Role of Free Testosterone in Interpreting Physical Performance in Elite Young Brazilian Soccer Players

Alexandre Moreira, Arnaldo Mortatti, Marcelo Aoki, Ademir Arruda, Camila Freitas, and Christopher Carling

This study investigated the contribution of salivary testosterone (sT) concentration, years from peak height velocity (YPHV) and height by body mass interaction on jumping performance (Countermovement jump; CMJ) and aerobic fitness (Yo-Yo intermittent endurance test, level 1) in young elite soccer players. Forty-five participants (age: 12.5 ± 0.5y; body mass: 48.6 ± 10.2kg, height: 155.7 ± 10.0cm) belonging to a top level Brazilian soccer club were evaluated at four time points across a single semester. None of the assessed players had reached PHV. The data from the four evaluations were averaged and multiple linear regression analysis conducted. For CMJ, the model explained 42.88% of the variance ($R^2 = 42.88$; $p < .000$); sT concentration was the primary contributor ($R^2 = 32.84$) and the YPHV contributed 9.95% of the variance. The model explained 28.50% ($p < .000$) of the variance in Yo-Yo. The sT was the primary and single significant contributor ($R^2 = 21.32$). A significant difference was noted between high and low testosterone groups divided a posteriori to CMJ performance ($t = 3.35$; $p = .001$). These results suggest an important role for hormonal status in interpreting physical performance in preadolescent soccer players.

Measures of performance in tests of functional capacities such as endurance, speed, power and strength are habitually used by coaches and researchers to investigate physical attributes in young soccer players (16). Several authors have reported large variations across individuals in physical performance measures as well as in morphological variables, soccer-specific skill tasks, and in motor proficiency during puberty with ability closely associated to maturity status (24,32). Indeed, in youth soccer, advanced physical development is considered an advantage and less developed players (considered late maturers) are frequently disadvantaged throughout the talent identification and selection process (15). Some talented young soccer players might be overlooked for selection into elite academies simply because they are behind in biological maturity and less developed physically.

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The endocrine system influences anthropometric characteristics and body composition (6,17) which in turn can affect neuromuscular capacities and athletic performance (5,10). During adolescence the endocrine system is subject to major alterations and many hormones such as growth, thyroid and adrenal hormones are involved in the maturational process (30). Hypothalamic-pituitary-gonadal axis activation is the main factor that induces progressive secretion of testicular sex hormones which ultimately are responsible for the changes associated with biological, morphological and psychological dimensions that occur during puberty (14). Moreover, as highlighted by Marshall and Tanner (26), the timing of the adolescent spurt, associated with genital and pubic hair development is in line with the assumption that androgens from the testes play a key role in accelerating growth.

In recognition that testosterone helps to indicate acute and chronic changes in neuromuscular capacity for explosive performance (8), it is reasonable to suggest that in youth soccer players, interindividual differences in free testosterone levels are associated with variations in physical performance. Indeed, in young players participating in the same age category, there are significant interindividual differences in puberty-related hormonal patterns (9). Late physical development could therefore be associated with lower endocrine hormonal levels. In the practical setting, the issue of endocrine hormone levels, notably testosterone, might therefore be taken into consideration by medical, fitness and coaching practitioners. Observed differences in physical performance among individuals could be explained, at least in part, by androgen circulating levels, which in turn might aid in informing the strength and conditioning process in young players.

Unfortunately, there is a lack of information regarding the relationship between pubertal development, endocrine hormone concentrations and functional performance measures in the formal training processes of young preadolescent soccer players. Biological maturation associated with hormone status could be considered concomitantly with functional performance measures when selecting and training young soccer players (21). Indeed, knowledge of individual hormonal status in conjunction with maturational status measures across different periods during preadolescence and adolescence might aid decision-making during long-term development training programs.

Therefore, the aim of this study was to assess the contribution of salivary testosterone (sT) concentration, in addition to maturity status (years from peak height velocity; YPHV) and anthropometric measures to variations in jump height and aerobic performance in elite young Brazilian soccer players. The authors suggest that a model integrating these measures could help to explain potential variations in physical performance.

**Methods**

**Participants**

Forty five young soccer players belonging to one of the major professional soccer clubs in Brazil voluntarily agreed to participate in the study. After ethics approval by the local Institutional Review Board the protocols were explained in detail. Written informed consent was obtained from each participant and their respective parents or guardians.

