A NUMBER OF ADAPTATIONS to endurance exercise occur quite rapidly. Increases in maximal \( O_2 \) uptake are seen within 1 wk of the beginning of exercise (15), and the half times \( t_{1/2} \) of the increase in maximal \( O_2 \) uptake are the same (between 10 and 11 days) after successive time courses of training (17). The \( t_{1/2} \) of the increase in ven- tricular mass and cardiac and skeletal muscle mitochondrial proteins are 5–7 days after the onset of endurance training (2, 18). By comparison, there is also evidence for a rapid response to resistance-type exercise. Strength accumulation is seen as early as 1 wk after the onset of heavy-resistance training in previously untrained individu- als (14). Additionally, the results of isometric contraction studies obtained over 30 yr ago indicate that isometric strength improvement proceeds for several weeks until a plateau is reached (see Ref. 25). Yet the rate of strength development in response to a resistance-type exercise; weight training; androgens; glucocorticoids; testoster- one; cortisol; prolactin; muscle fiber types; muscle fiber area; thigh girth, skinfold thickness

Steroid hormones are known to have profound and opposing effects on muscular growth (22). Androgenic compounds, principally testosterone, exert anabolic actions, whereas glucocorticoid hormones, pri- marily cortisol, exert catabolic effects in skeletal mus- cles. The relationship between strength, muscle mass, and testosterone in particular is not firmly established, but it is assumed that high circulating levels enhance or facilitate the building of muscle mass in humans. These observations are based primarily on the widespread use of anabolic steroids among body builders and athletes participating in strength, speed, and power events (22). In general, steroid hormones are found to increase in the circulation of males in response to heavy-resistance training sessions, although diurnal variations can influ- ence the outcome (4, 8, 21, 27). In females the responses are more variable (3, 4, 27). The contribution of anabolic and catabolic steroid hormones to strength training, in response to a constant exercise stimulus in which there are rapid and slow phases of strength development, has not been studied in any detail. Existing data indicate little or no changes in resting steroid hormone levels in strength-trained individuals or after an extended train- ing period (6, 9, 7, 11), but several studies indicate posi- tive correlations of resting androgen concentrations and/or the changes in the concentrations with certain strength-associated measures (7, 12, 13). Therefore, a third aim was to determine whether the potential for ex- ercise to increase serum androgens (testosterone) and glucocorticoids (cortisol) is related to specific phases of strength development. The experimental design of the strength time courses permitted testing of 1) whether the highest resting and exercise-induced increases in serum androgens in response to a constant exercise stimulus are seen during the most rapid phase on the strength-re- sponse curve and 2) whether the serum hormone levels are also dependent on exercise intensity. In addition to cortisol, the responses of prolactin, another stress hormo- ne, were also determined.
Subjects and training program. Ten subjects (5 males and 5 females) volunteered to participate in the study. They had an average height of 176 ± 3 cm and an average age of 28.8 ± 1.3 yr at the start of the program. Eight of the subjects had limited or no weight-training experience, whereas two subjects had performed regular resistance training previously. Of these two, one individual was not included in the bench press phase, since recent training in this exercise had been ongoing up to several months before the start of this study. The other subject had not trained for several years. Most of the subjects were active recreationally, and one subject swam competitively three to four times per week at the club level. None of the subjects was taking any type of medication. Because blood was sampled weekly for the first several weeks, no control for menstrual cycle differences was attempted.

The exercise program consisted of weight training 3 days/week. The following exercises were performed: bench press and parallel squats using Olympic-style weights, five sets of five repetitions; and knee extensions, knee flexions, and standing triceps-pressdowns on a Universal Gym, three sets of five repetitions. Exercises were performed at a resistance that was initially 80% of the one-repetition maximum (1 RM) in the bench press and parallel squat or were performed with as much weight as possible for the required repetitions in the other exercises. Each subject’s resistance (training work load) was kept constant over the first 8 wk of training. The sets were separated by 2 min rest periods. The bench press and squats were performed at a cadence corresponding to 13 repetitions/min. After the initial 8 wk of training, resistance was increased to the new 80% of the 1 RM and the same protocol was followed as described above. The higher training loads were maintained with out change for an additional 8 wk. Differences in strength levels between the end of the first and beginning of the second time course were due to the withdrawal of one subject from the study and injury to another subject in the parallel squat exercise (see Table 1). Overall, this program might be considered as a low- to moderate-volume regimen. However, the exercise intensity (80% of 1 RM) is considered high, at least during the initial days of each time course, on the basis of the following results. The maximum number of repetitions that could be performed at this intensity was 7.6 ± 0.5 for the bench press and 8.0 ± 0.4 for the parallel squat. Thus, when incorporated into a five-repetition-five set training mode with 2-min rest periods, the exercise stress was at or near the limits initially of what the subjects could complete.

