Original Paper DOI: 10.5114/biolsport.2017.69817 Biol. Sport 2017;34:305-311

Is the technical performance of young soccer players influenced by hormonal status, sexual maturity, anthropometric profile, and physical performance?

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ABSTRACT: The aim of this study was to examine the influence of hormonal status, anthropometric profile, sexual maturity level, and physical performance on the technical abilities of 40 young male soccer players during small-sided games (SSGs). Anthropometric profiling, saliva sampling, sexual maturity assessment (Tanner scale), and physical performance tests (Yo-Yo and vertical jumps) were conducted two weeks prior to the SSGs. Salivary testosterone was determined by the enzyme-linked immunosorbent assay method. Technical performance was determined by the frequency of actions during SSGs. Principal component analyses identified four technical actions of importance: total number of passes, effectiveness, goal attempts, and total tackles. A multivariate canonical correlation analysis was then employed to verify the prediction of a multiple dependent variables set (composed of four technical actions) from an independent set of variables, composed of testosterone concentration, stage of pubic hair and genitalia development, vertical jumps and Yo-Yo performance. A moderate-to-large relationship between the technical performance set and the independent set was observed. The canonical correlation was 0.75 with a canonical R^2 of 0.45. The highest structure coefficient in the technical performance set was observed for tackles (0.77), while testosterone presented the highest structure coefficient (0.75) for the variables of the independent set. The current data suggest that the selected independent set of variables might be useful in predicting SSG performance in young soccer players. Coaches should be aware that physical development plays a key role in technical performance to avoid decision-making mistakes during the selection of young players.

CITATION: Moreira A, Massa M, Thiengo CR et al. Is the technical performance of young soccer players influenced by hormonal status, sexual maturity, anthropometric profile, and physical performance? Biol Sport. 2017;34(4):305–311.

Received: 2016-11-10; Reviewed: 2017-01-10; Re-submitted: 2017-03-18; Accepted: 2017-03-23; Published: 2017-09-20.

Key words:
Testosterone
Tanner scale
Weight
Height
Endurance
Power

INTRODUCTION

Considering that the morphological and physiological changes related to biological maturation are driven by sex hormones (e.g. testosterone) during adolescence [1], it seems reasonable to hypothesize that a higher concentration of such hormones could affect the athletic performance of young athletes. Previous findings have consistently shown that testosterone may affect a variety of anthropometric characteristics [2], which in turn can influence neuromuscular capacities and physical performance [3, 4]. Moreover, there is consistent evidence regarding the association between hormonal status and physical performance in cohorts of young soccer players. For instance, Gravina et al. [5] reported that salivary testosterone concentration at the beginning of the season positively correlated with the improvement in performance in the countermovement jump and drop jump tests, as well as an increase in relative VO_{2max}, during the season in a sample of young Spanish soccer players. These results are in line with those of other studies that have also reported that hormonal status plays a key role in determining physical performance (Yo-Yo test and vertical jump test) in pre-adolescent soccer players [6].

A better physical performance, in association with a more developed hormonal status, may be considered to be a significant advantage for youth soccer players during long-term training soccer programmes, as well as for talent identification and selection processes [7]. However, despite knowledge regarding the influence of hormonal status and maturity on physical performance, less in known about

the influence of these variables on technical performance. A complex interplay between changes in sex hormone status, central nervous system development and associated behaviours occurs during adolescence [8, 9, 10], suggesting that technical performance may also be affected by testosterone concentration.

A viable approach to assess soccer technical performance seems to be the evaluation of small-sided games (SSGs) [11]. Recently, Unnithan et al. [11] proposed that SSGs could be employed to provide a more ecological approach for identifying players with the capability to perform well at the 11-a-side level and, therefore, could be considered to be an alternative tool for talent identification. Despite this recent claim regarding the usefulness of SSGs, studies describing the technical performance of elite young soccer players participating in these games are still scarce. Additionally, data regarding the influence of hormonal status, anthropometric measurements, and physical performance on technical performance during SSGs are somewhat limited for this population.

Therefore, the aim of this study was to examine the influence of hormonal status, sexual maturity level, anthropometric profile, and physical performance on SSG technical performance in elite youth soccer players. It was hypothesized that early maturation players who present an advanced sexual maturity level, a higher testosterone concentration, a favourable anthropometric profile (higher stature and body mass), and a higher level of physical performance would perform better in a technical performance evaluation.

