**Research Article**

**Associations between Testosterone, Body Composition, and Performance Measures of Strength and Power in Recreational, Resistance-Trained Men**

**Jones MT1, Jagim AR2 and Oliver JM3**

**Abstract**

The objective of the current cross-sectional study was to determine whether relationships existed between testosterone (TEST), back squat (BS) one-repetition maximum (1RM), body composition, and power-oriented tests of jumping ability in recreational, resistance-trained males. Twenty-nine men (mean ± SD: age 26.2 ± 4.5 years; height 176.6 ± 6.9 cm; weight 84.7 ± 11.7 kg; 15.2 ± 6.3 % body fat) participated. Total TEST, body composition, SLJ, CMVJ, and BS 1RM were assessed. Lower body power output was calculated from body mass and CMVJ height. Bivariate (Pearson) correlations were computed to determine significance (p=0.05). The 1RM BS-to-body-mass ratio was 1.80 ± 0.2. Total TEST was 34.3 ± 10.2 nmol/L. There were correlations between lean mass (LM) and peak power (r=0.48; p=0.01), LM and BS 1RM (r=0.64; p=0.001), BS 1RM and peak power (r=0.70, p<0.001), and CMVJ and SLJ (r=0.57, p=0.001). There were no correlations between TEST and performance measures (SLJ, r=-0.03; CMVJ, r=-0.18; 1RM BS, r=-0.21). Total TEST levels are not correlated with performance measures of lower body strength and power in this population; however, BS 1RM is correlated with lower body power and LM. TEST cannot be used to predict select measures of performance in a cross-sectional sample of recreational lifters, but consistent adherence to recreational resistance training may have a positive effect on SLJ and CMVJ performance.

**Keywords:** Back squat; Body composition; Countermovement vertical jump; Hormones; Maximal strength; Standing long jump

**Introduction**

Hormones play a key role in the maintenance of physiological processes within the body and can have a significant impact upon performance and training adaptations [1]. In regard to athletic performance, anabolic hormones are of primary interest due to their role in promoting the growth and maintenance of skeletal muscle [1-3]. Testosterone (TEST), the primary male hormone, is generally regarded as the principal anabolic hormone in terms of its growth promoting effects. A number of studies have demonstrated that higher TEST levels may augment resistance training [2-4]; therefore, TEST is often investigated in regard to its effects on training adaptations over time. Evidence has suggested that ratios of specific biomarkers, such as TEST to cortisol or TEST to sex-hormone binding globulin (SHBG) may reflect the overall training status or anabolic environment of an athlete, and thereby could be used to determine an athlete’s readiness to train [5-7]. For example, one longitudinal study reported a positive relationship between changes in the TEST to SHBG ratio and muscular strength in elite weight lifters engaged in a year-long strength training program [8].

The exact mechanism of the relationship between TEST and acute measures of strength and power is not well understood; however, it has been postulated that TEST may influence the transmission speed of certain central and peripheral neuromuscular pathways [9,10]. As evidence, recent studies have demonstrated that TEST levels are correlated with performance measures of lower body strength, power, and speed in elite athletes [6,10-12], and thus, may be used to predict certain measures of performance [13]. For example, Cardinale et al. [10] reported a relationship (r=0.61, p<0.001) between countermovement jump and TEST in a cross-sectional study of elite athletes and, therefore, concluded that TEST plays an important role in neuromuscular function. Additionally, Crewther et al. [6,10] performed repeated measures of baseline levels of salivary free TEST in elite, resistance-trained rugby athletes, who were classified into groups based upon back squat one-repetition maximum (1RM). The authors reported strong correlations between TEST levels and back squat 1RM (r=0.92, p<0.01), and TEST levels and sprint speed (r=-0.87, p<0.01) in athletes with a 1RM squat >2.0 times their body mass. No relationships were observed in those with a 1RM squat <1.9 times their body mass, prompting the authors to suggest that free TEST is a strong predictor of performance measures of speed and strength in elite athletes with high strength levels. Thus, the relationship between TEST and performance may only be present in those above a specified strength threshold.