Measurement of strength. Upper body and lower body strength was assessed by determining the maximum amount of weight that could be lifted for one repetition in the bench press and parallel squat, respectively. Requirements for the bench press included 1) the grip width could not be wider than 1 m and 2) the weight was stopped on the chest in the lowest point of the lift. In the parallel squat, the required lowest position was reached when the line of the femur was parallel to the ground. The subjects were familiarized with all procedures before testing and were evaluated several times within a 3- to 4-wk period. They performed multiple single repetitions against increasing work loads to failure with ~3-4 min elapsing between lifts. Test-retest correlations for testing dates, in which the highest values at failure were observed, were r > 0.99 for the bench press and r = 0.95 for the parallel squat. The criterion for determining strength was the inability to complete a single repetition. Subsequent strength testing was performed on the 1st day of each training week (Monday), which was separated by 72 h from the last training session.

To evaluate the effect of the weekly testing procedures, weekly measurements of strength were also made on five additional subjects (4 males and 1 female) who served as controls during the study. They received the same testing procedures as the experimental subjects but did not receive the training.

Hormone testing and assay methods. Serum hormonal responses to the training protocol were measured on the 1st training day and, thereafter, after 1, 2, 3, 5, 7, 9, 15, and 16 wk of training. These tests were performed on the 2nd training day (Wednesday) of the following week, because strength testing was performed on the 1st weekly training day. The subjects had not exercised before the testing, and they maintained the same or similar diets on this testing day throughout the study. The tests were performed between 12:30 P.M. and 5:00 P.M. However, the time of testing for each subject remained relatively constant (within 1 h of appointment) throughout as they were studied sequentially. Blood samples were taken from an antecubital vein with either 20- or 22-gauge needles before the exercise and after ≥ 15 min of rest and were obtained as soon as possible on completion of training (<5 min). A portion of the sample was taken for hematocrit, and the remaining sample was allowed to clot, was centrifuged, and was stored at −20°C until analysis. In the male subjects, the hormonal evaluation for the second training period was not completed because of injury to one subject and scheduling difficulty for others on several occasions. Hormone assays were performed in a single batch after the end of the study.

Plasma cortisol was assayed without extraction after dilution in 0.01 M citrate buffer, pH 4.0 (26). The endogenous steroids cross-reacting >0.1% were 11-deoxycortisol (17.4%) and corticosterone (5.4%). The sensitivity of the assay (2SD at the lowest range) was 17 ng/ml. The interassay coefficient of variation (CV) of the last 20 assays (mean 93 ng/ml) was 19%; the intra-assay CV was 11% (mean 112 ng/ml).

Testosterone was measured in plasma by a direct radioimmunoassay with materials, including 125I-labeled testosterone, from Pantex (Santa Monica, CA). Antibody-bound testosterone was precipitated from plasma by the addition of a secondary antibody in polyethylene glycol. The sensitivity of the assay (2SD at the lowest standard) was 10.0 ng/dl. The interassay CV of the last 20 assays (mean 504 pg/ml) was 15%; the intra-assay CV was 9.9% (mean 49 ng/dl). The steroids that cross-reacted with the antiserum >0.1% were dihydrotestosterone (1.7%), 5α androstane-3α,17α-diol (0.8%), and ethisterone (1.3%).

