Serum Testosterone Response to High-Intensity Resistance Training in Male Veteran Sprint Runners

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Reference Data

ABSTRACT
The purpose of this study was to examine the influence of an 8-wk high-intensity resistance training program on muscular strength and basal serum testosterone in male veteran sprint runners. Twelve healthy veteran sprint runners, ages 45–79, were recruited as subjects and randomly assigned to an experimental (n = 8) or control (n = 4) group. Measured in both groups before and after the resistance training period were body mass, total skinfolds, isoinertial strength (bench press, leg press), peak torque (knee extensors, knee flexors), and basal testosterone levels. ANOVA revealed significant increases (p < 0.05) in both the isoinertial and isokinetic strength of the experimental group following resistance training. However, no significant increase in basal testosterone level was observed in that group after 8 weeks of resistance training. The results suggest significant improvements in muscular strength in veteran male sprint runners following 8 weeks of high-intensity resistance training. Furthermore, the strength gains are not explained by changes in basal serum testosterone and may be due to neurological, physiological, and morphological factors.

Key Words: aging, performance, strength, masters

Introduction
Androgens such as testosterone are known to play a role in muscle hypertrophy and strength development in young men following high-intensity resistance training (21). Testosterone appears to have a direct effect on strength development by enhancing both skeletal muscle growth (12) and the size and function of the neuromuscular junction (20).

Previous investigations have suggested that age related decreases in androgen levels may help explain the decline in muscular strength observed in aging men (14, 31). A number of investigations have shown both increased muscular strength and chronic elevations in basal testosterone levels in young men following high-intensity resistance training programs (4, 16, 17), but recent investigations have also examined the effects of low-volume, low-intensity, small-muscle-group resistance training on both muscular strength and basal serum testosterone levels in sedentary elderly men (15, 25). While these studies all reported increased muscular strength following 12–16 weeks of resistance training in the previously sedentary older men, no chronic increases in serum testosterone were observed. It might be suggested that these sedentary older men, through inactivity, may have lost the ability to form the hormone-receptor complexes that increase the transcription of genes located on nuclear DNA that code for contractile protein synthesis (18).

Veteran sprint runners may have maintained this ability through run training at high intensity, an activity that has been shown to acutely stimulate testosterone release in younger men (22, 32). It remains to be investigated whether a high-volume, high-intensity resistance training program can induce chronic elevations in serum testosterone in active aging individuals.

Muscular strength decreases with age in both sedentary individuals (2, 11) and track and field athletes (26). However, it has also been observed to increase in elderly sedentary individuals to the same relative degree as in younger individuals following a strength training program of sufficient intensity (1, 7, 9, 13). It remains to be investigated whether a high-intensity resistance training program can induce similar strength changes in male veteran athletes. Thus the purpose of this study was to examine the influence of high-intensity resistance training on both muscular strength and basal serum testosterone in veteran male sprint runners.

Methods
Subjects and Procedures
Twelve male (45–79 years) veteran sprint runners with no recent history (<10 yrs) of high-intensity resistance training were recruited for the study. Sprint runners were used since they were familiar with high-intensity...
physical training. They were randomly assigned to either the experimental group (n = 8) or control group (n = 4). Each subject was prescreened by a sportsmedicine practitioner for history or signs of cardiac or pulmonary disease, medication known to influence exercise performance, hypertension, or any condition contraindicating participation in the study. Each subject also underwent a maximal stress test at a private hospital under the supervision of a consultant cardiologist. All subjects signed informed consent and the study was approved by the university’s medical review ethics committee.

During the 8-week training period, 2 subjects from the experimental group were injured in incidents unrelated to the resistance training program and were unable to complete the study. The other 6 subjects from the experimental group completed all resistance training sessions. Subjects’ physical characteristics (E = experimental group, C = control group) were as follows:

- Age (yrs): E: 54.7 ± 5.5; C: 56.0 ± 5.6
- Height (cm): E: 176.0 ± 2.3; C: 176.0 ± 1.8
- Body mass (kg): E: 68.9 ± 1.7; C: 78.5 ± 4.9
- Sum of 8 skinfolds (mm): E: 68.9 ± 6.5; C: 101.2 ± 1.8

Body mass and skinfold values were significantly (p < 0.05) different between groups. Prior to the 2 injured athletes dropping out from the experimental group, no significant differences were observed in body mass and skinfold total scores.