MATERIALS AND METHODS

Participants

The sample included 40 soccer players representing São Paulo Futebol Clube (SPFC), a major professional soccer club in Brazil. At the professional level, SPFC has previously won six Brazilian National Championships, two Toyota Intercontinental Cups (1992 and 1993) and one FIFA Club World Championship (2005). The club has several young teams distributed into age categories with the aim of developing professional soccer players. The soccer players voluntarily agreed to participate in the study. All players were born in 1998 (15.1 ± 0.2 years, 174 ± 6 cm, and 63 ± 7 kg).

Experimental design

The present investigation was conducted in 2013, at the beginning of the second semester (August), after a one-month training period. The data collection occurred on two days that were separated by two weeks. On the first day, the players provided saliva samples approximately 15-20 minutes before the anthropometric and performance measurements. On the second day, each player was assessed during a SSG. The SSGs were filmed and individual technical performance annotated for further analysis. The testing sessions began at 3:00 PM. In general, the players assessed were involved in a training programme comprising 10 to 12 sessions per week, each with a duration of 90 to 120 minutes, including strength and conditioning sessions, soccer-specific drills, and small-sided games. All players were familiar with the performance tests and experimental procedures. It should be highlighted that the compliance with training/testing was high for all players, as they had been part of a professional academy for some time before this study. Prior to starting the study, all players underwent thorough medical screening to assess their health status. All players were free from illness and none were taking any prescribed medications. After being informed of the experimental procedures, including benefits and potential risks, the participants, and their parents, gave written consent to participate in the study. The research procedures were approved by the local University Research Ethics Committee.

Small-sided games (SSGs)

The SSGs were performed with a five-a-side team composition (five vs five) and one goalkeeper (GK) for each team. The GKs were not included in the analysis. The SSGs were organized into two sets (periods) of eight minutes. A passive recovery of three minutes between sets was prescribed. The coach was asked to divide the teams so that the technical level of the players was approximately equal. Each player assessed participated in only one SSG. Players were encouraged to drink water, ad libitum, between match periods (sets). The pitch area adopted measured 46 (width) x 60 (length) metres. All players were well familiarized with this protocol, as it was habitually used during their training programme.

Video analysis

Video recordings of SSGs were collected using two fixed cameras (Sony, Brazil; 60 Hz frequency acquisition). One was located 15 m above and to one side of the long axis of the pitch, while the other was placed five m to one side of the pitch to facilitate the players' identification. The Gamebreaker (Sports Code, USA) software for automatic tracking throughout the match sequence was used. The reliability of the analysis was determined by repeating two trials for each SSG, which were analysed by two researchers experienced in soccer-match analysis. The kappa values for the analysed variables ranged from 0.90 to 0.98 (intra-observer) and 0.82 to 0.91 (inter-observer). Technical performance indicated by the frequency of actions was recorded during each SSG. Data were chosen and adapted according to criteria proposed previously [12, 13], namely:

- Involvements with the ball: all situations where the player was in contact with the ball; more than one touch on the ball before releasing or losing it was recorded as only one involvement.
- Goal attempts: the number of attempts to score a goal.
- Complete tackles: the number of situations in which a player contested the ball with an opponent. The situation should involve a clear physical contact between players.
- Incomplete tackles: the number of situations in which a player contested the ball with an opponent, but did not necessarily impose a change in ball possession.
- Total tackles: the sum of incomplete and complete tackles.
- Successful passes: the number of short and/or long passes per-

formed by a player and successfully received by another player of his own team.
- Unsuccessful passes: the number of short unsuccessful and/or long passes performed by a player. Unsuccessful passes that imposed a change in ball possession.
- Total number of passes: the sum of successful and unsuccessful passes.
- Total headers: the number of times in which a player touched the ball with his head.
- Effectiveness: the number of successful passes per total number of passes performed during the match.

Anthropometric profile

The anthropometric measurements made included height and body mass. Height was measured with a vertical stadiometer that was 210 cm long and had a 0.1 cm precision (Welmy, Sao Paulo, Brazil). Body mass was measured using a digital platform scale (Welmy, Sao Paulo, Brazil), which was calibrated and graduated from 0 to 150 kg, with precision of 0.1 kg.

