Hormonal Responses After Strength Training and Detraining in Prepubertal and Pubertal Boys

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ABSTRACT
Forty-two untrained prepubertal and pubertal boys formed 2 experimental groups, group STG1 (n = 9; 11–13 years old) and group STG2 (n = 13; 14–16 years old) and 2 control groups (groups CG1 and CG2) of the same age ranges and similar pretraining hormonal levels. Informed consent was obtained from the children and their parents. Groups STG1 and STG2 were submitted to a 2-month resistance training program (6 exercises, 3 × 10 repetition maximum, 3 times a week), followed by a 2-month detraining period. Blood samples were obtained to determine hormonal responses to training and detraining conditions. Their maturation stage was evaluated. Posttraining mean testosterone values of the STG1 and STG2 groups increased by 124 and 32%, respectively (p < 0.001), whereas the free androgen index mean value of the STG1 group increased by 74% (p < 0.005). Significant differences in serum testosterone existed between the experimental groups before and at the end of the training period. At the end of the detraining period, the mean hormonal parameters remained practically unaltered. We conclude that strength training stimulates the anabolic and androgenic activities differently in prepubertal and pubertal untrained boys.

Key Words: resistance training, androgens, untrained boys


Introduction
The participation of boys in resistance training programs has become popular recently, which—besides its apparent effect on strength (14, 22–24, 27, 31)—leads to a positive influence on their physical condition by parallel increase of their performance capacity in sports and to a protection from possible sports- or recreation-associated injuries (17). It also improves the quality of their life, giving them the chance to develop habits influencing their health positively, and changing their attitude toward wellness for a long life (28). Different hormones, such as testosterone (T), cortisol, thyroid-stimulating hormone, growth hormone, and immunoglobulin F, control the skeletal muscle tissue (5). These hormones are influenced by resistance training, thus changing the mechanisms of catabolic-anabolic muscle process, which leads to the synthesis of new muscle proteins (33). Data on the influence of prolonged resistance training and detraining on androgen levels of adults are contradictory because of inherent methodological differences of the relative studies (1, 7–12), although a relative lack of similar information about prepubertal, pubertal, and adolescent boys exists (6, 19, 20).

Therefore, our purpose was to investigate the influence of a short (2-month), supervised, progressive resistance training program with isotonic equipment and a 2-month detraining program on T, sex hormone-binding globulin (SHBG), and free androgen index (FAI) blood concentration in 2 different age groups of untrained prepubertal and pubertal Greek boys.

Methods
Forty-two untrained high-school pupils, 11–16 years of age, were divided randomly into 4 groups: 2 experimental groups (STG1, n = 9, aged 11–13 years; and STG2, n = 13, aged 14–16 years) and 2 control groups (CG1, n = 10; CG2, n = 10; control groups were age-matched to the experimental groups). They participated voluntarily after information of the purpose of the study and the potential risks associated with a strength-training program and after obtaining written consent from their parents. The study was approved by the Department of Physical Education, University of Athens. The subjects' personal characteristics are given in Table 1. Their maturation stage was evaluated according to Tanner (29) on the basis of external gen-
italia and pubic hair development. All subjects underwent medical evaluation before their selection for the study.

**Experimental Design**

The experimental groups were submitted to a 2-month resistance-training program. The training program variables were designed according to the basic principles described by Kraemer and Fleck (16). Every training session included 3 sets of a predetermined 10 repetition maximum (RM) of 6 different exercises for the upper-body part in a variable resistance machine (supine bench press, wide grip cable, pull-downs, biceps curl, triceps extension, seated row, and overhead press). The exercise program was designed for the upper extremities because it is known that the legs of the boys are relatively stronger (23, 26), and in this context, the subjects might have been capable of greater strength gains after the end of the training protocol. Among the sets were a 1-minute rest and a 3-minute rest. The duration of the training sessions was about 60 minutes, and the training frequency was 3 times per week (48 hours between each training session). Each session was supervised by a coach and included a warm-up of about 10 minutes, with jogging, static stretching, light exercises of the involved muscle groups, and approximately 5–8 minutes of stretching to cool down. Every 15 days, the subjects were submitted to a test (10RM) to readjust the training effort. The training period was followed by a 2-month detraining period, during which the boys did not participate in any training program except their normal school physical education classes. Before the beginning of the 2-month training at the end of the second month, and at the end of the detraining period, blood samples were obtained from the antecubital vein in resting conditions for hormonal determination. The control groups were not subjected to resistance training but followed similar anthropometric test and blood assay protocols. No injuries resulted from the training sessions. A small number of subjects complained of acute pain and soreness in the initial 3 sessions, which disappeared after the first week of training followed by extra stretching exercises.