The ability to predict certain performance outcomes using simple tests or measurements can be beneficial to athletic development staff and exercise practitioners. Indices of lower body strength, such as the squat, have been shown to correlate with lower body power-oriented tests of jumping ability and speed, and, therefore, may offer a convenient method of predicting lower body power [14-17]. However, a biochemical marker, like TEST, may provide a more detailed description of an individual’s training status, and thus, serve as a stronger predictor of performance [10]. Whereas previous studies suggest a relationship exists between TEST and performance tests, all were conducted in elite level athletes at specific times in competition. Elite athletes follow sport-specific regimens and are involved in regular activities with definite neuromuscular demands. While these assessments may provide insight into the training status of an individual, levels of fatigue, and/or their potential performance outcomes [18], their relationship to TEST in recreational, resistance-trained men has been undocumented. Therefore, the purpose of the current cross-sectional study was to determine whether or not a significant relationship existed between TEST, back squat 1RM, body composition, and power-oriented tests of horizontal and vertical jumping ability in recreational, resistance-trained males.
Methods

Experimental approach to the problem

This study was designed to determine whether or not a relationship existed amongst measures of muscle mass, strength, power, and resting TEST. Twenty-nine men from a mixed training background with ≥ 1 year of resistance training experience, specifically with the back squat exercise were recruited. In a single session, blood samples were obtained for determination of TEST, followed by body composition assessment, and performance tests of lower body strength and power-oriented jumping ability. Correlational analyses were performed to assess the relationship amongst the measures of muscle mass, strength, power, and TEST.

Participants

Twenty-nine apparently healthy males between the ages of 20 and 35 (mean ± SD age 26.2 ± 4.5 years; height 176.6 ± 6.9 cm) were recruited based upon their current resistance training experience. As such, all participants were required to have ≥ 1 year resistance training experience to include the back squat, and be actively participating in a structured resistance training program to include the upper and lower body ≥ 1 day per week. Further inclusionary criteria included having a back squat 1RM to body mass ratio of ≥ 1.5. Those taking thyroid, androgenic, or other medications known to affect endocrine function or consumption of ergogenic levels of insulin-like substances or anabolic/catabolic pro-hormones within the previous 6 months were excluded from participation. The Human Subjects Committee of the Institutional Review Board at Texas Christian University approved this study. All participants signed an approved informed consent.

Testing protocol

All testing was done on a single day. In keeping with previously published methods, participants arrived to the laboratory following an overnight fast (>8 hours) and within 2 hours of waking [10]. Upon arrival to the laboratory, body composition was determined followed by the collection of a blood sample for determination of total TEST. Participants were then allowed to eat a light snack up to fifteen minutes prior to a standard warm-up and performance of standing long jump, countermovement vertical jump, and one-repetition maximum back squat.

Body composition: Body height and mass were determined to the nearest 0.5 cm and 0.1 kg, respectively; using a stadiometer and self-calibrating digital scale (Seca; Chino, CA) with participants in socks or bare feet. Body mass was subsequently measured in shoes for use in calculation for conversion of countermovement vertical jump distance to peak and average power in Watts. Body density was calculated for determination of body fat and lean mass according to previously described procedures [19] from seven site skin fold using Lange® skin fold calipers.

Testosterone analysis: Following body composition measures, participants were seated quietly in a phlebotomy chair. A blood sample was taken from the antecubital fossa region via venepuncture using standard sterile phlebotomy techniques. Blood was collected into a 7-mL vacutainer tube containing no additive (BD Biosciences; San Jose, CA). Samples were allowed to coagulate in cooling beads for ≥30 minutes, and subsequently centrifuged at 2,500 rpm for 10 minutes (Beckman Coulter Allegra X-12, Beckman Coulter; Brea, CA). After centrifugation, serum was subsequently removed and stored in aliquots at -80°C for later analysis. Total TEST was analysed via radioimmunoassay (RIA; Siemens, Washington, D.C.). All samples were run in duplicate on an ISO Data 100 gamma counter (Tritertek; Pforzheim, Germany). The coefficient of variation for the assay was 4.8%.

Performance tests

Standing long jump: Prior to performance tests, all participants completed a ten-minute warm-up consisting of four minutes of stationary cycling followed by six minutes of dynamic body weight exercises targeting the lower body. Determination of power-oriented horizontal jumping ability was assessed by the standing long jump (SLJ), a test that has been shown to correlate with other explosive movements [20]. Research personnel demonstrated proper form prior to performance. Two trials of less than maximal effort were allowed prior to data recording. Participants began with their toes on a marked line corresponding to the 0-cm mark of a measuring tape affixed to the floor. In an explosive movement with an arm swing, participants propelled forward landing alongside the measuring tape. After performance of the SLJ, the distance from the 0-cm mark and the rearmost heel strike was measured. If a participant fell backwards, the trial was repeated [20]. Three trials were performed separated by two minutes rest. If the third attempt was greater than the first two, another attempt was allowed until a decrease in jump distance was observed with no more than five maximum SLJ allowed. The furthest distance was recorded for subsequent analysis.