Stage of pubic hair and genitalia development

A trained medical doctor assessed the stages of secondary sex characteristic development by clinical observation. The rating of the stages of sexual maturation was made using the criteria described by Tanner [14]. Briefly, stage 1 indicates the prepubertal state (absence of each characteristic). Stage 2 indicates the initial development of each secondary sex characteristic. Stages 3 and 4 indicate continued maturation in which the adolescent can be considered as sexually maturing. Stage 5 indicates an adult (mature) state for each sex characteristic.

Salivary testosterone assessment

Each player provided a saliva sample approximately 15 to 20 minutes before the anthropometric and performance measurements. Saliva collection was performed 90 min after lunch and 24 hours after the last exercise session. The participants were seated, with their head tilted slightly forward with minimal orofacial movement. The saliva sample was collected in a pre-weighed sterile 15-ml centrifuge tube over a five-minute period and stored at -80°C until assay. Salivary T concentration was measured in duplicate using an enzyme-linked immunosorbent assay (ELISA, Salimetrics testosterone expanded range kit, USA), according to the manufacturer's instructions. The average intra-assay coefficient of variation for the testosterone assay employed in the present analysis was 3.2%. The minimum detection limit for the T assay was 21 $\rho mol \cdot L^{-1}$.

Physical performance tests

Countermovement jump (CMJ) and squat jump (SJ)

The CMJ and SJ were performed on a contact (jump) mat (Ergojump Jump Pro 2.0 – CEFISE, Brazil) connected to a computer, as described previously [5, 6, 15]. Three jumps for each type of jump (CMJ and SJ) were performed with two-minute rest periods provided between trials. The jump mat provides valid measures of jump height compared to a criterion system ($r = 0.967$) [15]. Pilot testing indicated that the jump mat system also provides reliable measures (CVs < 2.0%) for both CMJ and SJ.

Yo-Yo intermittent test level 1

The Yo-Yo intermittent recovery test (level 1) was performed, as described by Bangsbo [16], to evaluate intermittent endurance performance. The total distance covered (in metres) was recorded.

Statistical analyses

Initially, a factor analysis was used to identify the structure of relationships between the technical performance measurements to examine whether it would be possible to reduce the number of representative variables without compromising information, and to identify the most representative variables that could be used in the subsequent multivariate analysis. To obtain factor solutions, the principal components analysis (PCA) extraction method was adopted and components with an eigenvalue of less than 1 were removed. The initial factor matrix was submitted to the varimax normalized rotational method to maximize the sum of variances of required loading. Values > 0.70 were adopted to indicate the statistical significance of a factor loading. The factor loading represents the correlation between a variable and its respective factor. A multivariate canonical correlation analysis (CCA) [17] was employed to examine the prediction of multiple dependent variables [using the most representative technical performance measurements extracted from the PCA (Table 1)] from multiple independent variables (testosterone

TABLE 1. Eigenvalues and variance for factors extracted by principal component analysis.

Factor	Eigenvalue	% Total variance	Cumulative eigenvalue	Cumulative %
1	3.08	30.88	3.08	30.88
2	2.42	24.28	5.51	55.16
3	1.51	15.15	7.03	70.31
4	1.36	13.65	8.40	83.97

TABLE 2. Principal component analysis with factor loadings.

	Factor 1	Factor 2	Factor 3	Factor 4
Involvements with the ball	0.882*	0.227	0.056	0.189
Goal attempts #	0.001	0.400	0.044	0.751*
Complete tackles	0.039	-0.166	0.826*	0.264
Incomplete tackles	-0.075	0.019	0.399	-0.702*
Total tackles #	-0.016	-0.128	0.962*	-0.237
Successful passes	0.967*	-0.166	0.008	-0.025
Unsuccessful passes	0.312	0.910*	-0.146	0.076
Total number of passes #	0.980*	0.126	-0.037	0.001
Total headers:	0.067	-0.216	0.264	0.609
Effectiveness #	0.095	-0.962*	0.165	0.032

* = loadings are >.70 (the factor loadings represent the correlation between a variable and its respective factor; values above 0.70 were adopted to indicate the statistical significance of a given factor loading [17]; # the extracted variable used in the subsequent canonical correlation analysis (CCA).

concentration, stage of pubic hair development, stage of genitalia development, and squat jump height, countermovement jump height and Yo-Yo intermittent recovery distance). The CCA was used to reduce the risk of a type I error, which could occur if a series of multiple regressions were used to examine each dependent variable separately [18]. Therefore, the relationships between the set of the four dependent technical performance variables, which were extracted from the PCA, and the set of independent variables were examined simultaneously. The level of significance for the canonical correlation analysis was set at $p \leq 0.05$. The practical significance was shown by the size of canonical correlations (R) and the squared correlations (R^2). The standardized canonical function coefficients and structure coefficients were presented to aid in the understanding of the patterns among the variables. Structure coefficients, which represent the bivariate correlation between the variables and a set formed by them, of equal to or above 0.45, were employed following previous recommendations [18]. Statistical analysis was performed using Statistica (version 10, StatSoft, Tulsa, USA).