At senior level, the present club has previously won five National Championships and has participated in the FIFA Club World Championship. It has several young teams
distributed into age-categories with the aim of developing professional soccer players. Players are divided into categories according to chronological age. Two of these categories were selected for investigation: under 12 (U12; $N = 19$) and under 13 (U13; $N = 26$). The two age categories were chosen as these are considered essential stages in the long-term development training process. Indeed, in these two age groups, players are either selected or not to continue their development in the present professional club.

The 45 players were characterized as a single group for all analyses as no significant differences were observed between U12 and U13 categories in testosterone concentration, years from PHV and performance in functional tests. None of the participants reported any injury or illness over the course of the study. All had either been engaged in the club’s regular soccer training program for at least thirty months after recruitment during an annual selection scheme or had been recruited by coaches and staff members from another team. The players participated in three training sessions (90–120 min) and one game per week, the latter taking place at weekends.

**Experimental Approach to the Problem**

Resting saliva sampling to determine testosterone levels and anthropometric and performance measurements were performed on four occasions by the same researcher and at the same time on each testing day. Testing was conducted in the same afternoon as regular training sessions and completed before training commenced. All participants were familiar with all the test procedures which are habitually performed by the club’s coaches during the season. Regarding saliva collection, the participants were familiarized with the procedures before the start of the investigation.

The investigation period was structured as follows: a 12-week preparatory training phase (preseason training), a 7-week competitive and a 2-week detraining phase. All measurements were performed on four occasions for each participant; before (T1) and after (T2) the preseason phase, and after the competitive (T3) and detraining phases (T4). The competitive phase included 7 official matches. All measurements were performed in the afternoon (14:00), at least 90 min postlunch. Anthropometric measures included height, body mass, sitting height. Height was measured using a digital platform scale (Welmy©, São Paulo, Brazil), calibrated, graduated from zero to 150 kg; level of precision of 0.1 kg; sitting height using a vertical stadiometer, 210 cm long and 0.1 cm precision (Welmy©, São Paulo, Brazil). The thickness of five skinfolds thickness (triceps, subscapular, suprailiac, abdominal, and medial calf) was measured using a Harpenden® skinfold caliper (St. Albans, UK) by the same investigator to the nearest 0.2 mm, with the participants in the reference standing position. All skinfold measurements were taken on the right side of the body. Body fatness was subsequently estimated using the skinfold equation proposed by Slaughter et al. (35).

**Procedures**

**Maturity Status**

Maturity status was assessed in accordance with methods described by Mirwald, Baxter-Jones, Bailey, & Beunen (28). This approach has been proposed as a somatic maturity indicator and predicts the time before or after PHV from measures of age, height, body mass, sitting height, and leg length. It has been used in adolescent
male soccer players (23), swimmers (34), gymnasts (22,31), figure skaters and ballet dancers (29) and schoolchildren (20) among others. The somatic maturational assessment by means of years from peak height velocity (YPHV) using anthropometric variables, is predicted in males using the following equation (23,28): $[-9.236 + 0.0002708 \cdot \text{Leg Length and sitting height interaction} - 0.001663 \cdot \text{age and leg length interaction} + 0.007216 \cdot \text{age and sitting height interaction} + 0.02292 \cdot \text{weight by height ratio}]$. By using the age of PHV as a maturational indicator and describing the measurement as years from PHV, the subtraction of the age of PHV from the chronological age at the time of the measurement allows the differences in years to be defined as a value of maturity offset (28).

**Countermovement Jump Height (CMJ)**

CMJ was performed on a contact mat. The participants lowered themselves from an initial standing position to a self-selected squat position and performed a vertical jump keeping their hands placed on their hips as quickly as possible with maximal effort. While no restrictions were placed on the knee angle attained during the eccentric phase of the jump, participants were instructed to maintain straight legs during the flight. The jump mat provides valid measures of jump height compared with a criterion system ($r = .967; 18$). Pilot testing indicated that the jump mat system also provides reliable measures (CV’s < 2.0%).

