Journal of Strength and Conditioning Research, 2007, 21(2), 354–361

THE EFFECT OF SHORT-TERM USE OF TESTOSTERONE ENANTHATE ON MUSCULAR STRENGTH AND POWER IN HEALTHY YOUNG MEN

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ABSTRACT. Rogerson, S., R.P. Weatherby, G.B. Deakin, R.A. Meir, R.A. Coutts, S. Zhou, and S.M. Marshall-Gradisnik. The effect of short-term use of testosterone enanthate on muscular strength and power in healthy young men. *J. Strength Cond. Res. 21(2):354–361. 2007.*—Use of testosterone enanthate has been shown to significantly increase strength within 6–12 weeks of administration (2, 9), however, it is unclear if the ergogenic benefits are evident in less than 6 weeks. Testosterone enanthate is classified as a prohibited substance by the World Anti-Doping Agency (WADA) and its use may be detected by way of the urinary testosterone/epitestosterone (T/E) ratio (16). The two objectives of this study were to establish (a) if injection of 3.5 mg·kg^{-1} testosterone enanthate once per week could increase muscular strength and cycle sprint performance in 3–6 weeks; and (b) if the WADA-imposed urinary T/E ratio of 4:1 could identify all subjects being administered 3.5 mg·kg^{-1} testosterone enanthate. Sixteen healthy young men were match-paired and were assigned randomly in a double-blind manner to either a testosterone enanthate or a placebo group. All subjects performed a structured heavy resistance training program while receiving either testosterone enanthate (3.5 mg·kg^{-1}) or saline injections once weekly for 6 weeks. One repetition maximum (1RM) strength measures and 10-second cycle sprint performance were monitored at the pre (week 0), mid (week 3), and post (week 6) time points. Body mass and the urinary T/E ratio were measured at the pre (week 0) and post (week 6) time points. When compared with baseline (pre), 1RM bench press strength and total work during the cycle sprint increased significantly at week 3 ($p < 0.01$) and week 6 ($p < 0.01$) in the testosterone enanthate group, but not in the placebo group. Body mass at week 6 was significantly greater than at baseline in the testosterone enanthate group ($p < 0.01$), but not in the placebo group. Despite the clear ergogenic effects of testosterone enanthate in as little as 3 weeks, 4 of the 9 subjects in the testosterone enanthate group (~44%) did not test positive to testosterone under current WADA urinary T/E ratio criteria.

KEY WORDS. steroid, performance, drug testing, T/E ratio

INTRODUCTION

Anabolic androgenic steroids reportedly are abused by athletes participating in sports that require muscle strength and power (7, 18). However, they are classified as prohibited substances in sport, because their use can offer an unfair performance advantage and potentially may be associated with adverse effects on health (17). Well-designed placebo-controlled studies investigating the ergogenic effects of testosterone esters have been limited. Bhasin and coworkers (2) reported that testosterone enanthate administered at a dosage of 600 mg·wk^{-1} was able to facilitate gains in muscular strength in resistance training and nonresistance training groups. Giorgi et al. (9) investigated the effect of testosterone enanthate (approximately 300 mg·wk^{-1}) combined with resistance training during a 12-week administration phase. It was reported that 1 repetition maximum (1RM) bench press strength increased significantly more in the testosterone group at weeks 6 and 12, with the majority of the steroid-induced improvements being made during the initial 6 weeks.

Despite testosterone being shown to have anabolic and ergogenic effects when taken for a period of 6–12 weeks (2, 9), there is limited data on whether the effects on strength and power are evident in less than 6 weeks. Previous research has found that the greatest gains in strength were evident in the initial 6 weeks of a 12-week testosterone administration period, suggesting that the most rapid gains in strength occur shortly after the commencement of administration (9). The potential for testosterone to facilitate improvements in strength and performance over a short time period could have significant implications for the timing of drug testing in sport. Testosterone is classified as a prohibited substance both in and out of competition by the World Anti-Doping Agency (WADA) (16). The key measure to detect testosterone abuse is the urinary testosterone/epitestosterone (T/E) ratio (16). Weatherby et al. (15) reported that when strength-trained athletes received testosterone enanthate for 12 weeks, their performance on a 30-m sprint test was enhanced. Of potentially greater significance was the finding that 12 weeks after testosterone administration was discontinued, the ergogenic effect on sprint performance was maintained, although the urinary T/E ratio had returned to baseline (15). Many athletes abusing testosterone enanthate use long administration phases (12 weeks), which increase the chances of being identified by a random drug test. If the ergogenic effects of testosterone enanthate can be achieved using brief administration phases (3 weeks), athletes may be able to cycle the drug over a period of weeks instead of months, thereby receiving the performance-enhancing effects while reducing the chances of being identified by a random drug test. If this is true, this represents a threat to sports drug testing and protocols may need to be modified to increase the chances of identifying athletes using testosterone esters.

