Testosterone Concentration and Lower Limb Power Over an Entire Competitive Season in Elite Young Soccer Players

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Abstract

Arruda, AFS, Aoki, MS, Freitas, CG, Spigolon, LMP, Francisco, C, and Moreira, A. Testosterone concentration and lower limb power over an entire competitive season in elite young soccer players. J Strength Cond Res 29(12): 3380–3385, 2015—The aim of this study was to investigate salivary T changes and its relationship with power performance over a 1-year competitive season in elite young soccer players. Soccer players were divided into 2 age categories (U15, n = 16 and U17, n = 23). A resting saliva sample was taken to determine T level, and power was assessed using the countermovement jump test with a bar of 30% of body mass on the athletes’ shoulders on 3 occasions (T1: beginning of the competitive season, T2: end of the regular season, and T3: end of the playoffs). There was a decrease in T concentration at the end of the competitive season (T3) as compared with the beginning of the season (T1) for both age categories (p ≤ 0.05). Conversely, power performance parameters were increased for both age groups (U15: mean power and relative mean power and U17: peak power, mean power, relative peak power, and relative mean power; p ≤ 0.05). No significant correlation was identified between the relative changes in T concentration and power performance in both groups. The findings of this study suggest that T changes and power changes are not related.

Key Words countermovement jump, fitness monitoring, hormones

Introduction

Adolescence refers to the transitional stage of physical and psychological human development that occurs between 12 and 18 years of age (15,22,28,29). During this period, major alterations in the endocrine system occur to modulate this maturational process (26). The activation of the hypothalamic-pituitary-gonadal (HPG) axis has a key role in the maturation of young boys, inducing progressive secretion of sex hormones, such as testosterone, which ultimately mediate the changes associated with the behavioral (1,23), biological, morphological, and psychological dimensions that occur during adolescence and, in particular, during puberty (2,19).

Testosterone (T) hormone stimulates anabolic processes, leading to muscle hypertrophy and strength-power gain (8,9). Therefore, a strong association between T concentration and neuromuscular performance should be expected. It is reasonable to assume that such association between T and both strength and power performance might occur during adolescence and adulthood.

In adult athletes, this relationship has been demonstrated for different athletic population. Cardinale and Stone (6) showed a significant relationship (r = 0.62) between T concentration and performance in countermovement jump (CMJ) for male soccer and handball players and sprinters. Similarly, Crewther et al. (10) also found a significant relationship between T concentration and speed over 10 (r = 0.48) and 20 m in rugby athletes (r = 0.56). Moreover, Nunes et al. (27) demonstrated a relationship between resting salivary T change and 1 repetition maximum (1RM) increment (bench press, r = 0.65 and half-squat, r = 0.64) after a periodized training plan in elite female athletes. However, Gorostiaga et al. (16) and Koundourakis et al. (21) did not demonstrate such relationships in young soccer players and professional soccer players, respectively. These findings highlight that the influence of T concentration on power performance in athletic population is not yet entirely clear.

Among the few studies that investigated the association between T and performance with young soccer players, Gravina et al. (18) reported that salivary T concentration at
the beginning of the season was positively correlated with an improvement in CMJ and drop jump performance in soccer players aged 10–14 years. Moreover, Moreira et al. (25) investigated soccer players aged 12.5 years and showed that salivary T concentration was the primary contributor to a model that explained 42.88% of the variance for CMJ performance. The authors also reported a significant difference between high and low T groups for CMJ performance. Although literature data have suggested that T concentration can affect performance, to date, there has been a lack of knowledge regarding the fluctuation of T concentration across a competitive season and the effect of this steroid hormone on power performance in elite adolescent soccer players. Therefore, the aim of this study was to investigate salivary T changes and its relationship with power performance over a 1-year competitive season in elite (under 15 [U15] and under 17 [U17]) soccer players. It was hypothesized that T concentration would influence power output during the competitive season.