**Yo-Yo Intermittent Endurance Test**

The Yo-Yo intermittent endurance test, level 1 (3), was performed in line with the procedures adopted by Figueiredo et al. (11) in their investigation in young male soccer players. Groups of eight to ten participants were evaluated each time. Four assistants (researchers and staff members) were each responsible for two or three participants. This test involves 5–20 s intervals of running interspersed by regular short rest periods of 5 s. Briefly, participants ran outdoors on a grass flat surface between 2 markers set at a 20 m distance apart. In addition to these two markers, a third marker is positioned 2.5 m behind of the start marker. Starting at the first marker, the athletes ran to the 20 m marker on an audio cue from a CD player, before turning and running back toward the first marker, which they had to reach by the next signal. When the start marker was reached, the players continued forward, jogging (lower tempo runs), until they reached the third marker, and then ran back to the start marker. They then stopped and waited for the next signal. The starting speed at level 1 was 8.0 km·h$^{-1}$, and throughout the test, the speed increased progressively. The test was finished when the athletes were not able to maintain the indicated speed for two trials. A warning was given when they were unable to reach the start marker, and on a second warning the athletes were instructed to stop. The total distance covered was recorded in meters.

**Saliva Collection and Hormone Assessments**

The players provided saliva samples approximately 15–20 min before the anthropometric and performance measures. The participants abstained from food and caffeine products for at least 1.5 hr before saliva collection. In a seated position and with the head tilted slightly forward, unstimulated saliva samples were collected by passive drool into sterile 15-ml centrifuge tubes over a 5 min period. The
saliva samples were then stored at -80 °C until assayed for testosterone. Salivary testosterone concentrations were measured in duplicate using an enzyme-linked immunosorbent assay (ELISA, Salimetrics testosterone expanded range kit) in accordance with the manufacturer instructions. Briefly, a microtitre plate is coated with rabbit antibodies to testosterone. Testosterone in standards and unknowns competes with testosterone linked to horseradish peroxidase for the antibody binding sites. After incubation, unbound components are washed away. Bound testosterone peroxidase is measured by the reaction of the peroxidase enzyme on the substrate tetramethylbenzidine (TMB). This reaction produces a blue color. A yellow color is formed after stopping the reaction with sulfuric acid. Optical density is read on a standard plate reader at 450 nm. The amount of testosterone peroxidase detected, as measured by the intensity of color, is inversely proportional to the amount of testosterone present. The average intra-assay coefficient of variation for testosterone assay verified in the present analysis was 3.2%. The minimum detection limit for the T assay, in accordance with the manufacturer, was 21 pmol/L.

Statistical Analysis

SPSS 17.0 was used for all statistical analyses. The distribution of the data were analyzed by the Shapiro-Wilk test and Mauchly’s Test of Sphericity performed. Descriptive statistics were calculated for the total sample (n = 45) and expressed as mean ± SD. An ANOVA with repeated measures was used to compare the four time points (T1, T2, T3, and T4) for salivary testosterone, CMJ, Yo-Yo intermittent endurance test, body mass, PHV, and height. Tukey’s HSD post hoc test was used if necessary. In the case of violation of the assumption of sphericity, the significance was established by utilizing the Greenhouse-Geisser correction. As results from ANOVA showed no significant differences between moments, data on each variable from the four distinct periods were averaged and a multiple linear regression analysis was conducted to estimate the relative contribution of testosterone levels, YPHV, and height by body mass interaction to variation in Yo-Yo and CMJ performance. Since height and body mass are highly related (24,25), residuals (individual values minus the mean) were used in the regression. A height by body mass interaction was calculated as the product of the residuals for height and body mass as proposed by Malina et al. (24,25). This method reduces the collinearity among the independent variables, thus these are considered more stable predictors of the dependent variables (24). The stepwise regression protocol was used.

Finally, as we were interested in determining the effect of testosterone concentration on physical performance, participants were divided into low and high testosterone groups according to the median-split technique. An independent t test was used to compare CMJ and aerobic performance between groups. The level of significance for all statistical analyses was set at $p \leq .05$.

Results

Descriptive statistics from the four individual assessments are presented in Table 1. No significant differences were observed for any assessed variables across the 4 assessments.
The results from multiple linear regression analysis showed that relative to CMJ performance, the model explained 42% of the variance ($R^2 = 42.88$). Salivary testosterone (sT) concentration was the primary contributor ($R^2 = 32.84$) and the PHV added 9.95% of the variance (Table 2).

Regarding the aerobic performance test, the model explained 28.50% of the variance. Running performance in the Yo-Yo test was explained solely by sT concentration ($R^2 = 21.32$). This was the only variable which attained a significant F to enter into the model (Table 2). A significant difference was observed to CMJ ($t = 3.35; p = .001$) between low and high testosterone groups, divided according to the median-split technique. However, the groups did not differ in Yo-Yo performance (Table 3).