A recent publication highlighted that scientific studies indicate the usage of anabolic steroids in athletics is no higher than 6%, whereas anecdotal evidence suggests the usage is as high as 20–90% (1). One potential explanation for this is that some drug tests may not be completely effective, so that some athletes are able to pass a drug test despite using the drug that the test was designed to identify. The urinary T/E ratio is the key test to monitor

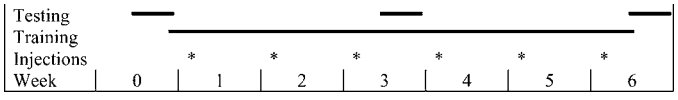

FIGURE 1. A schematic of the experimental design of the 6-week testosterone study.

exogenous testosterone abuse. Normally, the urinary T/E ratio is approximately 1:1, and if the ratio exceeds 4:1, the athlete is investigated further to determine if a doping infraction has occurred (16). However, there is very little data to indicate what effect the administration of exogenous testosterone esters such as testosterone enanthate have on the urinary T/E ratio.

The two objectives of this study were to establish (a) if a weekly dosage of 3.5 mg·kg^{-1} testosterone enanthate could increase muscular strength and cycle sprint performance in 3–6 weeks; and (b) if the WADA-imposed urinary T/E ratio of 4:1 could identify all subjects being administered 3.5 mg·kg^{-1} testosterone enanthate per week.

METHODS

Experimental Approach to the Problem

The study utilized a double-blind, placebo-controlled 2-group design. At the beginning of the study, each subject's height was measured to the nearest 0.5 cm using a wall-mounted stadiometer (Inter 16; Seca, Hamburg, Germany) and body mass was measured to the nearest 0.1 kg using an electronic scale (Mettler ID2 Multirange; August Sauter, Giessen, Germany).

Baseline testing consisted of measuring body mass, maximal upper and lower body strength, and cycle sprint performance. Following baseline testing, subjects were paired based on weight, height, performance measures, chronological age, training age, nationality, and previous reported steroid use. Subjects then were assigned randomly to either a testosterone enanthate or a placebo group. Both groups of subjects followed the same 6-week strength and conditioning program. During training, the testosterone enanthate group received 3.5 mg^{-1}·kg^{-1} testosterone enanthate (Primoteston Depot, Schering AG, Germany) intramuscularly once per week for 6 weeks (Figure 1). This dosage of testosterone enanthate exceeds clinical replacement levels and has been administered previously without serious side effects (9). The placebo group received an equivalent volume of saline solution (AstraZeneca, New South Wales, Australia). The muscular strength and power testing was conducted at the pre (week 0), mid (week 3), and post (week 6) time points. Strength testing was conducted first, with a 48-hour recovery period allowed before the cycle sprint test to ensure that fatigue did not influence the experimental outcomes. Body mass was measured at the pre (week 0) and post (week 6) time points only. Urine samples were collected for determination of the urinary T/E ratio at the pre (week 0) and post (week 6) time points.

Subjects

Eighteen healthy young men were recruited for this study. Two subjects did not complete the study, one due to injury and the other for personal reasons. The characteristics of the 16 subjects who completed the study are presented in Table 1. All subjects were fully informed of the experimental procedures and signed an informed consent document approved by the Human Research Ethics Committee of Southern Cross University (ECN-04-99).

TABLE 1. Mean ± *SD* age, body mass, height, and training frequency of the subjects prior to the study (n = 16).

	Testosterone	Placebo
n	9	7
Age (y)	24.8 ± 2.9	25.1 ± 4.7
Weight (kg)	79.2 ± 6.8	77.6 ± 5.7
Height (cm)	181.2 ± 6.8	182.1 ± 7.9
Strength training (sessions per week*)	2.7 ± 1.5	2.9 ± 0.9

* Training frequency was classified as the mean number of strength training sessions the subjects performed per week during the 12 months prior to the study.

Screening and Health Monitoring

Subjects were required to be between 21 and 35 years of age and to have used no prohibited substances or performance-enhancing supplements in the previous 6 months. All subjects reported previous resistance training experience and, based on self-reported training backgrounds, were considered moderately to well trained (Table 1). Prior to inclusion in the study, all subjects underwent a comprehensive screening process. This included relevant family medical history, past and present medical condition, as well as current medication and nutritional supplement use. A physician performed a physical examination, which included cardiovascular, respiratory, neural, abdominal, and musculoskeletal assessment. To identify any preexisting conditions that may have been exacerbated by androgen administration, a complete blood count, lipid profile, liver function test, and resting 12-lead electrocardiogram was performed. During the study, subjects were monitored for unusual behavioral or physical responses; at each weekly dose, a physical check was performed that included resting blood pressure and heart rate, as well as questions on specific known steroid effects. These tests were performed as a safety and ethical requirement and the results were not intended to be utilized as research data.

At the initiation of the study, no subject reported the use of any nutritional supplements or nonprescription drugs. As a condition of acceptance into the study, each potential subject was required to supply a urine sample that was analyzed for the presence of prohibited substances according to WADA criteria (16).

Training

The primary objective of the resistance training program was to increase strength and lean body mass. The resistance training program scheduled a total of 2–3 resistance training sessions per week across the 6-week experimental period. To this end, the resistance training program prescribed a total of 16 sessions. These sessions utilized a simple split routine format (Table 2), typically allowing a minimum 48 hours' recovery before the next resistance training session utilizing the same body part. Upper body exercises included bench press, dumbbell press, shoulder press, lat pull-down, one-arm dumbbell row, bicep curl, and tricep dip. Lower body exercises included the squat, leg press, leg extension, leg curl, lunge, and calf raise.

