Neuromuscular adaptations and serum hormones in women during short-term intensive strength training

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Summary. The effects were investigated in ten women of intensive heavy resistance strength training lasting for 3 weeks on electromyographic (EMG) activity, muscle cross-sectional area (CSA) and voluntary force production characteristics of leg extensor muscles. Blood samples for the determinations of serum hormones were taken from five of the subjects. Significant increases occurred in the higher force portions of the isometric force-time curve with an increase of 9.7 (SD 8.4)% (P<0.01) in maximal peak force. An increase of 15.8 (SD 20.9)% (P<0.05) took place also in the maximal neural activation (integrated EMG) of the trained muscles, while an enlargement of 4.6 (SD 7.4)% (P<0.05) occurred in the CSA of the quadriceps femoris muscle. Maximal force per muscle CSA increased significantly (P<0.05). No statistically significant changes were observed during the training in the mean concentrations of serum testosterone, free testosterone, cortisol and sex hormone binding globulin (SHBG). The individual concentrations of serum testosterone:SHBG ratio correlated with the individual changes obtained during the training in the muscle CSA (r= 0.99; P<0.01). The present findings in women indicated that the increases in maximal strength during short-term but intensive strength training were primarily due to the increased voluntary neural activation of the trained muscles, while muscle hypertrophy remained limited in magnitude. Large interindividual differences in women in serum testosterone concentrations could indicate corresponding differences in muscle hypertrophy and strength development even during a short-term but intensive strength training period.

Introduction

It is generally agreed that initial increases in maximal strength especially among previously untrained subjects may be accounted for largely by the increased voluntary neural activation of the trained muscles, while muscle hypertrophy will have a gradually increasing role in strength development as the training proceeds. This seems to be true both in men and women (e.g. Moritani and DeVries 1979; Cureton et al. 1988; Häkkinen et al. 1989).

Androgens reportedly play an important role in strength training. The sex differences therefore become very apparent with regard to the absolute magnitudes of muscle mass and strength after prolonged strength training of several months or years (e.g. Häkkinen 1989a).

The purpose of the present study was to examine in women the effects of short-term but very intensive strength training on the neuromuscular system as well as on serum levels of endogeneous hormones. Because the interindividual differences in basic serum testosterone concentrations are known to be relatively high in women, it was in addition of physiological interest to examine whether this would also reflect interindividual differences in muscle hypertrophy and/or strength development even during short-term strength training.

Methods

Subjects. Ten women volunteered for the study. Their mean age was 28.9 (SD 4.8) years. They were physically active but did not have a background of regular strength training. Table 1 presents their physical characteristics.

Experimental strength training. The subjects participated in a supervised 3-week period of strength training. In general, the subjects trained intensively the same muscle groups every 2nd day. The intensity and volume of strength training was maintained at a high level for the first 2 weeks of the entire experimental period. The overall volume of strength training was reduced during the last (3rd) week of training, but the intensity of the training was still maintained at a high level. The 1st day of training in the last
Table 1. Physical characteristics of the subjects before and after 3 weeks of strength training

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>SD</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>60.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>24.0</td>
<td>4.0</td>
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</table>

The cross-sectional area (CSA) of the quadriceps femoris (QF) of the right thigh was measured with a compound ultra-sonic scanner (Aloka Fasonic, SSD-190) and 5 MHz convex transducer before and after the 3-week experimental period. The CSA was measured at the midpoint between the greater trochanter and lateral joint line of the knee. The CSA of the QF was then calculated from the picture by a computerized system of the apparatus (Ryushi et al. 1988).

The percentage of fat in the body was estimated from the measurements of skinfold thickness (Durnin and Rahaman 1967).

Analytical methods. At 8 a.m., after 1 rest day and after 12 h of fasting and 8 h of sleep, blood samples were drawn from the antecubital vein of five subjects. Serum samples for the hormone and sex hormone binding globulin (SHBG) determinations were kept frozen at -20 °C until assayed. The assays of serum cortisol and testosterone were performed by radio-immunoassays using reagent kits from Farmos Diagnostica (Turku and Oulunsalo, Finland). Serum free testosterone concentrations were measured using RIA kits obtained from Diagnostic Products Corporation (Los Angeles, Calif., USA). The concentrations of serum SHBG were determined by fluorescent-immunometric methods using reagent kits from Wallace Oy (Turku, Finland). All assays were carried out according to the instructions of the manufacturers.

Conventional statistical methods were used for calculation of means, standard deviations (SD), standard errors of the mean (SEM) and coefficient of correlation. Differences between the values before and after the training period were tested for significance by Student's paired t-test (two tailed).

Results

A significant (*P<0.01) increase from 2212 (SD 558) to 2431 (SD 664) N took place in the maximal isometric force of the experimental group during the 3-week training period (Fig. 1). The increase in maximal force was already significant (*P<0.05) after the first 2 weeks of training but the force reached its highest average value at the very end of the last reduced training week. A significant (**P<0.05) increase took place during the 3-week training period in the averaged maximal iEMG of the muscles examined in the subject group (Fig. 2). The averaged maximal iEMG of the trained muscles reached its highest average value also at the very end of the last reduced training week.

![Fig. 1. Mean and SEM maximal voluntary isometric leg extension force in the women before, during and after 3 weeks of strength training. * P<0.05, ** P<0.01](image)