RESULTS

The mean (±SD) salivary testosterone concentration of the cohort was 546.9 ± 157.8 ρmol·L^{-1}. The mean (±SD) stages of pubic hair development and genitalia development were 3.4 ±1.0 and 3.1 ±0.7, respectively. For SJ, CMJ, and Yo-Yo intermittent recovery tests, the means were 35.5 ± 3.7 cm, 39.6 ± 4.4 cm, and 1627 ± 334 m, respectively. Table 1 shows the results for the eigenvalues of each factor, the corresponding percent of variance, and the cumulative, eigenvalue and percent of variance.

TABLE 3. Canonical solution for technical performance set.

Technical performance set		
Variable	**Coefficient**	**Structure coefficient**
Total number of passes	0.514	0.570*
Effectiveness	-0.390	-0.325
Goal attempts	0.244	-0.093
Total tackles	-0.777	-0.773*

*Structure coefficients equal to or greater than 0.45.

TABLE 4. Canonical solution for predictor set.

Predictor set		
Variables	**Coefficient**	**Structure coefficient**
PHD	0.039	0.667*
GD	0.505	0.437
Testosterone	0.951	0.756*
Stature	0.109	0.019
Body mass	-0.572	0.139
SJ	-0.019	-0.098
CMJ	-0.363	-0.178
Yo-Yo	-0.376	-0.115

PHD =Stage of pubic hair development; GD = Stage of genitalia development; SJ = squat jump; CMJ = countermovement jump; Yo-Yo = Yo-Yo intermittent recovery 1; *Structure coefficients equal to or greater than 0.45.

Considering the variables which presented higher factor loading for each component (factor), the following technical performance variables were retained for analysis: total number of passes (factor 1), effectiveness (factor 2), total tackles (factor 3), and goal attempts (factor 4). Despite not being included in the subsequent canonical analyses, all other variables that demonstrated a factor loading of above 0.70 were also highlighted (*) (Table 2).

A significant canonical correlation ($\chi^2 = 82.52$; $R = 0.75$; $p < 0.001$) was observed between the multiple dependent variables and the multiple independent variables. The canonical R^2 obtained was 0.45. Significant results from the first canonical function are presented in Tables 3 and 4. The structure coefficients that are ≥0.45 are highlighted to indicate the strength of this relationship.

DISCUSSION

The main finding of the present study was that there is a moderate to large relationship between the technical performance set (dependent variables set – total number of passes, effectiveness, goal attempts, total tackles) and the independent variables set, composed of testosterone concentration, stage of pubic hair development (PHD), stage of genitalia development, and vertical jump performance and intermittent endurance performance. Data suggest that this independent variables set might be useful in predicting SSG performance in young soccer players, at least when SSG performance is measured based on the frequency of specific playing actions. Moreover, the findings suggest that testosterone concentration and the frequency of tackles performed during SSGs are the main contributors to the multivariate correlation observed.

These results partially corroborate the initial hypothesis, as the current data set suggests that sexual hormonal concentration (together with PHD) plays a key role in determining SSG technical performance. These "untrained factors", therefore, seem to be an advantage for SSG technical performance among those players with advanced hormonal status and sexual maturity development. It also suggests that hormonal status (notably, testosterone concentration) and sexual maturity level are associated with each other, and indicates that changes in hormonal status and, consequently, in sexual maturity level may partly influence the variations in SSG technical performance. These findings may be considered novel and add to the literature, as data show that testosterone exerts some influence on the SSG technical performance of youth players, extending previous knowledge related to the role of hormonal status and sexual maturity development in the physical performance of youth players [4,5,6].