Testing
Each subject was tested before and after the 8-week resistance training period. Subjects had refrained from any form of training for the 36 hrs prior to testing and reported to the laboratory after an overnight fast.

Anthropometric measures were recorded on the first visit to the laboratory, during which the subjects were familiarized with the protocols and test modalities to be used. Anthropometric data included height to the nearest 0.5 cm (Kau We, Model 44442, Germany), body mass to the nearest 0.1 kg (Mercury Scales, Model AD4316, Japan), and skinfold measures (biceps, triceps, subscapular, suprailiac, midaxillary, abdominal, thigh, calf). Skinfolds were measured in triplicate by a Level III ISAK (International Society for the Advancement of Kinanthropometry) accredited anthropometrist using calibrated John Bull calipers (British Indicators Ltd.) with the median value (mm) recorded (29).

A Cybex 340 isokinetic dynamometer (Lucem Corp., Bay Shore, NY) was used to determine peak torque of the quadriceps and hamstring muscle groups during maximal voluntary isokinetic contractions. Following a 5-min warm-up at 50–100 watts on a front-access cycle ergometer (Exertech EX10, Repco, Australia), each subject was seated in the standard Cybex chair with back support. The leg to be tested was then attached to the dynamometer lever arm according to the manufacturer’s instructions. To prevent extraneous movement, the trunk, hips, and thigh were fixed to the chair using wide, slightly elastic straps.

Before the maximal test contractions, 5 submaximal ones were undertaken to warm up the muscle tissue, check limb and lever arm alignment, and refamiliarize the subject with the contraction mode and test velocity. Each subject was then instructed to move the dynamometer lever arm as fast and forcefully as possible throughout the full range of motion (90°) for 3 consecutive knee extensions and flexions at an angular velocity of 60° per sec. A 5-min rest period was provided before testing the alternate limb. The mean quadriceps and hamstrings peak torque (N m · kg⁻¹) for both limbs was used for statistical analysis. Results were not gravity-corrected.

The protocols for testing isoinertial lower and upper body strength were similar. Prior to both tests, 10 submaximal efforts comprised the warm-up. The subjects were instructed to breathe deeply prior to each effort, then exhale during the exertion phase. Initial test resistance was subjectively determined by the investigators with resistance gradually increased until only one repetition could be completed (1-RM). A 1-min rest period separated each trial.

Isoinertial leg strength was established using a leg press device attached to a Universal (DVR-790610) weight training device. Subjects were seated in the leg press position with their lower back supported, hands gripping the laterally placed handles and knees flexed at 90°. Isoinertial upper body strength was measured using a bench press device attached to the same Universal weight training device. The subjects lay supine, knees flexed and feet resting on the bench. Shoulder and elbow joints were aligned in the vertical plane with the bench press grip bar. Grip width was standardized with the elbow joint flexed at 90°.

Blood Sampling
The subjects arrived at the laboratory between 8 and 10 a.m. following an overnight fast, approximately 8 hrs sleep, and at least 36 hrs postexercise. Venous blood (5 ml) was drawn from the antecubital vein before and after the 8-week training period by a trained phlebotomist at the same time of day. Serum was frozen at −20 °C until analyzed. Samples were analyzed commercially for basal testosterone levels using a radioimmunoassay technique (Byk-Sangtec Diagnostica, Germany) and an automatic gamma-counter (LKB-Wallac, Finland).

Training
Both groups were asked to maintain normal dietary habits and run-training schedules throughout the training and testing period. Each subject undertook a run-training schedule of 2 sprint-training sessions a week consisting of 10- to 200-m runs with a total volume, excluding warm-up and cooldown, of 400 to 1,000 m. In order to monitor training habits, each subject’s training log was collected and reviewed after the training pe-
period, revealing that all subjects had complied with this request.

The experimental group performed high-intensity resistance training 3 times a week for 8 weeks under the supervision of one of the investigators. A familiarization period of 1 week was included so the subjects could learn techniques and adjust to the training loads imposed. Each resistance training session consisted of a warm-up set of 20 reps at 20–40% of a predetermined 1-RM. Three sets (12, 10, 8 reps) of each exercise were then undertaken at 80% 1-RM, with a 1-min recovery between sets and 5 min between each exercise. Four exercises were completed sequentially for the lower limbs: leg extension, leg curl, leg press, and half squats. Five core and upper body strength exercises were then undertaken in the following order: bench press, upright row, biceps curl, triceps pushdown, and abdominal crunch. Each subject’s 1-RM capacity was determined every 2 weeks and training resistance were adjusted accordingly.