Methods

Experimental Approach to the Problem

Resting saliva collection (to determine T concentration) and a vertical CMJ (to determine power, in watts) were performed on 3 occasions (February [T1], August [T2], and November [T3]) at the same time on each testing day. T1 was the beginning of the regular competitive season phase, T2 was the end of the regular competitive season phase, and T3 was the end of the playoff phase. The U17 group reached first place in the state championship, whereas the U15 group did not reach the finals. Saliva samples were collected at 7:00 AM at the team’s training facility after a 7- to 8-hour fast and at least 18 hours after the last bout of exercise. The assessed athletes were living and sleeping at the club’s training facilities. After saliva sampling, the athletes had breakfast, and approximately 90 minutes after that, anthropometric measures were obtained and the vertical CMJ test was performed. All individuals were familiar with the performance test and anthropometric procedures, which are habitually performed by the club’s coaches during the season. Regarding saliva collection, the individuals were familiarized with the procedures before the start of the investigation.

Subjects

Fifty young male soccer players, members of a Brazilian soccer club, voluntarily agreed to participate in the study. The assessed club has been participating in the main state and national leagues for these age groups (U15 and U17), achieving regularly the final rounds (finals and semifinals) of these championships. Two inclusion criteria were used to recruit subjects for this investigation: (a) the players were required to participate in at least 75% of the training sessions during the experimental period and (b) to complete all 3 assessments. Although 50 players initially took part in the study, data for 39 were actually considered because of nonavailability of 11 players. Therefore, the 11 players who had incomplete data were not included in the analysis.

Players were divided into 2 categories according to their chronological age: under 15 (U15: N = 16, age 14.8 ± 0.4 years, 1.5 ± 0.7 years from peak height velocity, height 170.6 ± 9.4 cm, body mass 64.9 ± 7.1 kg) and under 17 (U17: N = 23, age 16.3 ± 0.6 years, 2.6 ± 0.5 years from peak height velocity, height 178.9 ± 6.3 cm, body mass 70.6 ± 6.9 kg). These age categories were chosen because they are the first 2 categories of the assessed club participating in the official state and national championships in their respective age groups. These 2 categories are considered essential by club coaches and staff members to the long-term development training process. None of the 39 participants reported any injury or illness over the course of the study. All had been engaged in a formal and regular soccer training program for at least 12 months. The players participated, on average, in 16–17 hours of training per week (5–8 soccer training sessions, including small-sided games, 3–4 strength training sessions, and 1–2 conditioning sessions, including repeated sprints and intermittent running), and they played in 1 competitive match each week, the latter taking place on weekends. Training load and training volume did not change over the investigated period. Approximately, 70% of the training volume (time in hours) was composed of soccer training and conditioning sessions, including small-sided games, intermittent running, and repeated sprint bouts. The strength training intensity zone remained unchanged over the investigated period (12–15RM). In general, the lower body exercises were leg press (45°), half squat, adapted Olympic weightlifting exercises, and knee flexion and knee extension, whereas the upper body strength exercises were bench press, seated row, fixed pull-down, biceps curl, triceps kickbacks, adapted Olympic weightlifting exercises, and lateral and forward dumbbell raises.

After approval by the local university research ethics committee, the experimental protocols were explained in detail to the subjects. Written informed consent was obtained from each participant and their respective parents or guardians.