An RM training range was prescribed for each exercise within each session of the resistance training routine. The prescribed repetition ranges (6–12RM per set) utilized in this study typically are prescribed in programs designed to increase muscle size and general strength (8).

TABLE 2. Individual training session focus across the experimental period.

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Total body				Total body		
2	Lower body		Total body		Upper body		
3	Legs and shoulders		Chest, back, and arms		Legs and shoulders		Test group 2 only upper body
4			Test group 1 only upper body		Legs and shoulders		
5	Legs and shoulders		Chest, back, and arms		Legs and shoulders		Chest, back, and arms
6	Legs and shoulders	Chest, back, and arms					

The average prescribed repetition range for each of the 16 resistance training sessions is presented in Figure 2. A group training format was implemented to ensure that motivation during training remained high. A qualified strength and conditioning coach closely supervised all 16 training sessions, ensuring that all athletes trained at the designated intensity.

The resistance training program was periodized and applied the basic principles of program design (8). The average number of repetitions prescribed per week for the 6-week study is presented in Figure 3. The total number of working sets per session ranged from a maximum of 24 to a minimum of 14 (average, 20.5 ± 2.9), and recovery between sets was standardized at 1–2 minutes. The sequence of exercises in each session was typically from large muscle mass to small muscle mass. Each subject was provided with a training diary in which they were required to record the actual load (kg) used and the number of completed repetitions per set.

1 Repetition Maximum Strength Testing

Lower body 1RM strength was monitored using a 45° leg press machine (Kolossal, Sydney, Australia). Stoppers were used to allow the sled to be lowered so that the subjects' knee joints reached an angle of 90°. Subjects self-selected their preferred foot width on the sled, and this position was marked and recorded for standardization of future trials. Upper body 1RM strength was monitored using a modified Smith machine (Plyopower Technology, Lismore, Australia). Stoppers were used to allow the bar to be lowered to a position 5 cm above each subject's chest. Subjects selected their preferred grip widths, and this position was marked and recorded for standardization of future trials. The bench press and leg press exercises were selected, because the potential subjects were familiar with these lifts.

Isotonic 1RM testing was conducted according to standardized procedures published previously (4). Prior to performing any lifts, a 5-minute standardized general cardiovascular warm-up was implemented on a cycle ergometer (Monark 868; Monark-Crescent AB, Varlberg, Sweden). A specific warm-up then was implemented, consisting of 8 repetitions at 50% of the estimated 1RM, followed by another set of 3 repetitions at 70% of estimated 1RM. Two minutes separated the 2 warm-up sets. Subsequent lifts consisted of progressively heavier resistances until the subject was unable to successfully complete a repetition using correct form. A weight midway between the last successful lift and the failed lift then was attempted to determine the 1RM. Strong verbal encouragement was provided to all subjects to ensure maximum efforts (12). A 3-minute recovery period was allowed after each trial.

10-Second Cycle Sprint Test

Prior to performing the cycle test, a 5-minute standardized cardiovascular warm-up was implemented on a Monark 868 cycle ergometer (Monark-Crescent). The cycle sprint testing was conducted on an air-braked front access cycle ergometer (Exertech Exercise Technology, Sydney, Australia). The subjects' feet were secured to the pedals using both toe clips and tape to prevent excess movement. A 5-second countdown was provided and the subject was instructed to be cycling at maximum pace on the count of zero. The test was then initiated and the subject attempted to maintain maximal power output for the full 10 seconds. Strong verbal encouragement was provided to all athletes to ensure maximum effort (12). Peak power (W) and total work (kJ) were monitored by way of a photo-optically sensitive diode connected to the flywheel, with outputs being received by an AMLAB data acquisition and analysis system (AMLAB Technologies, Lewisham, Australia). The 10-second cycle test was se-

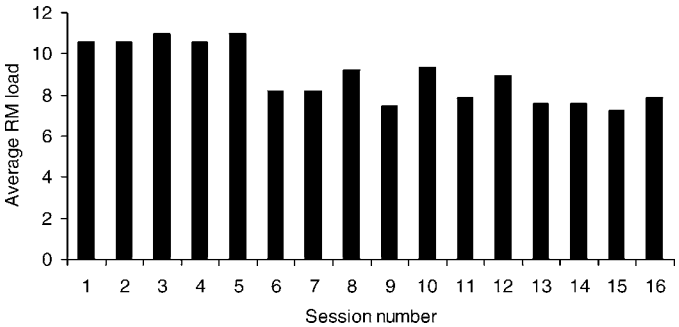

FIGURE 2. The average prescribed repetition range for each of the 16 resistance training sessions.