Prolactin was assayed with materials obtained from the National Hormone and Pituitary Program of the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) at the University of Maryland according to recommendations with the material. The reference and iodination materials for the prolactin assay were NIDDK-hPRL-RP-1 and NIDDK-hPRL-I-7, respectively. Antiserum was NIDDK-anti-hPRL-3. Iodinations and radioimmunoassays were conducted essentially as described by Hwang et al. (20). The sensitivity of the assay based on 2SD at the lowest standard was 2.1 μg/ml. The interassay CV of the last 20 assays (mean 504 pg/ml) was 15%; the intra-assay CV was 11% (mean 9.1 ng/ml).

Girth, skinfold, and skeletal muscle analyses. Thigh girth on each leg was measured as described previously (19). Skinfold thickness was measured at the following sites: triceps, subscapula, abdomen, supraillia, pectorals, anterior thigh, and axilla. Measurements were made before the strength training and at the end of the first (8 wk) and second (16 wk) training periods.

Muscle samples (30-70 mg) from the lateral portion of the quadriceps muscles (vastus lateralis) were obtained from nine subjects at rest and before and after the first and second training periods according to the percutaneous needle biopsy procedure of Bergstrom (1). The samples were processed and analyzed for fiber type and fiber area as performed earlier (16). The fiber typing was based on 511 ± 42, 488 ± 67, and 454 ± 22 fibers/subject at each biopsy. Generally, at least 50 fast-twitch
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TABLE 1. Adaptive changes in bench press and parallel squat strength during the two training periods

<table>
<thead>
<tr>
<th>Week of Training</th>
<th>n</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First training period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bench press</td>
<td>9</td>
<td>59.6±10.1</td>
<td>67.4±10.7†</td>
<td>63.6±11.1‡</td>
<td>65.4±11.6†</td>
<td>66.7±11.7†</td>
<td>67.2±11.7†</td>
<td>68.7±11.9</td>
<td>68.9±11.9</td>
<td>68.9±11.9</td>
</tr>
<tr>
<td>Parallel squat</td>
<td>10</td>
<td>35.2±14.0</td>
<td>101.1±13.4*</td>
<td>105.5±13.8*</td>
<td>108.1±13.9*</td>
<td>112.0±14.6*</td>
<td>113.0±14.5†</td>
<td>114.5±14.5</td>
<td>115.5±14.6</td>
<td>115.5±14.6</td>
</tr>
<tr>
<td><strong>Second training period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bench press</td>
<td>8</td>
<td>72.4±13.1</td>
<td>73.6±13.0</td>
<td>73.9±13.2</td>
<td>75.0±13.1</td>
<td>75.0±13.1</td>
<td>75.9±13.4</td>
<td>76.4±13.5‡</td>
<td>76.4±13.5‡</td>
<td>76.7±13.3</td>
</tr>
<tr>
<td>Parallel squat</td>
<td>11.2±13.6</td>
<td>112.8±13.8</td>
<td>113.9±13.8‡</td>
<td>115.1±13.4</td>
<td>117.0±13.8‡</td>
<td>117.3±14.0</td>
<td>117.9±14.0</td>
<td>119.0±13.9</td>
<td>119.6±13.8</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean ± SE in kg; n, no. of subjects. * Significantly different from preceding week; † significantly different from 2 wk earlier; ‡ significantly different from 3 wk earlier.

RESULTS

**Increase in bench press strength with training.** Upper extremity strength increased 16% from 59.6 to 68.9 kg during the first 8-wk period of training (Table 1). The changes occurred rapidly, with values significantly higher after the 1st wk of training. From this point through the 6th wk, values were significantly different at 2-wk intervals. There was no change in strength over the last 3 wk of this training phase. For the second training period, strength improved by 6% from 72.4 to 76.7 kg. However, increases were not significant until after 2 wk of training and were not increased again until after 5 wk. Values over the last 3 wk were essentially the same. The overall improvement from both training periods was 22%.

The five control subjects who were tested weekly for 8 wk increased their strength from 66.8 ± 9.1 kg to 70.0 ± 9.5 kg. Thus, the repeated testing alone has the potential to induce small strength improvements.

For calculation of the $t_{50}$ of the rate of strength development in response to the two training periods, we made the assumption that the increase was exponential. As shown in Fig. 1, the $t_{50}$ was 13.9 days for the first training period. For males the $t_{50}$ was 14.5 days, and for females it was 10.1 days. The $t_{50}$ for the second training period was 12.5 days (data not shown).