Countermovement vertical jump: Approximately five minutes after conclusion of the SLJ test, the determination of power-oriented vertical jumping ability was assessed by the countermovement vertical jump (CMVJ) with an arm swing. Body mass was recorded in the shoes used to perform the CMVJ. Reach height and jump height were recorded using a commercially available Vertec system (Sports Imports, Columbus, OH, USA). Research personnel demonstrated proper CMVJ form using an arm swing prior to the participants’ performance of two submaximal CMVJs. Approximately two minutes later, three maximum effort CMVJs were then recorded separated by two minutes rest. If the third attempt was greater than the first two, another attempt was allowed until a decrease in jump height was observed with no more than five maximum CMVJ allowed. The maximum attempt of record was later converted to peak and average mechanical power using previously published equations [21].

Back squat one-repetition maximum (1RM): Lower body strength was assessed during the back squat 1RM exercise approximately five minutes after completion of the CMVJ test. The researcher determined the progression strategy for the 1RM from each participant’s self-reported maximal value. Two warm up sets of 5 repetitions at 40–60% 1RM separated by two minutes rest were followed by a three minute rest period and one to two sets of 2-3 repetitions at a load corresponding to 60-80% 1RM. Participants then began performing sets of 1 repetition of increasing weight for determination of 1RM. Three to five minutes rest was provided between each successive attempt. All 1RM determinations were made within 3-5 attempts. Participants were required to reach top of the thigh parallel in the 1RM for an attempt to be considered successful as determined by laboratory personnel providing a verbal “up” command. The intra-class correlation coefficient and Pearson product-moment coefficient (r) for this method of 1RM determination has been previously reported to be 0.99 and 0.001, respectively, in a group of trained males [22].
Statistical analyses

Descriptive statistics (mean ± SD) were computed for all measures of physical characteristics, performance tests, and total TEST. Bivariate (Pearson) correlations were computed to determine significant relationships among variables of interest. Alpha was set at p ≤ 0.05 for statistical significance. The magnitudes of correlations were defined according to Cohen [23]. All analyses were performed using the Statistical Package for the Social Sciences (SPSS, Version 21.0; SPSS Inc., Chicago, IL).

Results

Descriptive statistics

The participants’ physical characteristics, performance test scores, and total TEST values are presented in Table 1. The 1RM BS-to-body-mass ratio was 1.81 ± 0.20, and when expressed relative to lean body mass the 1RM BS-to-lean-body-mass ratio was 2.12 ± 0.24.

Interrelationships among measures and tests

Table 1: Descriptive Statistics for Physical Characteristics, Performance Tests, and Total Testosterone.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Mass (kg)</td>
<td>84.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>15.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Lean Body Mass (kg)</td>
<td>70.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Back Squat 1RM (kg)</td>
<td>152.8</td>
<td>21.6</td>
</tr>
<tr>
<td>Countermovement Vertical Jump (cm)</td>
<td>61.2</td>
<td>9.1</td>
</tr>
<tr>
<td>Standing Long Jump (cm)</td>
<td>240.7</td>
<td>25.7</td>
</tr>
<tr>
<td>Average Power (Watts)</td>
<td>3175.9</td>
<td>474.0</td>
</tr>
<tr>
<td>Peak Power (Watts)</td>
<td>5971.8</td>
<td>917.5</td>
</tr>
<tr>
<td>Testosterone (nmol/L)</td>
<td>34.3</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Note: All data represent mean ± SD. N=29, except % Body Fat and Lean Body Mass, N=26

Abbreviations: BS: Back Squat

Bivariate (Pearson) correlations were computed among physical characteristics, performance tests, and total TEST. A significant, moderate negative correlation was observed between SLJ and % body fat (r= -0.40; p=0.04); while moderate positive correlations were observed between lean body mass and average power (r=0.43; p=0.03), and lean body mass and peak power (r=0.48; p=0.01). Lean body mass exhibited a significant strong correlation with back squat 1RM (r=0.64; p=0.001). The SLJ and CMVJ performance tests exhibited a strong correlation (r=0.57; p=0.001). Significant strong correlations were also found between CMVJ and average power (r=0.74; p=0.001), and CMVJ and peak power (r=0.71; p=0.001). Significant strong correlations were also determined between peak power and back squat 1RM (r=0.70; p=0.001), and average power and back squat 1RM (r=0.67; p=0.001) (Table 2).