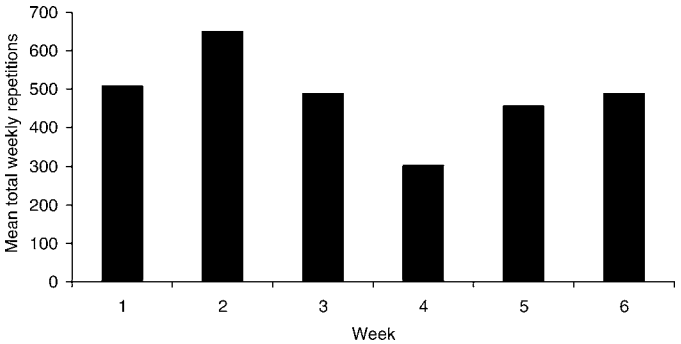

FIGURE 3. The average number of repetitions prescribed per week across the 6-week study.

lected because it had been reported previously to be a highly reliable measure of performance and is less likely than longer duration tests to be influenced by pacing (19).

Urinary Testosterone/Epitestosterone Ratio

Collected urine samples were frozen at −20° C until laboratory analysis. Analysis of the T/E ratio was performed in a National Association of Testing Authorities, Australia–accredited laboratory using gas chromatography-mass spectrometry according to the methods published previously (5).

Dietary Standardization

To ensure that the dietary intakes were similar, the subjects were provided all meals for the duration of the study. Because the research was investigating a drug said to increase muscle protein synthesis and anabolism, supplementary protein was allocated to both groups to control against inadequate protein intakes. The supplementary protein consisted of Whey Protein Concentrate (Body Science, Sydney, Australia) administered at a dosage of 60 $g \cdot d^{-1}$. The subjects were instructed to consume 30 g in the morning and 30 g in the evening.

One hour prior to baseline testing, subjects consumed a standardized meal in the form of a meal-replacement powder (Mass Monster, Body Science). The meal-replacement powder was used in an attempt to ensure that the final meal prior to each testing session was standardized for its total energy content, as well as its nutrient profile. This provided greater control over any performance variability that may have arisen secondary to dietary variations in the hours prior to each trial.

Standardization of Living Conditions

Accommodations were provided to the subjects for the duration of the study. Furthermore, because no subjects had occupational commitments during the 6 weeks of the study, their living conditions and environmental conditions were highly standardized. Physical activity outside of training was limited to light, organized social activities to minimize any interference with the training program.

Dose-Administration Blinding

Gluteal intramuscular injections were used, which subjects were unable to view. At the time of injection, subjects could not distinguish whether a steroid or a placebo had been injected. All injections were performed by a registered nurse. At the termination of the study, the 16 subjects who completed it were provided a questionnaire assessing how effective the blinding procedures had been. Four subjects (25%) were unable to determine whether they had been in the testosterone enanthate or placebo group. Six subjects (37.5%) were confident that they knew the group to which they had been assigned; of these 6, however, 3 had chosen the incorrect group. The remaining 6 subjects were not confident regarding the group to which they had been assigned, but they did choose the correct group (5 placebo, 1 steroid); the majority of them chose the placebo only because they were of the opinion that they had not gained sufficient weight to be in a steroid group. Overall, the blinding procedures appear to have been successful. It has been concluded that the study was conducted under strict double blind conditions.

Statistical Analyses

All data were summarized using descriptive statistics (mean ± *SD*), and all statistical analysis was performed using SPSS (version 9.0.1; SPSS, Inc., Chicago, IL). Statistical analysis for strength and cycle performance was conducted using a 2 × 3 (group [testosterone, placebo]) × (time [week 0, week 3, week 6]) analysis of variance (ANOVA) with repeated measures. Statistical analysis for body mass was conducted using a 2 × 2 (group [testosterone, placebo]) × (time [week 0, week 6]) ANOVA with repeated measures. Statistical significance was set at $p \leq 0.05$. When a significant F-ratio was identified, a Fisher's least significant difference test was used to locate the pairwise differences between means. Prior to the first dose, subjects were match-paired and a 1-way ANOVA was applied to the potential groups to ensure there were no differences between groups on any variable.

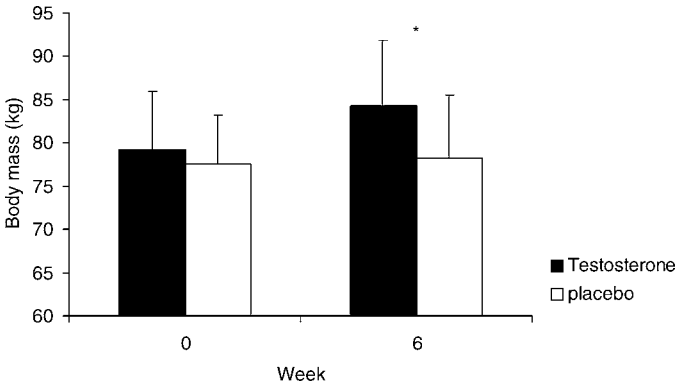

FIGURE 4. Body mass for testosterone ($n = 9$) and placebo ($n = 7$) groups before (week 0) and after (week 6) weekly intramuscular (im) injection of 3.5 $mg \cdot kg^{-1}$ testosterone or placebo. Error bars represent ± *SD*. * Significantly different from week 0 for testosterone group ($p < 0.01$).