**Measurements**

**Blood Tests.** Approximately 5 mL of blood was drawn from a forearm (antecubital) vein using a gauge needle-Vacutainer setup. The blood was allowed to clot at room temperature (22° C), and the serum was separated by centrifugation at 3,000 rpm for 15 minutes and stored at −30° C for later analysis (within 30 days). T was determined using a commercial radioimmunoassay kit (Direct Testosterone I\(^{125}\), Farmos ORION Diagnostica, Finland). Intra-assay and interassay variations were 4.6 and 4.9%, respectively, and the assay sensitivity was 0.30 nmol/L. The specificity was good, with minor cross reactions. SHBG was determined using the IRMA method of Farmos ORION Diagnostica. Intra-assay and interassay variations were 3.2 and 5.5%, respectively, with a sensitivity of 0.5 nmol/L. All samples for T and SHBG were determined in duplicate (as well as the standard curve), and high- and low-quality control sera were included in the test. Duplicate values were satisfactory ($r'T = 0.96; r'SHBG = 0.98$).

Finally, the FAI was derived using the following:

$$\text{FAI} = \frac{\text{concentration of total T (nmol·L}^{-1})}{\text{concentration SHBG (nmol·L}^{-1})} \times 100$$

**Anthropometry.** All 42 subjects were measured for height, weight, and triceps and subscapular skinfolds. The last measurements were taken with a Harpenden skinfold caliper (13). All anthropometric and body composition measurements were taken on all 3 occasions by the same investigator previously controlled for his test-retest reliability ($r > 0.92$).

**Statistical Analysis**

A 3 × 2 multivariate analysis of variance was used to test statistical differences among the 3 phases of the experimental design and among the experimental groups in hormonal variables. Gain analysis was used for the percentage of the timing alterations after determining the significant differences among mean val-

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**Table 1.** Anthropometric characteristics of experimental and control groups (mean ± SD).*

<table>
<thead>
<tr>
<th>Group</th>
<th>$n$</th>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Body fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STG1</td>
<td>9</td>
<td>$11.78 \pm 0.84$</td>
<td>152.18 ± 5.91</td>
<td>43.02 ± 9.5</td>
<td>14.05 ± 3.11</td>
</tr>
<tr>
<td>CG1</td>
<td>10</td>
<td>$12 \pm 0.82$</td>
<td>156.82 ± 8.68</td>
<td>43.18 ± 10.74</td>
<td>12.74 ± 2.64</td>
</tr>
<tr>
<td>STG1 - CG1</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>STG2</td>
<td>13</td>
<td>$14.92 \pm 0.86$</td>
<td>169.06 ± 9.25</td>
<td>55.47 ± 9.03</td>
<td>12.76 ± 3.10</td>
</tr>
<tr>
<td>CG2</td>
<td>10</td>
<td>$14.9 \pm 0.88$</td>
<td>166.47 ± 4.95</td>
<td>56.82 ± 5.96</td>
<td>13.67 ± 3.17</td>
</tr>
<tr>
<td>STG2 - CG2</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

* STG1 = experimental group 1; STG2 = experimental group 2; CG1 = control group 1; CG2 = control group 2; NS = not significant.
The primary findings demonstrated that 2 months of strength training resulted in significant increases in the level of T in STG1, STG2, and FAI of STG1, respectively. These postraining changes were in reverse ratios compared with the pretraining ones and were maintained after a 2-month detraining period.

Before the beginning of the program, each experimental group and the age-matched control one had
Table 6. Pretraining hormonal concentration of experimental and control groups (mean ± SD).*

<table>
<thead>
<tr>
<th>Group</th>
<th>T (nmol·L⁻¹)</th>
<th>SHBG (nmol·L⁻¹)</th>
<th>FAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>STG1</td>
<td>4.9 ± 5.7</td>
<td>69 ± 30.9</td>
<td>15.6 ± 26.1</td>
</tr>
<tr>
<td>CG1</td>
<td>6.1 ± 4.4</td>
<td>64.2 ± 21.8</td>
<td>12.7 ± 15.1</td>
</tr>
<tr>
<td>STG1 - CG1</td>
<td>−1.2 ± 2.4</td>
<td>4.8 ± 12.4</td>
<td>2.8 ± 9.9</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>STG2</td>
<td>14.6 ± 4.2</td>
<td>42.5 ± 9.1</td>
<td>36.1 ± 14.4</td>
</tr>
<tr>
<td>CG2</td>
<td>13.9 ± 2.9</td>
<td>44.9 ± 11.5</td>
<td>32.2 ± 10.2</td>
</tr>
<tr>
<td>STG2 - CG2</td>
<td>0.7 ± 1.5</td>
<td>−2.4 ± 4.4</td>
<td>3.9 ± 5.1</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

* T = testosterone; SHBG = sex hormone binding globulin; FAI = free androgen index; NS = not significant; STG1 = experimental group 1; STG2 = experimental group 2; CG1 = control group 1; CG2 = control group 2.