Table 2: Correlations between Measures of Body Composition, Performance, and Total Testosterone.

<table>
<thead>
<tr>
<th>Measure</th>
<th>% Body Fat</th>
<th>Lean Body Mass</th>
<th>SLJ Distance</th>
<th>CMVJ Height</th>
<th>Average Power (Johnson)</th>
<th>Peak Power (Johnson)</th>
<th>Back Squat 1RM</th>
<th>Testosterone</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Body Fat</td>
<td>r</td>
<td>P</td>
<td>n</td>
<td>r</td>
<td>P</td>
<td>n</td>
<td>r</td>
<td>P</td>
</tr>
<tr>
<td>Lean Body Mass</td>
<td>-0.01</td>
<td>0.98</td>
<td>26</td>
<td>-0.40</td>
<td>0.04*</td>
<td>26</td>
<td>0.351</td>
<td>0.37</td>
</tr>
<tr>
<td>SLJ Distance</td>
<td>-0.08</td>
<td>0.72</td>
<td>26</td>
<td>-0.07</td>
<td>0.26</td>
<td>26</td>
<td>0.43</td>
<td>0.03*</td>
</tr>
<tr>
<td>CMVJ Height</td>
<td>0.57</td>
<td>0.10</td>
<td>29</td>
<td>0.32</td>
<td>0.08</td>
<td>29</td>
<td>0.33</td>
<td>0.08*</td>
</tr>
<tr>
<td>Average Power (Johnson)</td>
<td>0.74</td>
<td>0.01*</td>
<td>29</td>
<td>0.71</td>
<td>0.01*</td>
<td>29</td>
<td>0.22</td>
<td>0.01*</td>
</tr>
<tr>
<td>Peak Power (Johnson)</td>
<td>0.99</td>
<td>0.01*</td>
<td>29</td>
<td>0.67</td>
<td>0.01*</td>
<td>29</td>
<td>-0.18</td>
<td>0.36</td>
</tr>
<tr>
<td>Back Squat 1RM</td>
<td>0.70</td>
<td>0.01*</td>
<td>29</td>
<td>0.70</td>
<td>0.01*</td>
<td>29</td>
<td>-0.22</td>
<td>0.26</td>
</tr>
<tr>
<td>Testosterone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.21</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Note: * Significant at p ≤ 0.05

Abbreviations: SLJ: Standing Long Jump; CMVJ: Countermovement Vertical Jump; r: Pearson (bivariate) correlation; n: sample size; p: level of significance

Discussion

The purpose of the current cross-sectional study was to determine whether or not a relationship existed between basal levels of total TEST, back squat 1RM, body composition, and power-oriented tests of horizontal (SLJ) and vertical jumping (CMVJ) ability in recreational, resistance-trained males. The main finding of the present study is that baseline total TEST levels are not correlated with performance measures of lower body strength and power in this population. Despite no observed relationship between TEST and performance, the findings from the current study in regard to relationships between measures of strength, power and body composition are in support of previously published findings. Lean body mass was strongly associated with lower body strength (r=0.64) and moderately associated with peak power (r=0.48). Previous
research has reported similar relationships in both trained [24,25] and untrained [26,27] individuals. Nicolaidis et al. [28] reported an inverse relationship between field tests of lower body power and body fatness in adolescent male team handball players. Likewise, when researching the effects of body composition and body mass index on muscle power in soccer athletes, Nicolaidis et al. [29] reported an inverse relationship between body fatness and mean power during the Wingate test. Thus, the results of the current study are in support of those previously reported in a variety of populations.

In agreement with previous studies in a variety of populations [16,30,31], we observed a significant correlation between lower body strength and lower body peak power as determined by CMVJ (r=0.70). A strong relationship was reported between maximal strength and power in professional rugby players [30]. Similarly, a significant correlation was observed between back squat 1RM and squat-jump power in recreationally trained males [16]. Further, the power-oriented performance tests of vertical (CMVJ height) and horizontal jumping ability (SLJ distance) were correlated (r=0.57; p=0.001), a relationship that has been previously demonstrated in preadolescent boys (r=0.73; p=0.01) [20] and male physical education majors (r=0.69; p=0.01) [32].