### Table 1 Descriptive Statistics (mean± SD; SD) and Results From ANOVA Across the Four Assessed Time Points

<table>
<thead>
<tr>
<th>Variable</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>F (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testosterone (pg·ml⁻¹)</td>
<td>53.9 ± 44.3</td>
<td>50.6 ± 30.0</td>
<td>49.2 ± 30.5</td>
<td>58.6 ± 46.7</td>
<td>0.20 (0.67)</td>
</tr>
<tr>
<td>YPHV (years)</td>
<td>-2.2 ± 0.8</td>
<td>-2.1 ± 0.8</td>
<td>-1.9 ± 0.9</td>
<td>-1.9 ± 0.8</td>
<td>1.10 (0.34)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>154.9 ± 10</td>
<td>155.9 ± 10</td>
<td>157.7 ± 10</td>
<td>158.2 ± 10</td>
<td>1.10 (0.87)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>47.5 ± 9.9</td>
<td>48.7 ± 10.2</td>
<td>49.6 ± 10.6</td>
<td>49.6 ± 10.7</td>
<td>0.39 (0.75)</td>
</tr>
<tr>
<td>Body fatness (%)</td>
<td>15.9 ± 6.3</td>
<td>15.7 ± 6.6</td>
<td>16.2 ± 6.3</td>
<td>16.1 ± 6.3</td>
<td>0.15 (0.92)</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>35.4 ± 4.9</td>
<td>35.1 ± 5.0</td>
<td>35.9 ± 5.3</td>
<td>34.8 ± 5.2</td>
<td>0.35 (0.78)</td>
</tr>
<tr>
<td>Yo-Yo (m)</td>
<td>1626 ± 382</td>
<td>1752 ± 306</td>
<td>1747 ± 302</td>
<td>1658 ± 317</td>
<td>1.66 (0.17)</td>
</tr>
</tbody>
</table>

YPHV = years from peak height velocity; Yo-Yo = Yo-Yo intermittent endurance test—level 1; CMJ = Countermovement vertical jump.

### Table 2 The Main Predictors of Performance on CMJ and Yo-Yo

<table>
<thead>
<tr>
<th>Functional test</th>
<th>Predictor</th>
<th>$R^2$</th>
<th>$R^2$ change</th>
<th>$\beta$</th>
<th>$p$</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMJ</td>
<td>Salivary testosterone (sT)</td>
<td>32.84%</td>
<td>32.84%</td>
<td>0.41</td>
<td>&lt; 0.00</td>
<td>0.57 (CMJ and sT)</td>
</tr>
<tr>
<td></td>
<td>sT, YHPV</td>
<td>42.88%</td>
<td>9.95%</td>
<td>0.35</td>
<td>&lt; 0.00</td>
<td>0.54 (CMJ and YPHV)</td>
</tr>
<tr>
<td>Yo-Yo</td>
<td>Salivary testosterone (sT)</td>
<td>21.32%</td>
<td>21.32%</td>
<td>0.38</td>
<td>&lt; 0.00</td>
<td>0.46 (Yo-Yo and sT)</td>
</tr>
</tbody>
</table>

CMJ = Countermovement vertical jump; Yo-Yo = Yo-Yo intermittent endurance test—level 1
YPHV = years from peak height velocity; $r$ = Pearson correlations between predictors and CMJ and Yo-Yo.
The aim of the current study was to assess the contribution of salivary testosterone (sT) concentration, years from peak height velocity (YPHV) and anthropometric measures to variation in vertical height (countermovement vertical jump; CMJ) and aerobic performance (Yo-Yo intermittent endurance test; Yo-Yo) in elite preadolescent Brazilian soccer players. The major findings were that salivary testosterone concentration emerged as the main contributor of the variance for both aerobic and vertical jump performance. However, its role was more prominent in vertical jump performance which is an indicator of ability to perform explosive movements in the vertical plane. In the countermovement jump test (CMJ) the high-testosterone group performed significantly better than the low-testosterone group. Finally, the stability observed in salivary testosterone concentration across the investigation period revealed that both seasonality and training content did not affect sT concentration.