RESULTS

One more subject suffered an injury in the final week and was unable to complete the 1RM leg press component of the testing, although he had completed all other aspects. Consequently, statistical analyses on most variables (i.e., body mass, bench press, peak power, total work, and the urinary T/E ratio) were completed on 16 subjects (testosterone enanthate, $n = 9$; placebo, $n = 7$), whereas the variable leg press was conducted on only 15 subjects (testosterone enanthate, $n = 9$; placebo, $n = 6$).

Body Mass

The body mass data are presented in Figure 4. A significant group × time interaction was identified for body mass ($p < 0.01$). Further analysis of this effect indicated that body mass was higher at week 6 than at week 0 ($p < 0.01$) in the testosterone group. No statistically significant changes in body mass were noted in the placebo group between weeks 0 and 6. The effect size for body mass is presented in Table 3.

1 Repetition Maximum Strength

The 1RM data for the bench press and leg press exercises are presented in Figures 5 and 6, respectively. A significant group × time effect was identified for 1RM bench press strength ($p < 0.01$). Further analysis of this effect indicated that 1RM bench press strength in the testosterone group was greater at week 6 than at weeks 3 ($p < 0.01$) and 0 ($p < 0.01$). Bench press strength was also greater at week 3 as compared with week 0 ($p < 0.01$). The mean percentage increase in bench press strength

TABLE 3. The effect sizes for body mass, 1 repetition maximum (1RM) strength measures, and cycle sprint performance.

	Pre-Post effect size week 0–week 3	Treatment effect size* (T – P)	Pre-Post effect size week 0–week 6	Treatment effect size* (T – P)
1RM bench press				
Placebo	0.1		0.1	
Testosterone enanthate	0.4	0.3	0.6	0.5
1RM leg press				
Placebo	0.4		0.5	
Testosterone enanthate	0.5	0.1	0.7	0.2
Peak power				
Placebo	0.1		0.4	
Testosterone enanthate	0.3	0.2	0.7	0.3
Total work				
Placebo	0.1		0.3	
Testosterone enanthate	0.6	0.5	0.9	0.6
Body mass				
Placebo	#	#	0.1	
Testosterone enanthate	#	#	0.8	0.7

* Treatment effect size is calculated by subtracting the Pre-Post effect size for the placebo (P) group from the Pre-Post effect size of the Testosterone enanthate (T) group (13). # = No measure of body mass was taken at the week 3 time point.

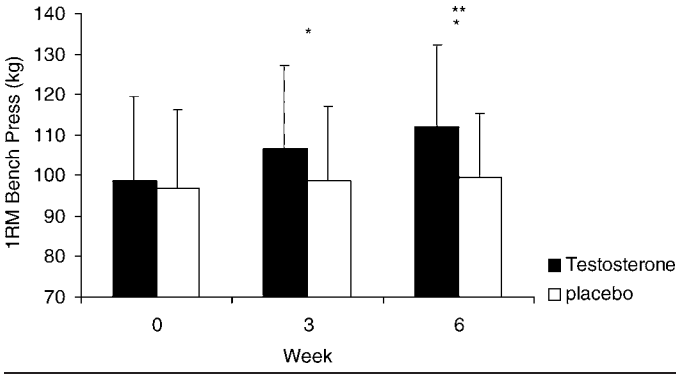

FIGURE 5. One repetition maximum bench press strength for testosterone ($n = 9$) and placebo ($n = 7$) groups at weeks 0, 3, and 6 after weekly intramuscular (im) injection of 3.5 mg·kg^{-1} testosterone or placebo. Error bars represent ± *SD*. * Significantly different from week 0 for testosterone group ($p < 0.01$). ** Significantly different from week 3 for testosterone group ($p < 0.01$).

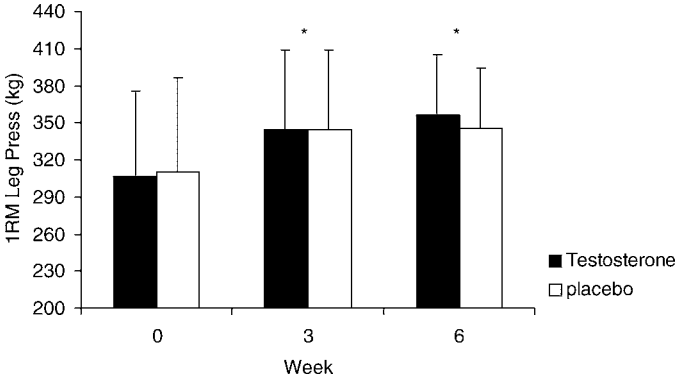

FIGURE 6. One repetition maximum leg press strength for testosterone ($n = 9$) and placebo ($n = 6$) groups at weeks 0, 3, and 6 after weekly intramuscular (im) injection of 3.5 mg·kg^{-1} testosterone or placebo. Error bars represent ± *SD*. * Significantly different from week 0, irrespective of group ($p < 0.01$).

from baseline for the testosterone group was 9% at week 3 and 15% at week 6. Although 1RM bench press increased slightly in the placebo group at both time points, this did not reach statistical significance. The mean percentage increase in bench press strength from baseline for the placebo group was 2% at week 3 and 4% at week 6. The effect sizes for 1RM bench press strength are presented in Table 3.