The resistance training followed in this study seems to stimulate Leydig cell activity and leads to an increase in the T levels in a manner reverse to the age, the different development stages, or the mean pretraining hormonal concentrations of the boys. Specifically, the mean posttraining T concentration of STG1 increased by 123%, whereas the STG2 group’s respective increase, which was 3 times greater than that of STG1, rose by 32%. These results are in contrast to those of another study in which high school pupils were submitted to an acute exercise in cycloergometer. In that study, no significant differences were observed between groups of different biological age with regard to pretraining and posttraining T concentrations (4).

Our results are not completely comparable to those of other researchers (6, 19, 20), owing probably to the methodological differences of the training protocols. In fact, Mersch and Stoboy (20) submitted only 3 prepubertal twins to isometric training, whereas Mero et al. (19) examined the annual influence of different training programs (tennis, weight training, endurance, and speed training) on the T and SHBG levels of prepubertal and pubertal boys. It must be noted that despite these differences, Mero et al. (19) found respective increases in the T levels (98%) after the end of the training programs, which is in accordance with our results. Furthermore, Fry et al. (6) submitted 28 elite adolescent male weightlifters with a maturity status similar to the subjects in this study to a relatively short (1-week) but high-volume resistance training. The observed significant T levels decreases because of the intensity of the training might not apply to other populations (untrained boys), because the training experience and the resulted physical condition of the subjects (18) could lead to different chronic adaptations of the hypothalamic-pituitary-gonadal axis.

The relative posttraining FAI increases of STG1 (74%; p < 0.005) and STG2 (98%; not significant), because of the unchangeable and nonsignificant SHBG response, underline the importance of the findings, as it is well known that FAI is an index of biological active unbound T (free T), which is available to tissues, and demonstrate whether the subjects are trainable or not (1, 10).

It has been well documented that increases in strength after resistance training in prepubertal subjects are probably caused by modifications of their neuromuscular activation and changes in intrinsic contractile characteristics of the muscles (3). The results of this study may provide some evidence as to the potential role of T in strength acquisition, influencing neural factors (17), and the possible muscle fiber transition of type II to more glycolytic profiles (2, 15).

Little information about the changes of T and FAI
exist in the resistance exercise detraining period in prepubertal and pubertal boys. Although the resistance-training adaptations of trained athletes or sedentary subjects may not relate to prepubertal and pubertal boys because of the large physiological differences, it is of interest to note that in trained boys, no significant differences were observed in this period (1, 9). On the contrary, other workers (12) found an increase in T and a significant decrease in cortisol, possibly because of the anabolic process after the end of the training program and its antagonism on protein degradation during the detraining period (33). The lack of significant changes during the detraining period reveals that the exercise-induced gains for T and FAI were maintained until the end of this period. This may be implied by the significant STG1 and STG2 T and STG2 FAI posttraining differences from the pretraining values (Tables 4 and 5).

By and large, one may conclude that the 2-month resistance training resulted in significant increases in the T concentration in prepubertal and pubertal boys; the extent of these changes was in reverse ratio to the pretraining status; and the posttraining gains were preserved for 2 months after the end of the training program.

Practical Applications

The significant increases in T and FAI during the short-term training program as well as the T and FAI concentrations, which remained practically unaltered after the end of the detraining period, are of great importance, revealing the subjects’ satisfactory potential trainability status, and this information may be useful to coaches for designing the periodization (especially the rest periods) of strength-training programs for athletes to strength training in two years. In: Children and Exercise 13. S. Oseid and K-H. Carlson, eds. Champaign, IL: Human Kinetics, 1989. pp. 165–183.

References


**Acknowledgments**

We would like to thank all of the participants and their parents for their enthusiastic contribution and patience shown during the project. We are also thankful to Dr. S. Chantzikonstantinou, Professor of Sports Medicine, Department of Physical Education and Sports Science, University of Athens, for his comments; to Dr. D.A. Adamopoulos, MD, PhD, Chief Endocrinologist, Helena Venizelos Hospital, for reviewing and correcting our manuscript; to Dr. A. Vagenas, Assistant Professor of Statistics, Department of Physical Education and Sports Science, University of Athens, for his advice; and to Mr. K. Tsolakis, Director of Biochemistry Laboratory, Sotiria Hospital, for his expert technical assistance.