The role of hormonal status in influencing youth athletic performances is receiving increasing attention by the sport science community (4,9). Baldari et al. (2) highlighted its importance in youth sports, particularly in talent identification and long-term training processes. Di Luigi et al. (9) reported that chronological age may not correspond to biological age, and consequently large interindividual variability in many parameters such as pubertal stage, testosterone concentrations, among others, could be observed within the same category of athletes habitually selected according to chronological age. Di Luigi et al. (9) reported a significant relationship ($r = .33; p < .01$) between baseline salivary testosterone and chronological age in young soccer players (9–17 years, $n = 110$). However, the low coefficient of determination observed might indicate that variables other than chronological age require consideration thereby aiding in explaining the correlation with salivary testosterone.

The influence of testosterone concentration on physical performance may be associated with its role in mediating the development of the neuromuscular system as well as with short-term changes in neuromuscular capacity, in particular for explosive performance (8,38). The development of the nervous system seems to be strongly associated with performance in endurance and power (37) being mediated by hormonal changes. Testosterone also promotes neural growth, myelination and axonal conduction velocity (36). Indeed, as pointed out by Styne and Grumbach (14), the progressive secretion of the testicular sex hormones are responsible for the changes associated with biological, morphological and psychological dimensions occurring during puberty. Therefore, it seems that functional performance depends on the development status of the neuromuscular system, which in turn, might be

### Table 3 CMJ and Yo-Yo Performance to Low and High Testosterone Groups Divided According to the Median-Split Technique (Mean± SD)

<table>
<thead>
<tr>
<th></th>
<th>Low-testosterone group</th>
<th>High-testosterone group</th>
<th>$t$ value (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMJ (cm)</td>
<td>33.0 ± 4.7</td>
<td>37.4 ± 4.0</td>
<td>3.35 (p = 0.001)</td>
</tr>
<tr>
<td>Yo-Yo (m)</td>
<td>1659 ± 345</td>
<td>1731 ± 185</td>
<td>0.86 (p = 0.38)</td>
</tr>
</tbody>
</table>

CMJ = Countermovement vertical jump; YoYo = Yo-Yo intermittent endurance test—level 1
Testosterone and Performance in Soccer

related to the development of other systems (i.e., metabolic, cardiorespiratory) while being mediated by hormonal status.

Testosterone exerts anabolic actions upon muscle tissue, therefore contributing to muscle growth, and improving strength-related performance (7). Among its indirect anabolic actions, testosterone stimulates the secretion of other hormones such as growth hormone. As salivary testosterone is suggested to provide a better indication of bioavailable testosterone, that is potentially available to tissue in comparison with plasma testosterone concentration (1), the influence of salivary testosterone (sT) on changes in functional performance verified in the current study might be explained by its key role in mediating neuromuscular performance.

The present results add novel information to the literature concerning the role of the sT concentration on physical performance in preadolescent soccer players. At early gonadarche, the pulsatile release of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) leads to increases in testosterone concentration (33). In future studies, the assessment of these hormones at different time points during a day, could improve knowledge about their influence on testosterone release as well as biological maturation that could ultimately affect the physical performance of young soccer players.

The present study demonstrated a lack of seasonal differences for testosterone and that variations in training content (volume, intensity, and frequency) did not affect sT concentration. Despite the inclusion of a period of high-volume training (12-week preparatory training phase; preseason training), a 7-week competitive and also a 2-week detraining phase, we did not observe any significant alterations in sT levels. The possible explanation for the lack of fluctuation in sT concentrations across the investigated period despite changes in training content may be related to incomplete sexual maturation in the assessed soccer players. This explanation was proposed by Matchokc et al. (27) who also noted the absence of seasonal fluctuations of testosterone in a sample of boys and girls. Moreover, the lack of fluctuation in sT concentration in both the current study (athletic population) and the study of Matchokc and coworkers (nonathletic population) reinforces the notion that sT measures are relatively stable and thus are pertinent for monitoring hormonal status in this population.

In addition, the observations of Granger et al. (12) that sT is stable over time, are also in line with the present findings. The authors (12) stated that such stability over time influences the probability of detecting longitudinal associations between testosterone and outcome variables. However, we cannot rule out that interparticipant variation could partly explain the stability of the testosterone concentration. Large variability could reduce the likelihood to observe a statistical significance. Therefore, this issue should be addressed in future studies to corroborate or refute the hypothesis that the stability observed is actually due to incomplete sexual maturation in the assessed population and not an artifact of intraparticipant variability.