A significant time effect was identified for leg press strength ($p < 0.01$). Further analysis of this effect indicated that leg press strength at week 3 was significantly higher than at week 0 ($p < 0.01$) and leg press strength at week 6 was significantly higher than at week 0 ($p < 0.01$). Leg press strength at week 6 was not significantly different from week 3. The mean percentage increase in leg press strength for all subjects from baseline was 13% at week 3 and 17% at week 6. The effect sizes for 1RM leg press strength are presented in Table 3.

Cycle Sprints

The cycle sprint data are presented in Figures 7 and 8. A significant time effect was identified for peak power ($p < 0.01$). Further analysis of this effect indicated that peak power at week 6 was significantly higher than at week 0 ($p < 0.01$) and at week 3 ($p < 0.01$) irrespective of group. There was a trend toward peak power being higher at week 3 compared with week 0, although this failed to reach statistical significance ($p = 0.09$). A strong trend toward a group × time effect was identified, although this failed to reach statistical significance ($p = 0.05$). The mean percentage increase in peak power from baseline for the placebo group was 1% at week 3 and 4% at week 6. The mean percentage increase in peak power from baseline for the testosterone group was 5% at week 3 and 12% at week 6. The effect sizes for peak power are presented in Table 3.

A significant group × time interaction was identified for total work ($p < 0.01$). Further analysis of this effect indicated that total work was higher in the testosterone group at week 6 than at weeks 0 and 3 (both, $p < 0.01$). Total work was also higher at week 3 as compared with

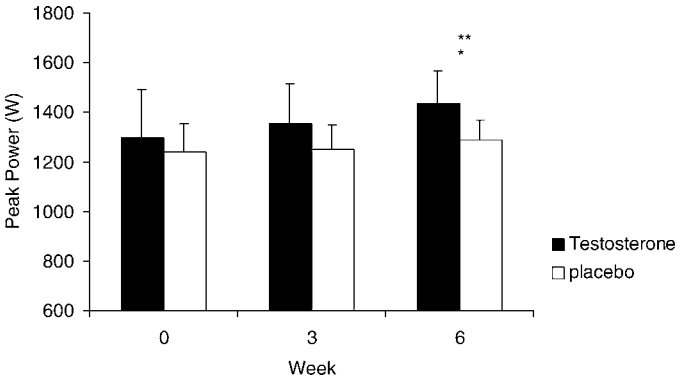

FIGURE 7. Peak power during the 10-second cycle sprint for testosterone ($n = 9$) and placebo ($n = 7$) groups at weeks 0, 3, and 6 after weekly intramuscular injection of 3.5 mg·kg^{-1} testosterone or placebo. Error bars represent ± *SD*. * Significantly different from week 0, irrespective of group ($p < 0.01$). ** Significantly different from week 3, irrespective of group ($p < 0.01$).

week 0 ($p < 0.01$). The mean percentage increase in total work from baseline for the testosterone group was 9% at week 3 and 14% at week 6. Although total work increased slightly in the placebo group at week 6, this did not reach statistical significance. The mean percentage increase in total work from baseline for the placebo group was 0% at week 3 and 3% at week 6. The effect sizes for total work are presented in Table 3.

Urinary Testosterone/Epitestosterone Ratios

At week 0, the T/E ratios for all subjects were within normal ranges and no urine sample exceeded the 4:1 cutoff imposed by WADA. At week 6, the urinary T/E ratios of all subjects in the placebo group remained stable and no subject exceeded the ratio for a positive test according to WADA criteria (16). At week 6, the urinary T/E ratios in the testosterone group showed large interindividual variability (Figure 9). The T/E ratios of 5 of the 9 subjects in the testosterone group exceeded the WADA cutoff. The T/E ratios of the remaining 4 subjects in the testosterone group were below the WADA cutoff, and based on WADA T/E ratio criteria (16), these subjects would not have tested positive for testosterone.

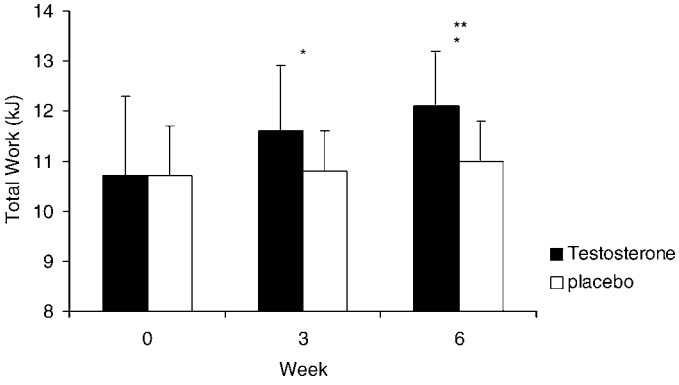

FIGURE 8. Total work during the 10-second cycle sprint for testosterone ($n = 9$) and placebo ($n = 7$) groups at weeks 0, 3, and 6 after weekly intramuscular injection of 3.5 mg·kg^{-1} testosterone or placebo. Error bars represent ± *SD*. * Significantly different from week 0 for testosterone group ($p < 0.01$). ** Significantly different from week 3 for testosterone group ($p < 0.01$).

