Growth Hormone Response to an Acute Bout of
Resistance Exercise in Weight-Trained and Non-
Weight-Trained Women

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ABSTRACT

The serum growth hormone (GH) response of 6 non-weight-
trained (NWT) and 6 weight-trained (WT) eumenorrheic,
ovulatory women performing a heavy resistance exercise
protocol (HREP) in the early follicular phase was examined.
The HREP consisted of 7 different exercises and utilized a
moderate resistance (10 repetition maximum) with short rest
periods (1 minute). GH was evaluated preexercise, immedi-
ately postexercise, and 5, 15, 30, and 60 minutes postexercise.
A significant difference was observed between groups
(n = 6) for GH at preexercise, immediately, and 5 minutes postex-
ercise (p < 0.05). The integrated area under the curve (AUC)
for GH revealed no significant difference between groups
(n = 6). However, after removing 2 subjects who were outliers
(n = 5), significant differences in both the GH response over
time (p < 0.01) and AUC GH (p < 0.01) were observed be-
tween groups. The most notable findings were that WT
women demonstrated lower preexercise GH concentrations
than their NWT counterparts with all subjects (n = 6; WT
2.47 ± 1.27 µg·L⁻¹; NWT 4.99 ± 1.23 µg·L⁻¹, p < 0.01)
and with the removal of outliers (n = 5; WT 1.21 ± 0.21 µg
·L⁻¹; NWT 4.08 ± 1.0 µg·L⁻¹, p < 0.01). Additionally, the
HREP elicited a greater overall GH response in the WT
group (n = 5; WT 179.6 ± 59.5 µg·L⁻¹; NWT −15.1 ± 16.7
µg·L⁻¹) as reflected by the integrated AUC (p < 0.01). The
lower preexercise GH concentrations and greater overall GH
response of the WT group suggest that, in women, GH re-
sponse to resistance exercise varies with training status.

Key Words: eumenorrhea, human growth hormone, es-
trogen, hypertrophy

Reference Data: Taylor, J.M., H.S. Thompson, P.M.
Clarkson, M.P. Miles, and M.J. De Souza. Growth hor-
monereponse to an acute bout of resistance exercise
in weight-trained and non-weight-trained women. J.

Introduction

Muscle tissue hypertrophy and strength develop-
ment resulting from resistance training are well
documented in the literature (6, 7, 15, 29, 30). The
physiological stress of resistance training is a powerful
stimulus for secretion of anabolic hormones (17, 20).
Several androgenic hormones (e.g., human growth
hormone [GH], testosterone) may influence growth
and development (10); however, the exact mechanism
remains unclear (25). GH is responsible for many bi-
ological actions, including metabolic regulation and in-
creasing protein synthesis, as well as mediating the
release of insulin-like growth factor-I (IGF-1), another
potent anabolic factor (20).

Differences in muscle hypertrophy and strength
development between women and men as a result of
resistance training are typically attributed to higher
testosterone levels observed in men (17, 21, 20). How-
ever, while men exhibit a higher production of testos-
sterone, women still experience similar relative training
responses (13, 29). Studies have demonstrated that
acute heavy resistance exercise stimulates an increase
in circulating levels of testosterone in men (9, 22, 23,
25, 32), and similar protocols have resulted in elevated
concentrations of GH in women (21, 23). In the case of
muscle development in women, hormones other than
testosterone must be of particular importance given
their relatively low testosterone levels and their gen-
eral lack of testosterone responsiveness to a variety of
resistance exercise protocols (13, 21, 23, 32, 33). Ex-
amination of other trophic hormones, such as GH, has
only recently begun, and results from these studies
indicate the potential of this endogenous anabolic hor-
monal mechanism to be responsible for physiological
adaptations to resistance training in women (21, 23).

The effect of resistance-training status on the GH
response to a resistance exercise protocol has yet to be
examined in women, as current studies primarily use non–weight-trained (NWT) women (21, 23). We hypothesized that women with weight-training experience would have a greater GH response to the exercise stimulus than NWT women. Chronic training has been shown to induce changes in muscular strength, size, and power production, and that the magnitude of a hormone response may depend on these adaptations (20). Therefore, the purpose of this study was to examine the response of circulating levels of serum GH during the early follicular phase to an acute bout of resistance exercise in relation to resistance-training status (weight-trained [WT] vs. NWT) in women.