Statistical Analyses

Group means and standard errors of the mean were calculated for each variable. Two-way ANOVA for repeated measures was undertaken to determine main effects and interactions of group (experimental, control) and time (pre-, posttraining) for each parameter measured. Statistical significance was established at the 0.05 level.

Results

As shown in Table 1, the high-intensity resistance training program significantly increased upper and lower body isoinertial strength in the experimental group (17.5 and 24.9%, respectively, \( p < 0.05 \)). Quadriceps and hamstring peak torque also increased significantly in the experimental group (10.3 and 12%, respectively). No significant changes in either isoinertial or isokinetic muscular strength were observed in the control group. No significant changes were observed in body mass or total skinfolds in either group. Prior to the 2 injured athletes dropping out of the experimental group, no significant differences were observed between groups in the pretraining values of the 4 strength measures.

Table 2 shows the wide intra- and interindividual differences in serum testosterone levels both before and after the 8-wk resistance training period. No statistically significant changes were observed in mean serum testosterone of either group following the resistance training program.

Discussion

The results of this study suggest that 8 weeks of high-intensity resistance training increases both isoinertial strength and peak torque in male veteran sprint runners, without influencing basal serum testosterone levels. These levels have been observed to increase follow-

| Table 1 |
|-------------------|-------------------------|-------------------------|-------------------|-------------------------|
|                 | Experimental (\( n = 6 \)) | Control (\( n = 6 \))    |                   |
| Variable         | \( M \pm SEM \) | \( M \pm SEM \) | \( M \pm SEM \) | \( M \pm SEM \) |
| Body mass (kg)   | 68.9 \( \pm 1.7 \) | 70.2 \( \pm 1.5 \) | 78.5 \( \pm 4.9^* \) | 79.2 \( \pm 5.7 \) |
| Total skinfold (mm\(^2\)) | 68.9 \( \pm 6.5 \) | 65.8 \( \pm 6.9 \) | 101.2 \( \pm 1.8^* \) | 101.0 \( \pm 1.9 \) |
| Bench press (kg) | 46.8 \( \pm 1.6 \) | 55.0 \( \pm 3.1^* \) | 55.0 \( \pm 1.7^* \) | 54.5 \( \pm 2.6 \) |
| Leg press (kg)   | 127.3 \( \pm 10.7 \) | 159.1 \( \pm 6.3^* \) | 127.3 \( \pm 10.0 \) | 126.4 \( \pm 9.0 \) |
| Knee ext (Nm \( \cdot \) kg\(^{-1}\)) | 2.5 \( \pm 0.2 \) | 2.8 \( \pm 0.2^* \) | 2.8 \( \pm 0.2 \) | 2.7 \( \pm 0.2 \) |
| Knee flex (Nm \( \cdot \) kg\(^{-1}\)) | 1.7 \( \pm 0.2 \) | 1.9 \( \pm 0.2^* \) | 1.8 \( \pm 0.0 \) | 1.7 \( \pm 0.1 \) |
| Testosterone (nmol \( \cdot \) L\(^{-1}\)) | 20.2 \( \pm 3.0 \) | 19.2 \( \pm 2.8 \) | 18.2 \( \pm 1.7 \) | 17.2 \( \pm 0.8 \) |

\(^1\text{Sum of 8 sites; } ^*\text{Signif. diff. from pretraining value, } p < 0.05; \)

| Table 2 |
|-------------------|----------------------|
|                  | Serum testosterone (nmol \( \cdot \) L\(^{-1}\)) |
| Subject           | Pre | Post |
| Experimental      |     |      |
| JC                | 61  | 25.0 | 24.0 |
| HG                | 45  | 18.0 | 21.0 |
| RH                | 45  | 14.0 | 13.0 |
| FR                | 46  | 12.0 | 17.0 |
| WS                | 79  | 20.0 | 12.0 |
| RW                | 52  | 32.0 | 28.0 |
| Control           |     |      |
| BH                | 71  | 18.0 | 18.0 |
| IS                | 47  | 22.0 | 18.0 |
| NG                | 58  | 19.0 | 15.0 |
| JC                | 48  | 14.0 | 18.0 |

Aging a period of high-intensity resistance training in both young (4, 16, 17) and middle-aged (28) men. The results from the current study suggest that high-intensity resistance training in veteran male sprint runners does not produce similar chronic increases in basal serum testosterone. This is in agreement with previous studies which found no changes in serum testosterone in elderly sedentary men following resistance training (15, 25).