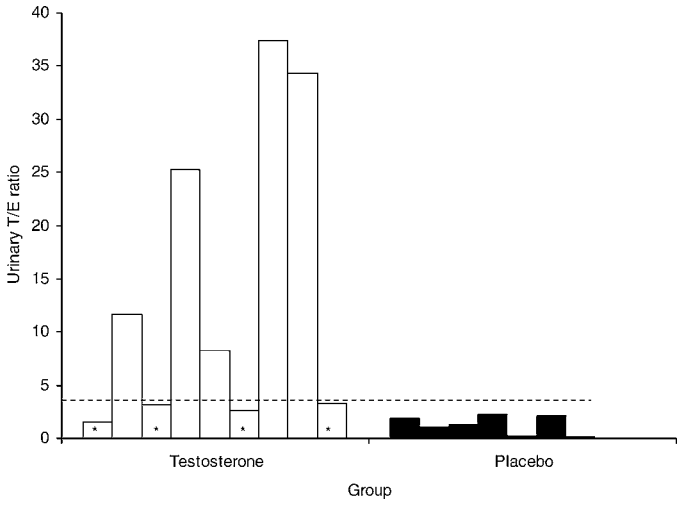

FIGURE 9. The individual urinary testosterone/epitestosterone (T/E) ratios for each volunteer in the testosterone ($n = 9$) and placebo ($n = 7$) groups collected 4 days after the final testosterone or placebo injection in week 6. The dashed line represents the 4:1 T/E ratio defined by the World Anti-Doping Agency (WADA) as the upper limit for T/E ratios. * Subjects in the testosterone group with T/E ratios below the 4:1 cutoff imposed by WADA, after 6 weeks testosterone use prescribed at a weekly dose rate of 3.5 mg·kg^{-1}.

DISCUSSION

This is the first double-blind, placebo-controlled study to report a significant increase in strength and athletic performance after only 3 weeks' use of testosterone enanthate. Crist, Stackpole, and Peake (6) reported no consistent effect of testosterone propionate on upper or lower body isokinetic strength after 3 weeks. However, the dose of testosterone used (100 mg·wk^{-1}) was low in comparison with that of the present study. Given that testosterone administration causes a feedback inhibition of endogenous luteinizing hormone and testosterone (10), it is unlikely that the administration protocol used by Crist, Stackpole, and Peake (6) increased testosterone concentrations outside of normal physiological ranges. In contrast, the dosage used in the present study (200–300 mg·wk^{-1}) can be considered a supraphysiological dose.

Previous research administering supraphysiological doses of testosterone also have reported ergogenic effects. In agreement with this study, Giorgi et al. (9) reported that testosterone enanthate administered at a dose of approximately 300 mg·wk^{-1} facilitated gains in 1RM bench press after 6 weeks. Likewise, Bhasin and coworkers (2) reported significant gains in 1RM bench press and squat following the administration of testosterone enanthate at a dose of 600 mg·wk^{-1} for 10 weeks. More recently, Storer and coworkers (14) reported a dose-dependent increase in maximum voluntary strength in healthy young men. It was reported that improvements in leg strength and power were significantly higher in subjects receiving 300 and 600 mg·wk^{-1} testosterone enanthate compared with those receiving doses of 25, 50, or 125 mg·wk^{-1} (14). The data from previous studies combined with the findings in this study suggest that supraphysiological doses of testosterone are necessary to elicit measurable increases in strength and power and that the ergogenic benefits are evident in as little as 3 weeks.

The greater gains in bench press strength, but not leg press strength, in the testosterone enanthate group likely

are attributed to the training background of the subjects. The resistance training backgrounds of the subjects indicated that most followed programs that favored their upper bodies. Consequently, the subjects can be considered more highly trained in the upper body and therefore less likely to experience rapid gains in upper body strength. This was evident in the strength gains between the upper and lower body. After 6 weeks, the mean percentage strength gains in the bench press exercise were 4 and 15% for the placebo and testosterone enanthate groups, respectively. In contrast, the mean percentage strength gains in the leg press exercise were 13 and 15% for the placebo and testosterone enanthate groups, respectively. The leg press was selected as the lower body 1RM testing exercise, because it requires less skill to perform than a squat does, and therefore reduced the likelihood of injury during 1RM testing. The greater gains in strength observed in the leg press in comparison to the bench press may have masked a testosterone effect.

Giorgi et al. (9) reported that during 12 weeks of testosterone enanthate administration, the greatest gains in bench press strength were during the first 6 weeks, suggesting that the body quickly responds to the presence of testosterone enanthate. As indicated in Figures 5 and 8, the greatest gains in bench press strength and total work during the 10-second cycle occurred during the first 3 weeks, which would indicate that the actions of testosterone enanthate occur more quickly than was thought previously. The effect sizes for 1RM bench press and total work are only slightly larger at week 6 as compared with week 3 (Table 3). Consequently, it may be that the initial weeks of testosterone enanthate administration are the most beneficial in the context of gains in strength and athletic performance.