**Increase in parallel squat strength with training.** Lower extremity strength in this exercise increased by 21% from 95.2 to 115.5 kg during the first 8-wk time course. Week-to-week improvement was observed for the first 4 wk of training, and strength levels remained constant over the last 3 wk of training (Table 1). The calculated $t_{50}$ of the increase was 9.8 days (Fig. 1). For males the $t_{50}$ was 10.5 days and for females 9.0 days. In the second training period, overall strength gains were 7% from 112.2 to 119.6 kg. As with the bench press, the increases were not significant until after 2 wk of training. Further improvement was seen after 4 and 7 wk of training. An estimation of the $t_{50}$ of the second time course was not made, since no clear-cut leveling-off was seen from the data, although the rate of improvement was slower than that observed during the first time period. Strength was increased by 29% after both training phases. Parallel squat strength in control subjects improved somewhat with the weekly testing. Values were initially 96.4 ± 11.3 kg and increased to 99.1 ± 12.0 kg by the end of the 8-wk testing period.

**Total body and skeletal muscle effects.** Average body mass and sum of skinfolds remained unchanged after 8 and 16 wk of training. Thigh girth was increased only after the second training period (Table 2). Vastus lateralis muscle fiber composition was nearly identical at all three measurement points. In specific fiber types, slow-twitch fiber area was not significantly increased after the first or second training periods, although a 9% improvement was seen at the end of the 16-wk training program. Type II fiber area was significantly increased by 19% after 16 wk of training. Enlargement was 18% in the males and 22% in the females.

**Hormonal responses to training.** In males, resting concentrations of serum testosterone, cortisol, and prolactin remained constant throughout the 9-wk period studied (Fig. 2). In response to the training sessions, serum testosterone levels were significantly increased by 22–53% at all but the 7-wk time point of the first training period. Serum cortisol concentrations were significantly elevated after exercise after 1 day and 2 and 3 wk of training. Thereafter, the exercise sessions did not produce a significant elevation in serum cortisol. Prolactin concentrations were increased between 30 and 86% immediately after the training sessions of the first training period, although only values at the 1st day of training attained statistical significance. The small increments in hematocrit (~2%) indicated that plasma volume differences were small.

and 50 slow-twitch fibers per subject (with one exception where 50 slow-twitch fibers were not found) were measured for the fiber area determinations.

**Statistical procedures.** The data were analyzed with repeated-measures multivariate and univariate analysis of variance. These data were analyzed according to the SYSTAT program of Wilkinson (28). All of the responses to the exercise program besides the hormone results were the same regardless of sex; thus, these data were combined for analyses. Because of differences in resting testosterone concentration between males and females and the sex-specific responses of cortisol and prolactin to the testing, the hormonal data were analyzed separately. In view of the small sample sizes, the hormonal data sets were not normally distributed, but the skewness for each variable remained relatively homogeneous throughout each testing week. The assumption of homogeneous variances was met for all resting hormonal data sets with the exception of the female prolactin values. However, the analysis of variance is relatively insensitive to departures from these assumptions (5). Statistical significance was set at the 0.05 level.
DISCUSSION

In previous studies from this laboratory, we have observed that parallel squat strength increased linearly on a week-to-week basis in response to a heavy-resistance training program designed to increase lower extremity strength (14). It was not possible to determine the \( t_{1/2} \) of the strength response to the training stimulus because the training intensities were increased each training session (14). To estimate a \( t_{1/2} \) of response to a specific training stimulus, the absolute resistance must remain constant, otherwise the \( t_{1/2} \) of strength improvement would be determined not only by the time course of the adaptive response but also by the time course of the increase in intensity of the training stimulus.

Theoretically, an accurate determination of the \( t_{1/2} \) of the adaptive increases in strength would require having the subjects perform the same exercise every day. For several reasons, a deviation from this experimental design was thought necessary. The selection of a 3-day/wk training protocol was based on observations that many strength-oriented exercise programs perform the same exercises 3 sessions/wk with at least 1 day of rest between training days. It is commonly thought that heavy-resistance training regimens of the type currently employed require 48–72 h of rest to optimize the recovery processes (i.e., muscular soreness). Consequently, although a higher training frequency has the potential to induce a shorter \( t_{1/2} \) of the adaptive increase in strength, the 3-day/wk stimulus represented a compromise between observing a more “accurate” \( t_{1/2} \) and possible incomplete recovery so that the same training sessions would not be able to be completed on a regular basis without interruption. In addition, the training injury to one subject during the second training period suggests that other components of strength training and injury prevention need to be included to minimize injury.