Saliva Collection and T Assessment

Saliva samples were collected with the subject in the 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-minute period. The saliva samples were then stored at −80°C until assayed for T. Salivary T concentration was measured in duplicate using an enzyme-linked immunosorbent assay (T expanded range kit; Salimetrics State College, PA, USA), according to the procedure adopted by Moreira et al. (25). The average intra-assay coefficient of variation for the T assay verified in the present analysis was 4.2%. The minimum detection limit for the T assay, in accordance with the manufacturer, was 21 pmol·L⁻¹.
Power Assessment
Power was assessed using the CMJ test with a bar of 30% of body mass on the athletes’ shoulders. The CMJ required subjects to start in a standing position with 30% of their body mass load on the shoulders (free bar). The participants lowered themselves from this initial standing position to a self-selected squat position and performed a vertical jump keeping their hands placed firmly on the bar. Although no restrictions were placed on the knee angle attained during the eccentric phase of the jump, subjects were instructed to maintain their legs straight during the flight. The mean power during each repetition of the CMJ was obtained using the Encoder Linear Peak Power 4.0 instrument (CEFISE, São Paulo, Brazil). The equipment allows an electronic recording of the bar displacement, which is converted digitally and transferred to the computer. The displacement is recorded in millimeters, and the time, in microseconds (1 × 10⁻⁶ seconds), is recorded with a chronometer. The software analyzes load, time, and displacement to calculate velocity, acceleration, and power. These calculations are performed for the concentric phase only. Before the measurements, the equipment was calibrated using a known distance used as reference for all other displacements. Although the jumping methods in this study were rigorously controlled, slight variations in jumping technique and squat angle position between athletes because of the self-selected squat position may create differences in the power estimations. However, as all assessed players were largely familiarized with the technique and with the jumping procedures, it was assumed that the influence of these possible differences was minimal. The reliability of this equipment calculated by the intraclass correlation coefficient is 0.95, and power is calculated using standard procedures validated earlier (3).

Anthropometric Measures
Anthropometric measures included height, body mass, sitting height, and leg length. Body mass was measured using a digital platform scale (Welmy, São Paulo, Brazil), calibrated, graduated from 0 to 150 kg and with precision of 0.1 kg; sitting height was measured with a vertical stadiometer, 210 cm long and with 0.1 cm precision (Welmy, São Paulo, Brazil). Maturity status was assessed according to the methods described by Mirwald et al. (24). This approach has been proposed as a somatic maturity indicator and predicts the time before or after peak of height velocity (PHV) from measures of age, height, body mass, sitting height, and leg length. Thus, a maturity age of +1.0 indicates that the participant was measured 1 year after attaining peak velocity. All assessed players were measured after their PHV.

Statistical Analyses
SPSS 17.0 (Version 10.0; SPSS, Chicago, IL) was used for all statistical analyses. Data normality was assessed by visual inspection and analyzed by the Shapiro-Wilk test. The Mauchly’s test of sphericity was performed. Descriptive statistics were calculated and expressed as mean ± SD. A 2-way analysis of variance (ANOVA) with repeated measures was used to compare groups (U15 and U17) and time points (T1, T2, T3) for salivary T, peak power, and mean power (absolute and relative values). Another 2-way ANOVA with repeated measures was used to verify changes (relative changes) in these measures for each time interval (T1–T2, T2–T3, T1–T3). In case of significant F values, a Tukey’s honestly significant difference (HSD) post hoc test was used for multiple comparison purposes. In the case of violation of the assumption of sphericity, the significance was established using the Greenhouse-Geisser correction. The relationships

| TABLE 1. Testosterone, PP, MP, RPP, and RMP for both groups (U15 and U17) during the study period.*† |
|-----------------|-----------------|-----------------|-----------------|
|                 | T1              | T2              | T3              |
| **Under 15**    |                 |                 |                 |
| T (pmol L⁻¹)   | 616 ± 153       | 545 ± 151       | 441 ± 138§      |
| PP (W)          | 3,971 ± 673     | 4,252 ± 640     | 4,264 ± 515     |
| MP (W)          | 2,469 ± 495     | 2,670 ± 418     | 2,881 ± 456‡    |
| RPP (W Kg⁻¹)   | 63.3 ± 8.5      | 64.6 ± 6.9      | 64.7 ± 5.4      |
| RMP (W Kg⁻¹)   | 39.4 ± 7.0      | 40.6 ± 5.1      | 43.7 ± 5.7†     |
| **Under 17**    |                 |                 |                 |
| T (pmol L⁻¹)   | 775 ± 177§      | 665 ± 179§      | 611 ± 203§      |
| PP (W)          | 4,640 ± 742§    | 4,953 ± 513§    | 5,033 ± 496§    |
| MP (W)          | 2,878 ± 513§    | 3,445 ± 580§    | 3,217 ± 403§    |
| RPP (W Kg⁻¹)   | 64.0 ± 8.4      | 68.0 ± 6.4†     | 69.2 ± 5.8§     |
| RMP (W Kg⁻¹)   | 39.6 ± 5.1      | 47.1 ± 6.4      | 44.2 ± 5.1†     |