A significant increase in body mass was recorded for the testosterone enanthate group at week 6, with no significant increase in the placebo group. Although total energy intake was not controlled in the present study, all food was supplied to the subjects. Consequently, both the steroid and placebo groups had equal access to the same dietary source. Previous research also has reported significant gains in body mass after 6 weeks (9) and 10 weeks (2) of testosterone enanthate administration. Consequently, this study provided further support for the ability of supraphysiological doses of testosterone enanthate to facilitate gains in body mass, which may be advantageous to athletes participating in sports in which high body mass is considered beneficial.

The significant increase in total work in the testosterone enanthate group and strong trend toward a group $\times$ time effect on peak power in the cycle test is in line with the findings of Bhasin and coworkers (3), who reported that leg power increased significantly in men receiving 300 and 600 mg of testosterone enanthate per week, but not in men receiving 25-, 50-, or 125-mg weekly doses. Likewise Weatherby et al. (15) reported an ergogenic effect of testosterone enanthate on 30-m running sprints. The data from this study, with that of previous work, suggest that testosterone enanthate can enhance athletic performance on tests requiring rapid force development and short maximal efforts.

Detection of exogenous testosterone abuse is monitored by way of the urinary T/E ratio. Normally the urinary T/E ratio is approximately 1:1, and if the ratio exceeds 4:1, an athlete is investigated further to determine if a doping infraction has occurred (16). No previous study investigating the ergogenic effects of testosterone enanthate has reported urinary T/E ratio data. This study has raised some serious concerns as to how effective the urinary T/E ratio is at identifying athletes using moderate doses of testosterone esters. The dose of testosterone enanthate used in this study clearly enhanced performance in as little as 3 weeks, however 4 of the 9 subjects in the testosterone group (44%) would not have tested positive to testosterone according to the latest WADA urinary T/E ratio criteria (16). The large interindividual variability in the T/E ratios following testosterone enanthate administration suggests that some individuals may be able to use supraphysiological doses of testosterone enanthate and display only small increases in their urinary T/E ratios.

The long-term use of anabolic androgenic steroids is associated with adverse health effects (17). In this study, the subjects were monitored for side effects of the testosterone enanthate. No changes in blood pressure or heart rate were detected in subjects in either the steroid or placebo group. In the placebo group, mild acne occurred in 5 of the 7 subjects for periods of 1 to 2 weeks; in the testosterone enanthate group, however, acne occurred in 6 of the 9 subjects, was more severe, and lasted for more than 4 weeks after appearing in the first 1 to 2 weeks after the first dose was administered. Six of the 7 placebo subjects had periods of mild moodiness and irritability; 6 of the testosterone group, however, had more severe moodiness and irritability over several weeks. Subjects were asked about their libido during the 6-week study. Four of the placebo group reported small changes, but for 7 of the 9 testosterone subjects, a pattern of decreased libido in the first week with an increase in the third and successive weeks was reported. One reported no change, and the remaining subject reported a small decrease in the third week only. One symptom reported by the testosterone group (5 out of 9) was nipple tenderness from week 3 until the conclusion of the study. Three subjects in the testosterone group felt that their testicular size had decreased, whereas one subject reported that he had increased body hair. Three of the subjects in the testosterone group reported that the area around the injection site was sore after some injections. Overall, the placebo group did not report side effects of any seriousness; those in the testosterone group, however, reported adverse effects consistent with testosterone administration (9) that generally appeared from weeks 2–3 of the administration period. The manifestation of these adverse effects appears to parallel the ergogenic effects produced.

In any study investigating testosterone or other anabolic androgenic steroid, the possibility of a placebo effect must be acknowledged. Previous research has reported that when elite power lifters were given placebo capsules and were told they were oral anabolic steroids, their strength levels increased significantly in only 7 days (11). Testosterone can be associated with side effects such as acne that may not be seen with a placebo (9). Therefore, the effectiveness of the blinding procedures needs to be carefully monitored and reported in research investigating athletic performance or any other variable that may be influenced by the subjects' expectations. Not all previous studies have reported the success of their blinding procedures and consequently, the influence of a placebo effect in these studies cannot be ruled out. In the present study, the majority of subjects were unable to confidently determine the group to which they had been assigned, suggesting that this study was conducted under strict

double-blind conditions and that the results are unlikely to have been influenced by expectancy effects.

PRACTICAL APPLICATIONS

This study provides evidence of the ability of anabolic androgenic steroids to enhance muscle strength and power within weeks of beginning administration. Additionally, the WADA-imposed urinary T/E ratio of 4:1 did not identify all athletes who were administered testosterone enanthate in this study. The findings of this study suggest that some athletes may be able to use testosterone enanthate to significantly enhance their performance without testing positive.

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Acknowledgments

This study was funded by a grant from Mentorn London Television Corporation. Protein supplements and meal replacement powders utilized in this study were supplied by Body Science Australia. Appreciation is expressed to Associate Professor N. Travis Triplett for her constructive feedback and proofreading of the manuscript. The results of the present study do not constitute endorsement of the product by the authors or the National Strength and Conditioning Association.

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