For the first 8-wk training period, the \( t_{1/2} \)’s for upper extremity (14 days) and lower extremity (10 days) strength development support previous observations that strength acquisition develops rapidly with heavy-resistance training. There was also good agreement in the time course responses between two widely different muscle regions and types of exercise. The findings also support the concept that the relative training stimulus was essentially the same for both muscle areas.

Strength development involves the coordinated functioning of several processes within the body. Among these components, the ability to generate maximal force has been attributed to both neural and muscular components (see Refs. 23, 24). Contributing neural factors include the number, rate of firing, synchronization, and coordination of motor units, as well as protective inhibitory mechanisms. Muscular factors include fiber type, contractile protein composition, amount of muscle mass, and musculoskeletal relationships (i.e., tendon attachments). It is believed that the neural contribution has the initial predominant role that is responsible for strength acquisition (23, 24). With prolonged training, the participation of the muscular adaptation is considered to become more important to the adaptive response (23, 24).

On the basis of the involvement of both neural and
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TABLE 2. Total body and skeletal muscle effects in response to two successive resistance training time courses

<table>
<thead>
<tr>
<th>Training State</th>
<th>Body Mass, kg</th>
<th>Skinfolds, cm</th>
<th>Thigh Girth, cm</th>
<th>Fiber Type, (% fast twitch)</th>
<th>Fiber Area, μm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before training</td>
<td>78.3±6.4</td>
<td>119±18</td>
<td>54.3±1.7</td>
<td>59±3</td>
<td>4,956±252</td>
</tr>
<tr>
<td>After 1st training period</td>
<td>78.9±6.5</td>
<td>118±16</td>
<td>54.7±1.8</td>
<td>60±4</td>
<td>4,956±311</td>
</tr>
<tr>
<td>After 2nd training period</td>
<td>79.5±6.4</td>
<td>121±15</td>
<td>55.5±1.4*</td>
<td>58±4</td>
<td>5,385±400</td>
</tr>
</tbody>
</table>

Values are means ± SE; n = 9 subjects, except for skinfold and thigh girth determinations, n = 7 subjects. * Significantly different from before training.

Intramuscular processes in the response, we anticipated that the t₁'s of the first time course would be faster because of a rapid neurogenic adaptation, whereas the second time course t₂'s would be slower and would reflect adaptations within the muscle (i.e., hypertrophy). However, on the basis of the t₂'s, this pattern of response was seen in parallel squat strength but not in bench press strength, where both time course results were about the same with t₂'s of 14 and 13 days. One explanation for this apparently different pattern between the two types of exercise was that the factors contributing to the strength improvement varied. This could be related to a number of external variables, including daily usage patterns in which the lower body muscles are generally used more than the upper body muscles or even fiber type variation between muscle regions. An alternative explanation is that the much smaller increments in strength observed after the second time course than after the first time course may limit the interpretation as to whether actual differences in rates of strength development existed among muscle regions. Besides the t₂'s and the absolute and relative magnitudes of improvement between both

FIG. 2. Serum testosterone, cortisol, and prolactin concentrations in male subjects at rest and immediately after exercise during 1st time course and after 1st week (9th overall) of 2nd time course. There were 4–5 observations per measurement day.
time courses, there was additional evidence to suggest a greater training response to the first training period. On a week-to-week basis, significant differences in both upper and lower extremity strength were readily seen during the initial training period for the first several weeks, whereas in the second training period significant changes were observed after the first 2 wk of training and longer intervals were needed to obtain subsequent significant differences.

The strength results also offer the possibility that a shift in factors contributing to strength improvement had occurred. For example, even though there was no change in fiber type throughout the entire 16-wk program, on the average increased muscle girth and skeletal muscle enlargement of fast-twitch fibers in vastus lateralis muscles were found only after the second time course. Thus, at least some of the strength improvement in the second time course can be related to an increase in muscle mass. The fiber area effects in the quadriceps are also seen at a time consistent with the longer time course of adaptive improvement in strength.

