lower extremities, players performed jump tests (counter movement jump—CMJ) using an optical acquisition system (Optojump, Microgate, Udine, Italy), developed to measure with $10^{-3}$ s precision all flying and ground contact times. The optical system is triggered by the feet of the subject at the instant of taking-off and at contact upon landing. Then, the height of jump was calculated in real time by a specific software [27]. From the standing position, the subjects were required to bend their knees to a 90° angle and perform a maximal vertical thrust (stretch–shortening cycle). To avoid any effect of arm swing, the hands are held on the hips during the jump. Subjects were instructed to keep their body vertical throughout the jump and to land with knees fully extended. Any jump that was perceived to deviate from the required instructions was repeated. The highest of three jumps was used for further analysis. Slinde et al. [28] showed a high test–retest stability coefficient (range 0.80–0.98) for CMJ performances.

**Statistical analysis**

Statistics were performed using the statistical package IBM SPSS (ver. 19). Data are reported as means and standard deviations, and a 0.05 level of confidence was selected throughout the study. A normality test was applied to ascertain the normal distribution of data. Then, an analysis of variance (ANOVA) among categories was applied. When a significant effect was found, Fisher’s least significant difference was used as post hoc analysis to identify differences between means. Furthermore, Pearson correlation among variables was calculated considering all subjects and also within categories. Correlation values <0.1, from 0.1 to 0.30, from 0.3 to 0.5, from 0.5 to 0.7, from 0.7 to 0.9, >0.9 and 1.0 were considered trivial, small, moderate, large, very large, nearly perfect and perfect, respectively [29].

**Results**

Means, standard deviations and statistical differences ($p < 0.05$) of anthropometric data across age groups are presented in Table 1.

No significant difference in BMI was observed among age groups. The percent body fat decreased with the age, but statistically significant differences were only observed for “Giovanissimi” and “Juniores” ($F_{(2.31)} = 3.4$, $p = 0.01$; $\eta^2 = 0.18$; observed power = 0.60). The results have shown statistical differences emerged among all categories...
in body fat weight ($F_{(2,31)} = 29.2, p < 0.0001; \eta^2 = 0.65$; observed power = 1) and PDS ($F_{(2,29)} = 18.5, p < 0.0001; \eta^2 = 0.59$; observed power = 1). Pubertal status showed statistical differences among “Giovanissimi” and the other categories ($F_{(2,29)} = 4.5, p = 0.01; \eta^2 = 0.42$; observed power = 0.99).

Figure 1 shows the statistical differences ($F_{(2,30)} = 28.3, p < 0.0001; \eta^2 = 0.66$; observed power = 1) among categories in CMJ evaluations.

Results showed significant correlations among variables (Table 2). In particular, CMJ with FFM ($r = 0.68$) and PDS ($r = 0.63$), PDS with FFM ($r = 0.66$) and BMI with %BF ($r = 0.71$) and FFM ($r = 0.71$) showed a high correlation.

In addition, a high correlation was found between %BF and CMJ ($r = -0.66$) and FFM ($r = 0.61$) within “Giovanissimi” category and moderate ($r = -0.59$) between %BF and PSD in “Juniores”. Despite that BMI showed a high correlation with %BF ($r = -0.94$) and FFM ($r = 0.78$) in “Giovanissimi”, it showed correlation only with %BF ($r = 0.88$) in “Allievi” and only with FFM ($r = 0.85$) in “Juniores”.

Table 3 reports the number and the frequency distributions (%) for each group of subjects.

**Discussion**

The purpose of this preliminary study was to investigate the relationship among performance, anthropometric and pubertal characteristics in male youth soccer players. This is the first study in soccer that assesses the pubertal characteristics by a simple and valid self-administered questionnaire. The main findings of this study were that there is not a correlation between chronological age and pubertal status.

Despite the fact that in youth sport competitions children are also divided according to their chronological age,
significant variation in performance may arise because of differences in growth and development between those born early and late in the selection year [30]. In fact, although an age difference of <12 months may have little relevance for adults, it may be significant in children.

Although the BMI is widely used in adult populations, and a cut off point of 30 (kg/m²) is recognized internationally as a definition of adult obesity [31], BMI in childhood changes substantially with age [32, 33]. According to Cole and Lobstein [34], 79 % of all soccer players were of normal weight, while 12 % overweight and 9 % obese. Within categories, we found a high (45 %) and moderate (15 %) prevalence of overweight and obese in “Giovanissimi” (Overweight: BMI > 21.89) and in “Allievi” (Overweight: BMI > 23.28), respectively. No overweight and obese values were found in “Juniores” category. Compared to Degache et al. [35], soccer player’s BMI value was high (19.1) for “Giovanissimi”, while it was low (21.8) for “Juniores”. Our values were similar (21.4) to those reported by Di Luigi et al. [36] for 15-year-old soccer players but higher for 13-year-olds (18.8).

According to Lindsay et al. [37], in this study we found a higher correlation between BMI and body fatness in all age groups, with highlight in Giovanissimi compared with Juniores. Although the BMI is considered a fast and simple test to determine body mass and tends to correlate well with body fat, it is a biometric quantitative value. In particular, soccer players with a high BMI may have more muscle mass and body fat low, but they are still classified as overweight or obese. In this direction, Dantas et al. [38] have reported an increase in muscle strength and no significant changes in body composition after physical training program in non-athletic adults.

Various studies [8, 39, 40] have shown that better players tend to be leaner than lower level players, even in the younger age groups. For this reason, percentage of body fat is a standard measurement in soccer. In this study, we have found higher value of % body fat than that reported by Canhadas et al. [41] and by Vanttinen et al. [42] in same age group. Soccer player’s % body fat value of “Giovanissimi” and “Allievi” was higher (16.6 and 17.1, respectively) than that reported by Di Luigi et al. [36]. In addition, our study was in agreement with Baldari et al. [43] that showed a negative correlation between body fat and standing long jump.