* T = testosterone; PP = peak power; MP = mean power; RPP = relative peak power; RMP = relative mean power.
† Values are presented as mean ± SD.
§ Significantly different from T1 (p ≤ 0.05).
‡ Significantly different from U15 for the same time point (p ≤ 0.05).
between the change in T concentration and the change in power measures (pooled data from the 3 time intervals) were verified using Pearson’s product-moment correlation. The level of significance for all statistical analyses was set at $p \leq 0.05$. Observed statistical power was above 0.92 for all dependent variables (G*Power program was used to perform statistical power analysis).

**RESULTS**

Table 1 shows the descriptive data regarding both age groups (U15 and U17). Higher T concentration and power performance were observed for the U17 players when compared with the U15 players ($p \leq 0.05$). There was a decrease in T concentration at the end of the competitive season (T1) compared with the beginning of the season (T1) for both age categories (U15 and U17; $p \leq 0.05$). At the end of the competitive season (T3), power performance parameters were increased for both age groups (U15: mean power and relative mean power and U17: peak power, mean power, relative peak power, and relative mean power) when compared with the beginning of the season (T1).

Figure 1 shows the relative change (%) in T concentration. Significant differences were detected between time intervals ($F = 3.87, p = 0.025$). There was a relative decrease (%) in T at the end of the competitive season (T3), compared with T1 and T2, as well as between T1 and T2 for both age groups.

Figure 2 shows the relative change (%) in peak power (Figure 2A) and mean power (Figure 2B). Significant relative changes in peak power ($F = 7.8, p = 0.01$) and mean power ($F = 5.85, p = 0.005$) were observed for time periods. A relative increase (%) in power performance (peak power and mean power) from T1 (beginning of the competitive season) to T3 (end of the competitive season) was verified for both groups ($p \leq 0.05$). There was also a significant relative increase in power performance (peak power and mean power) from T1 to T2 for the U15 and U17 groups ($p \leq 0.05$).

**Relationship Between Changes in T Concentration and Power Measures**

No significant correlation ($p > 0.05$) was identified between relative change in T concentration and change in power performance (peak power and mean power) for either the U15 or U17 group.

**DISCUSSION**

The main aim of this study was to examine salivary T changes and to verify whether salivary T concentration could affect power performance over an entire season in elite young soccer players from the 2 age categories (U15 and U17). The results corroborate the expected higher T concentration and greater power performance for U17 compared with U15 players. However, contrary to the initial hypothesis, despite the decrease in T concentration, there was an evident increase in exercise (power) performance over the investigation period for both the U15 and U17 groups. Therefore, the influence of T concentration on power performance in elite young soccer players is not entirely clear, based on the results of this study.

The assumption that T concentration might influence power performance in young soccer players was based on previous studies conducted on young and adult athletes and on the well-known effect of T in mediating adaptive training responses (6,11,13). Moreover, considering that HPG axis activation induces progressive secretion of testicular sex hormones, and mainly T, which are important for the changes associated with behavioral (2), biological, morphological, and psychological aspects during puberty (19), it seemed reasonable to assume that the alteration in this hormone concentration might affect explosive-type performance. Nevertheless, the
results presented here neither corroborate the initial hypothesis nor are in line with findings from those few studies conducted with young soccer players in which associations between T concentration and performance were demonstrated (18,25).