The known effects of testosterone in increasing muscle mass and promoting positive nitrogen balance and the ability of androgenic-anabolic steroids (synthetic analogues of testosterone) to influence muscle growth have formed the basis for examining the androgenic responses to resistance types of exercise (22). Similarly, the participation of glucocorticoids, potential testosterone antagonists that have catabolic and muscle wasting effects in muscle when present in excess, are also considered im-

FIG. 3. Serum testosterone, cortisol, and prolactin concentrations in female subjects at rest and immediately after exercise during both time courses of training. There were 3-5 observations per measurement day.
important to the metabolic environment of muscle undergoing increased strength- and muscle mass-induced changes (22). Of the previous studies that have evaluated changes in serum hormones with strength development, experimental conditions were employed in which the relative stress remained constant or even increased during the course of training. Under these situations, basal androgen levels are not necessarily changed (6, 9, 7, 11), but changes in the serum testosterone to sex hormone binding globulin ratio (free androgen index) and in the testosterone-to-cortisol ratio have been demonstrated to have significant correlations to the changes in strength performance in men (7, 11). Furthermore, repetitive intense resistance exercise can even reduce resting serum testosterone levels when the overall training stress is exceptionally high for too long a period (10). In females, the serum testosterone response to resistance exercise bouts is inconsistent, as a number of studies report no change, whereas others observed small increases (3, 4, 27). It has been reported that women who demonstrate large inter-individual differences in basal serum testosterone concentrations have the high levels of this androgen that are important for muscle hypertrophy and for strength development (12, 13). Serum glucocorticoid levels in females are less well studied, with one report indicating cortisol increases in some but not all subjects (3).

By contrast, androgen and glucocorticoid hormone responses to resistance training were presently studied using a protocol in which the absolute training loads remained constant while the relative stress declined as strength increased. By determining steroid hormone levels throughout a complete training time course, we attempted to determine whether the serum responses of these hormones were associated with the development of strength and whether the changes were a function of absolute or relative exercise intensity. Although we were limited by studying only one complete training period in the males, serum cortisol exhibited a decline in response to exercise during the latter stages of the first time course as the increased strength levels had plateaued. Both serum testosterone and prolactin responses were significant during the initial phases of the first training period but were not when the relative exercise intensity was lower at the 7th wk. In females, serum testosterone changes were small and the training sessions were without effect on either serum cortisol or prolactin. A priori, there is no evidence to suggest a sex difference in the cortisol and prolactin responses to exercise between males and females. The differences in the cortisol and prolactin data between males and females indicate that the absolute magnitude of the work loads is an important factor in eliciting hormonal responses. Training resistances were, on average, 70–120% higher in the men. Thus the inability of the stress hormones cortisol and prolactin to increase with the training in women suggests that some critical absolute (not relative) amount of resistance may be required to elicit an effect.

In conclusion, the time course data showed an initial and rapid improvement in strength that is effective for ~6 wk of heavy-resistance training. However, when the same initial exercise is subsequently employed, strength development is reduced in magnitude and in rate for certain measures. These results do not disprove some current theories on the components involved in initial and continued strength accumulation. On the basis of the serum hormone results, an androgenic component was not observed in the processes associated with the rapid or slow phases of strength acquisition. The nature of the training program itself may not have been optimal for demonstrating an androgen effect on the strength-related variables, since the intensity can be considered high mainly during the initial days of each time course. This investigation also did not consider androgen interaction on anabolic processes within muscle cells. Additionally, hormonal responses by specific populations of athletes may have led to more significant effects and specific relationships between certain training variables than those presently observed. The variability in training background among the current group of training subjects may have also masked some of these responses. Thus the present hormonal responses and even time course effects should not be universally generalized to all types of strength training. Other training programs that involve different training intensities and volumes may produce different hormonal responses than those currently observed. For example, rapid progressive loading vs. maintenance of training load would likely lead to different hormonal as well as strength responses. Besides other programs, selected subject types, larger sample sizes, and even different exercises, including different measures of strength (i.e., dynamometers), are needed to further study this area.

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