A possible explanation for these results might be the possible association between technical performance and the known pleiotropic testosterone effects. For example, testosterone has been implicated in spatial memory and cognition [19, 20], visuospatial ability [21], and inhibition of unconscious fear [22]. Youth players with a higher testosterone concentration and an advanced maturity status might perform better in tasks (technical actions) that are dependent upon such factors. This association should be empirically investigated in future studies to elucidate this assumption, as published studies derive largely from adults and populations of non-athletes [20, 22]. However, it should be highlighted that the present results indicate a promising field for the investigation of technical performance of youth soccer players.

Interestingly, testosterone, PHD, genital development, and stature demonstrated the same coefficient sign (+) when the results of the canonical solution were presented. This finding indicates that these variables are positively related, reinforcing the assumption that testosterone, PHD, genital development, and stature are not independent from each other, and that a certain degree of collinearity might exist. The data also indicate that these 'untrainable' aspects contribute to the technical performance of young soccer players and should be put in context by coaches and staff members during training assessments and selection procedures, to avoid equivocality in decision-making in favour of those who are more developed than their peers at a given time point.

The present results, however, refute the hypothesis that anthropometric parameters and performance in physical tests could also play an important role in SSG technical performance. As previous findings suggest that intermittent-endurance fitness was significantly correlated with physical match variables [23], it could be speculated that the constraints of the SSG, such as reduced field area per player, reduced match-time duration, compared to official soccer matches, and possibly the greater emphasis on technical ability than on physical performance, could diminish the influence of the assessed physical performance (Yo-Yo and jumping test performances) on the technical performance in the present study. This condition might be useful to aid in evaluation of the technical performance of adolescent players, and in reducing the effect of physical attributes on match performance. However, this hypothesis should be tested in future studies that compare SSG and official matches to advance this knowledge, while providing insightful data to coaches and club staff working with this population.

While it is important to highlight the need for further studies to test the effectiveness of the SSG for evaluating real match performance, it is plausible that the results of the present study might be useful for inferring competition performance, as the study was designed using an "ecological testing approach" [11, 24]. Unnithan et al. [11] and Waldron & Worsfold [25] proposed that adopting the SSG as a unit of analysis may be more realistic, and that the findings for skills (technical) involved in SSGs might be considered to be more "transferable" to actual competitions. Adopting the SSG as a unit of technical analysis allowed the observation of the importance of the defensive action in overall SSG technical performance. The importance of the defensive capability is a key finding of the present study and suggests that further evaluation of technical parameters in youth players should include defensive actions in an ecological environment. The fact that the "tackles" made a primary contribution to the canonical correlation not only confirmed such a specific requirement in the youth players' evaluation process, but also suggested that

players with a higher testosterone level may exhibit greater readiness and motivation to perform [26] such defensive actions, in turn helping to explain the higher level of overall SSG performance.

Despite the important results presented in this investigation, some limitations should be highlighted. The present study evaluated a relatively small number of participants and used a cross-sectional experimental design. Future studies adopting the analysis used in the present investigation, but using a greater number of participants and longitudinal design, may advance the knowledge regarding the research question addressed in the present investigation. Additionally, as only one team was assessed, this study may be viewed as a case study. Therefore, caution is required when making inferences regarding its results. Indeed, future studies should focus on a more detailed assessment of tactical demands during SSGs, while evaluating the influence of physical performance, anthropometric profile, hormonal status, and tactical knowledge on technical performance, or even on the decision-making capabilities of youth players. Such an approach would allow a more comprehensive understanding of this association and the possible impact of changes on different attributes of youth soccer performance.

CONCLUSIONS

The results of the present study indicate that SSG technical performance is affected by hormonal status. Testosterone level was the strongest factor in the technical performance measurements. Additionally, the present results suggest that technical variables, such as tackles, may contribute most to the correlation observed. The current findings indicate that the technical performance of young players, at least in the SSG (which has often been claimed to be an indicator of performance during real matches), also seems to be influenced by hormonal status and biological maturity level. As these factors are untrainable and due to the fact that there might be considerable variation between players within the same team, coaches and staff members should be aware of these issues to avoid decision-making mistakes during the selection process and during the evaluation of technical performance in young players.

Acknowledgements

The authors would like to thank the President Laudo Natel Athletes Development Center (São Paulo Football Club, São Paulo Brazil) staff for their assistance and great level of commitment to the experimental procedures implemented in this investigation. This study was supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo – Brazil; Grant: 2012/20309-3).

Conflict of interests: the authors declared no conflict of interests regarding the publication of this manuscript.

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