A novel and noteworthy aspect of the current study is the lack of any relationship between TEST and all measures of muscular strength, power, and body composition. The results of the current study are in direct contrast to those studies in which a relationship between TEST, strength, and power has been reported in elite strength and power athletes [6,10,11,33,34]. As previously noted, elite athletes follow sport-specific regimens and are involved in regular activities with definite neuromuscular demands. The subjects in the current study were recreational, resistance-trained men who were not following the same collective training protocol, and were likely of a more heterogeneous nature than elite athletes. Although experienced (≥ 1 year of back squat experience) recreational lifters, it is unlikely that the majority of the training performed by the subjects in this study focused on a goal of strength and power development. Further, some studies have demonstrated a link between macronutrient intake and TEST [35]. While not disclosed in those previous studies, elite athletes typically represent a homogenous group in terms of training, and often in terms of diet. Although dietary recall was not part of the present study it is a fair assumption that our participants were following a range of different diets and this may have affected the outcome.

It is recognized that power is related to neuromuscular adaptations and fibre type transitions as a result of training [36]. The previously cited research, of which a relationship between TEST and lower body power was observed, utilized larger elite athletes who were training for strength and power development [6,11,34] with considerably greater 1 RM back squat (210.5 ± 15.2 vs. 151.9 ± 21.8) and 1RM squat/body mass ratios (2.15 ± 0.12 vs. 1.8 ± 0.2) compared to subjects from the current study [6]. Previously published results, in which strong correlations between TEST levels and back squat 1RM were observed only in those elite athletes who were able to squat >2.0 times their body mass, lend support to the possibility that the relationship between TEST and performance may only be present in those individuals above a specified strength threshold [6]. Inclusionary criteria for the current study consisted of having a back squat to body mass ratio of ≥ 1.5, and the mean ratio for the twenty-nine participants was 1.8.

Training results in inconsistent, chronic changes in TEST levels and as a result may be a better indicator of the acute state of the body rather than long term training status Kraemer [1]. It is interesting to note that the TEST levels in the current study (9.9 ± 2.9 ng/ml) were higher than those observed in elite male volleyball, track and field, soccer and handball athletes (6.49 ± 0.37) [10], and elite male weightlifters (7.2 ± 2.1) [37]. It is possible that the elevated TEST levels we observed are a result of higher training volumes as higher TEST levels have been associated with higher training volumes and appear to increase concurrently with increases in training volume [8,38]. The total training volume and load of the participants in the present study...
was unknown and, consequently, an inherent limitation of the study. However, based upon self-reported training styles, it may be assumed that the majority of the participants in the present study were training with the goal of muscle hypertrophy and therefore, may have been utilizing a high training volume.

Previous research has shown muscle hypertrophy training to cause a shift in muscle fibre types to a more oxidative isoform (i.e. Type IIx to Type Ila) [39,40], which may reduce the power producing capabilities of the muscle [41,42]. Furthermore, a review of resistive exercise and muscle fibre adaptations indicated that bodybuilders, who typically utilize training programmes designed to elicit muscle hypertrophy, have a higher percentage of Type I fibres than Type II fibres, which is counter to ratios reported in both competitive weightlifters and power lifters [40]. It is conceivable that a training programme designed to promote muscle hypertrophy, as was likely used by many subjects in the present study, may have diminished the potential for a relationship between TEST and indices of lower body strength and power.

The lack of positive relationship between total TEST and the measures of back squat 1RM, CMVJ, SLJ, and lower body power suggests that TEST is not a valid indicator of lower body strength and power in a cross-sectional sample of recreational, resistance-trained men. However, it appears as though lower body strength and lean body mass may serve as predictors for lower body power. Further research is needed in this area to identify if long-term changes in the hormonal profile of recreational lifters may determine various parameters of athletic performance or identify the training status of an individual.

Conclusion

The results of the current study suggest lower body strength is correlated with lower body power output in trained, recreational lifters. Further, a relationship exists between body composition (i.e., lean body mass) and measures of strength and power. However, the positive relationship between TEST and jumping ability previously shown in elite athletes was not observed in the recreational athletes in the current study. Based on the results of the present study it does not appear that TEST can be used to predict select measures of performance in a cross-sectional sample of recreational weight lifters. However, consistent adherence to recreational resistance training may have a positive effect on standing long jump and countermovement vertical jump performance.

References


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