Taken together, the data suggest that aging individuals may lack the mechanisms to increase testosterone levels following resistance training. These mechanisms may include decreased activity of luteinizing hormone (23) and/or impairment of testicular function (6), both of which may decrease testosterone production.

In addition to a possible age related inability to elevate serum testosterone, several other factors may have contributed to the lack of an increase in serum testosterone following the resistance training program in the present study. First, the study’s training period may have been too short to elicit a chronic testosterone response. Previous studies demonstrating chronic elevations in testosterone in young men following strength
training have been conducted for 15 weeks or longer (4, 16, 17). The time course of the present study was only 8 weeks. Second, it has been suggested that chronic increases in serum testosterone in elite young weightlifters are more likely to occur if the resistance-training experience is 2 or more years (10). The veteran athletes in the present study had limited or no recent experience in resistance training.

A third factor affecting resting serum testosterone levels may be the time course of blood sampling after the last exercise bout (30). Furthermore, a recent study (5) has suggested diurnal rhythms in peripheral levels of hormones, including testosterone, in sedentary aging individuals. While every effort was made to control these factors by sampling at least 36 hrs postexercise, at the same time of day and early in the morning, the observed large individual variations in testosterone before and after training (see Table 2) may have masked possible changes in basal serum testosterone.

In confirming and extending previous reports of increased muscular strength following resistance training in sedentary aging individuals (1, 7, 9, 13, 15), the current study shows that veteran athletes who participate in a high-intensity resistance training program can significantly improve muscular strength. In this study, both lower and upper body isoinertial strength, as measured by the leg press and bench press, increased—by 25% for the lower body and 17.5% for the upper body. However, these percentage increases in isoinertial strength are significantly lower than those observed in earlier strength training studies on previously sedentary aging individuals (107–174%) (7–9). This may be due to the longer duration of the previous studies (>12 wks) or, more likely, the fact that our subjects were athletes who likely already possessed greater pretraining strength than the subjects in other studies.

Our results suggest that elevations in basal testosterone may not be responsible for strength gains in male veteran sprint runners following high-intensity resistance training. Several mechanisms have been suggested to explain strength gains following high-intensity resistance training in aging individuals. First, increased muscle cross-sectional area has been observed in previously sedentary aging populations following high-intensity resistance training (7–9, 13). Second, neurological adaptations such as increased coordination and motor-unit activation may enhance strength gains in aging individuals undertaking resistance training (24, 27). Third, several studies have suggested that intrinsic muscle property changes such as excitation/contraction coupling and muscle fiber composition changes may alter force production. For example, Brown et al. (3) reported increases in force production rates following resistance training in previously sedentary individuals.

In addition, it has been suggested that muscle membrane excitability may be enhanced following resistance training in older adults (19). Thus, while chronic changes in testosterone may not explain the increased muscular strength observed in the veteran athletes of the present study, any or all of the above factors may have contributed to the strength gains in the experimental group.

In conclusion, while acknowledging that the sample size is small, the results of the present investigation suggest that significant improvements in muscular strength are observed in veteran male sprint runners in response to 8 weeks of high-intensity resistance training. Furthermore, the current results suggest that the observed strength gains are not explained by changes in basal serum testosterone and may be due to a combination of neurological, physiological, and morphological factors that await further investigation.

**Practical Application**

The results of the present study suggest that hypertrophy resistance training leads to significant increases in both upper and lower body muscular strength of veteran male sprint runners. While it is common practice for younger sprint runners to undertake resistance training in order to improve muscular strength and power, the results of the present study strongly suggest that older sprint runners can also significantly improve upper and lower body strength through high intensity resistance training. Given the importance of muscular strength for speed and power development, hypertrophy resistance training of even short duration (8 weeks) may lead to improved sprint performance in male veteran sprint runners.

**References**


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