Although the PDS have been considered a reliable and valid tool to measure the pubertal development, no data are available about the PDS in youth soccer players. Over the years, the association between physiological maturational level and chronological age of the children and adolescents soccer players have been assessed by skeletal, endocrine (androgens, estrogens and progesterone) and somatic (development of secondary sex characteristics) changes [13, 36, 43, 44]. For these reasons, studies on physiological ages are often difficult to compare due to differences in the surveillance systems used and, in particular, the methods of collecting data and in the age groups studied. Usually, the Tanner Scale [45] is used to assess the pubertal stage development of subject classifying them as pre-pubescent (stages 1 and 2), pubescent (stage 3), post-pubescent (stages 4 and 5) or adult (stage 6 and higher). Using Tanner scale, Degache et al. [35] have found a high prevalence rates of pubescent (31 %) and post-pubescent (63 %) in 13-year-old and in 15-year-old soccer players, respectively, while Di Luigi et al. [36] showed 80 % of post-pubescent (stage 4 + stage 5) in 15-year-old soccer players. In this study, 26 % of all soccer players were at beginning of puberty, 35 % middle puberty, 26 % advanced puberty and 6 % post puberty. In particular, we found high prevalence rates of beginning (64 %), middle (62 %) and advanced (40 %) pubertal in 13-, 15- and >17-year-old soccer players, respectively. However, we did not find pre-pubertal cases in all categories and surprisingly only two event of post-pubertal in “Juniores”.

Countermovement has been deemed to be good functional test for fitness and talent selection [46–49]. Various studies [46, 50] have reported average values ranging from 47.8 to 60.1 cm and high correlation (0.78) with maximal muscular strength of jump height performances in professional soccer players. In addition, Malina et al. [14] showed that in young male soccer players aged 13–15 years performance in the vertical jump improves with increasing sexual maturity. In this study, we found that the CMJ values increased with the age and were lower than those reported by Vanttinen et al. [42] for all categories. Soccer player’s CMJ value was lower than to that reported by Castagna and Castellini [51] for Under 17 and Under 20 (40.9 and 40.2, respectively) and by Deprez et al. [52] for Under 15 and Under 17 categorized in the 4 birth quarters of the year (from 23.3 to 24.5 and from 26.7 to 27.7, respectively). Compared to Figueiredo et al. [13], value of the “Giovanissimi” was lower (31.9) for same age players.

The results from this preliminary study can provide useful information for the coach to create appropriate

**Table 3** Number and frequency distributions (%) for each group of subjects

<table>
<thead>
<tr>
<th></th>
<th>Giovanissimi (%)</th>
<th>Allievi (%)</th>
<th>Juniores (%)</th>
<th>total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepubertal</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Beginning</td>
<td>8 (73)</td>
<td>1 (8)</td>
<td>1 (10)</td>
<td>10 (29)</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midpubertal</td>
<td>2 (18)</td>
<td>8 (61)</td>
<td>2 (20)</td>
<td>12 (35)</td>
</tr>
<tr>
<td>Advanced</td>
<td>1 (9)</td>
<td>4 (31)</td>
<td>5 (50)</td>
<td>10 (29)</td>
</tr>
<tr>
<td>Postpubertal</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (20)</td>
<td>2 (6)</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Age Group</th>
<th>Number of Subjects</th>
<th>Frequency Distribution</th>
<th>Total (%)</th>
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<tbody>
<tr>
<td>Pubertal</td>
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<tr>
<td>Prepubertal</td>
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<tr>
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<td>Postpubertal</td>
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specific conditioning programs to minimize the risk associated with injuries and maximize physical condition of youth soccer players. In fact, the Italian Soccer Federation states that in the higher amateur soccer championship, sport clubs are compelled to use at least four “young” players distinct in relation to the age groups (1 player aged 20, 2 players aged 19, 1 player aged 18). Considering that we found only two subjects that have completed the maturation process in “Juniore” and that high-intensity physical activity can modify the development of puberty [53], coaches should take into account the needs and the problem of young soccer players to ensure the “safe” growth of the soccer player. A study of Baldari et al. [43] showed that boys who were advanced in biological maturity were generally better performers than their late maturing peers and suggests that physical education programs should be planned on the basis of biological age, and physical activity classes should be organized according to subjects’ biological characteristics and not according to their chronological age. Accordingly, youth training should be based on an adequate progression of load to meet the physiological characteristics of the young players. This study highlights the importance of the assessment of puberty in youth soccer teams. Since growth varies considerably in timing and duration, high inter-individual variability (pubertal stage, BMI, CMJ, etc.) may be found within the same class of athletes selected for chronological age and could determine a considerable difference in performance results. The method presented in this study may be used to make comparisons between the pubertal development and the soccer capabilities of different age-groups. Such data could be used to identify players with the ability to play at a particular level and to prepare players for the demands of successive playing levels through the modification of training loads according to the specific physiologic demands. Understandably, our study was subject to a number of limitations. First, this was a cross sectional study rather than a prospective study. Second, our statistical analysis with respect to chronological age included small groups of players. Third, in the present work the self-administered test has been used to assess the stage of puberty that, although it is widely used in the literature, may be affected by inadequate interpretations by the subject (limit of each self-administration test).

For these reasons, further longitudinal and large-scale study is recommended to ascertain the relationship between chronological and biological age and the physical performance of youth soccer player during in-season phase.

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Conflict of interest The authors declare that there are no conflict of interest regarding the publication of this article.

References


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