The role of free testosterone on physical performance in young soccer players has also been examined elsewhere. Despite lower amount of data in young athletes compared with adult populations regarding the role of free testosterone concentration in influencing athletic performance (4,9,30), a related study has demonstrated similar associations in young soccer players to those identified here. In a group of 66 Spanish soccer players aged between 10 and 14 years old, Gravina et al. (13), reported that salivary testosterone concentrations at the beginning of the season
were positively correlated with improvements in tests of countermovement jump and drop jump performance as well as an increase in relative VO$_{2\text{max}}$ during the season. A significant relationship ($r = .48$) between sT concentration at the beginning of the study and changes in CMJ was presented. The authors also demonstrated that the relationship between initial sT values and increments in relative VO$_{2\text{max}}$ ($r = .32$) was lower than verified to CMJ.

These results are partially in agreement with present findings. Following division of the groups according to low or high testosterone concentrations, we identified significant differences between groups regarding CMJ but not Yo-Yo performance. Moreover, the contribution of testosterone to explained variance in Yo-Yo for the whole group was lower than verified in CMJ. One could argue that the higher contribution from testosterone levels to CMJ performance can be related to it playing a more important role in strength/power-related performance compared with intermittent endurance type activities.

In contrast to the present findings and those observed by Gravina et al. (13), work by Baldari et al. (2) demonstrated no significant correlation between salivary testosterone concentrations ($r = .12$) and standing long jump performance in fifty-one players (10–14 years old) from two Italian soccer clubs. However, standing long jump length was positively and significantly correlated with salivary dehydroepiandrosterone (DHEA) concentrations ($r = .38$). Baldari et al. (2) speculated that the contrasting relationship between salivary DHEA and salivary testosterone concentration in relation to standing long jump performance could be explained, at least in part, by different concentrations in circulation during growth. The authors also suggested that their players could have had high DHEAS concentrations whereas high testosterone concentrations had not yet been reached.

In summary, the present observations show that hormonal status, notably testosterone levels, has a key role in determining the functional performance in young soccer players. Alterations in testosterone levels (increments) associated with pubertal development appear to be a reasonable predictor of variations in performance notably in power-strength related activities. These results could suggest that preadolescent players, in whom hormonal (testosterone) concentrations are elevated, could be favored in identification and selection schemes. Thus there is potential for sports science staff members to introduce systematic saliva sampling in training monitoring throughout the long-term talent selection and development process. The information could aid coaches in interpreting physical performance in elite preadolescent and adolescent soccer players. It is also important to highlight that in contrast to blood sampling, saliva sampling offers many benefits for assessing androgen hormones in young athletes. In contrast to the former, it is less-invasive and stress-free and thus repeated measurements can be performed (19).

The absence of seasonal fluctuations (6 months) of testosterone in preadolescent soccer players may indicate that monitoring sT could help researchers, support staff and coaching practitioners to understand and interpret appropriately the findings from studies in young athletes’ as well as changes in performance throughout the training process. As testosterone is very stable in preadolescent players, any significant changes in its concentration across the competitive season could predict variations in physical performance. Finally, it is important to highlight that the lack of changes in testosterone concentration across the four time points, might have contributed to the absence of any significant improvements in both CMJ and
Yo-Yo performance. These findings are partially in agreement with those in a recent study by Williams et al. (39). Despite observed changes in countermovement jump performance above the smallest worthwhile effect of 1.8% over a 6-month-interval, the authors did not demonstrate significant statistical differences across 6 months-intervals in performance in 12–13 year-old soccer players. They also demonstrated that there were no consistent differences between the rates of change observed during and outside the playing season in jump performance, and attributed these results to the prolonged development of motor coordination during childhood.

**Practical Applications**

In the current study, findings indicate a key role for hormonal status in interpreting physical performance in elite preadolescent soccer players. Boys who are advanced in terms of hormonal status might be at an advantage physically compared with peers. Sport science staff members and coaches could include salivary testosterone monitoring to track the hormonal status in young soccer players across the long-term training process. Greater knowledge about the relationship among hormonal status and physical performance could help to understand and interpret appropriately potential changes in performance throughout the training process. This approach based on the use in conjunction of testosterone concentration, YPHV, and anthropometric measures to interpret performance results may be useful in practical settings and could help to minimize the likelihood that talented young soccer players who are behind in biological maturity and less developed physically are not overlooked.

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