It is also important to mention the absence of a correlation between the alteration in T concentration and the changes in power performance observed in this study. This result seems to be in line with others that also did not demonstrate such relationships. For instance, recently, Koundourakis et al. (21) examined the effects of 3 training programs on androgen level (total testosterone, free testosterone, and 3a-androstane-diol-glucuronide [3a-Diol-G]) and performance parameters in adult male professional soccer players. The players were assessed in 3 occasions over a period of 42 weeks. Despite the improvement detected in all performance parameters, including CMJ, squat jump, and sprint times (10 and 20 m), the authors did not report a significant correlation between change in performance and any circulating androgen concentration throughout the study. Moreover, Gorostiaga et al. (16) investigated 21 young soccer players during an 11-week training period with respect to the load-vertical jumping curve (0–70 kg) and other performance measures, as well as with respect to serum T (total and free T) and cortisol concentrations. These researchers reported no significant change in serum concentration of free T regardless of the experimental group (strength training group vs. the control group) and also detected no correlation between individual change in explosive strength and individual change in serum T concentration from week 0–11 in either group. The present results, taken together with those from the aforementioned studies, suggest that change in performance, even for explosive-type actions (e.g., vertical jumps), may not be directly associated with alteration in T concentration among both adult and young team-sport athletes. One possible explanation for this finding could be the increased neuromuscular activation needed to maintain the power output because of reduction in the T concentration. Bosco et al. (4) reported a negative relationship between the T concentration and the electromyographic/power ratio during the half-squat test in track and field female and male sprinters after a strength training session. These researchers suggested that the decrease in T verified after the training session required an “additional” activation to maintain the power output. Despite the differences between the study conducted by Bosco et al. (4) and the current investigation regarding experimental design (acute responses vs. chronic response) and samples (adults vs. young athletes), the results from these studies suggest that power output in trained athletes may be associated with a complex interaction between hormonal profile and neuromuscular activation in which changes in 1 feature (i.e., decrease in T concentration) might result in a compensatory effect (e.g., increase in the other feature—EMG) as a mechanism to maintain the required level of power performance because both hormonal and neuromuscular factors may influence such performance.

The observed reduction in T concentration in both the U15 and under U17 groups over the study period could be attributed to variation in the training content and perhaps could be related to an inappropriate balance between stress and recovery (5,14,20). Previous studies have shown that the training period during the competition season may decrease resting plasma T concentration (22). In particular, Elloumi et al. (12) demonstrated a reduction of 15% in salivary T concentration in a group of adult rugby-trained males during the competitive season. These findings are in agreement with other studies that investigated adult team-sport athletes, which also found a decrease in T concentration after periods of intensified training load and during periods of prolonged competition (7,14).

Another possible factor that should be considered for the interpretation of the decrease in T concentration observed during this study is related to seasonal variations. The stability of salivary testosterone level over time influences the probability of detecting longitudinal associations between this androgen hormone and outcome variables (17). Therefore, the influence of the time of the year (seasonal variations) in T level alteration across a competitive season should be considered. Even taking this possibility into account, it is worth noting that previous studies have demonstrated a lack of fluctuation in T concentration because of seasonal alterations (22), including a study on pubertal boys and girls (17) and preadolescent male soccer players (25). Thus, it is unlikely that the decrease of salivary T concentration verified in this study was associated with instability of this hormone because of seasonal variation.

In summary, the current results showed that the T concentration and power performance outcomes did covary negatively over time in both U15 and U17 age groups. As expected, higher T concentration and greater power performance for U17 compared with U15 players were demonstrated. Nevertheless, the present findings do not allow us to make generalizations regarding the effect of T concentration on power performance in this population, as this is not entirely clear, based on current results. Even recognizing that T has a role in the power performance of young soccer players (18,25), the findings of this study suggest that other factors are involved in the ability of the young soccer players to produce power during explosive-type movements, such as the CMJ. Future studies should aim to investigate the influence of other factors on power measures among young soccer players.

**Practical Applications**

Taking into account the current findings in conjunction with results from the previous studies, coaches and staff members working with adolescent soccer players could consider the use of both T response and power performance, over the training season, in parallel to psychometric tools to optimize the training monitoring and to adjust the training program in an individualized level. As the findings of this study suggest
that other factors than T concentration alteration are involved in the ability of the young soccer players to produce power during explosive-type actions, strength and conditioning coaches should adopt a holistic approach for monitoring training to understand the long-term training process of young athletes.

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REFERENCES