Methods

Subjects

Twelve healthy, ovulatory, eumenorrheic (EUC) women were used for this investigation. Subjects initially completed a menstrual cycle questionnaire to characterize their menses history. In order to participate in the study, the women had to be both eumenorrheic and ovulatory. Eumenorrheic status was defined as subjects having a consistently recurring menstrual cycle at intervals of 26–33 days. Ovulatory status was identified through the use of a commercially available kit (OVU-QUICK) that detected the midcycle urinary luteinizing hormone (LH) surge. Both of these conditions were maintained for at least 3 consecutive months throughout the course of the investigation. None of the subjects reported any endocrine disorders, ingestion of hormonal medication, or intrauterine device use within 6 months of the beginning of the study. All subjects signed an informed consent document in accordance with the institutional review board. Additionally, all subjects completed an exercise history questionnaire. Six women were assigned to the WT group (WT; n = 6), having at least 1 year of consistent weight-training experience, while the NWT group (NWT; n = 6) had no regular weight-training experience for at least 6 months prior to beginning the study. All of the subjects were asked to maintain the same aerobic and/or weight-training routine they were accustomed to during the course of the investigation.

Experimental Design

Prior to testing, subjects participated in a familiarization period that consisted of 4 total visits: 3 visits to familiarize subjects with the exercise protocol, and 1 visit for determining the 10 repetition maximum (10RM). The 10RM determination was a modification of the 1RM protocol outlined in Kraemer et al. (17). In addition to the 10RM determination, the subjects were led through the exercise protocol during the fourth visit to ensure the 10RM to be an appropriate stimulus, allowing for weight adjustments if necessary.

The resistance exercise protocol consisted of 3 sets of 10 repetitions (3 × 10RM) for 7 different exercises and was performed on a BodyMasters I multistation apparatus (BodyMasters, Rayne, LA). The bench press and leg press exercises were performed first and consisted of a warm-up set followed by 3 × 10RM. The exercise protocol proceeded with 3 × 10RM for seated shoulder press or dumbbell (DB) overhead press, leg extension, lat pulldown, standing biceps curl, and triceps pushdown (Table 1). The DB overhead press was substituted for the seated shoulder press if the lowest amount of weight on the resistance apparatus prevented subjects from completing the prescribed number of repetitions in the first set. One-minute rest periods were given between sets and exercises. This exercise protocol was designed to simulate a resistance-training routine that produces increases in muscular strength, hypertrophy, and high-intensity muscular endurance (17). The order of exercises, rest periods, and equipment used during this period were the same as that used for the testing protocol. Additionally, foot stance and hand grip were kept constant throughout the study by marking the distance on the equipment when the subject was in the starting position.

Test Day Protocol

Twenty-four hours prior to testing, subjects refrained from medications and/or nutritional supplementation, caffeine, and alcohol, as well as any other resistance or aerobic training (8, 25).

The exercise protocol was performed during the early follicular phase (EF; 2–4 days after the onset of menses) of the menstrual cycle. To date the effect of fluctuating estrogen levels during the menstrual cycle on the response of GH to an exercise stimulus remains equivocal (1, 11). Investigations examining the resistance exercise-induced GH response have predominantly been performed in the early follicular phase because low levels of estrogen and progesterone char-

<table>
<thead>
<tr>
<th>Table 1. Heavy resistance exercise protocol (HREP).</th>
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<tbody>
<tr>
<td>Exercise order</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Bench press</td>
</tr>
<tr>
<td>Leg press</td>
</tr>
<tr>
<td>Seated shoulder press or DB overhead press</td>
</tr>
<tr>
<td>Leg extension</td>
</tr>
<tr>
<td>Lat pulldown</td>
</tr>
<tr>
<td>Biceps curl</td>
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<td>Triceps pushdown</td>
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acterize this phase (13, 21, 23, 32, 33). Therefore, testing occurred in the early follicular phase to help minimize the estradiol environment. Preexercise 17β-estradiol and progesterone levels were used to confirm that all subjects fell within the expected range for the early follicular phase of the menstrual cycle.

All blood sampling was done at the same time of day, between 7:00 and 9:30 AM, to minimize the effects of diurnal variation on GH (13, 16, 21–25). Examination of serum GH profiles reflect lower pulse levels in the early morning (16). Subjects reported to the lab between 6:45 and 7:00 AM prior to the start of the exercise bout for the insertion of the indwelling cannula (−30 minutes) in a superficial arm vein, followed by a 20-minute equilibration period. The equilibration period has been shown to remove any possible “anticipatory” effects that may elevate resting hormonal values (1–4, 8, 23). Baseline blood samples were taken at 10 (−10) and 5 (−5) minutes prior to the exercise protocol, which began immediately after the final preexercise blood sample (−5 minutes) was taken. Additional blood samples were taken immediately postexercise and at +5, +15, +30, and +60 minutes postexercise. These times encompass the maximal postexercise hormone concentrations, as was previously observed following a variety of resistance-exercise protocols (25).

**Hormonal Assays**

Blood samples were allowed to clot at room temperature before being centrifuged at 1500 g for 15 minutes. Serum was then aliquoted into 3 microcentrifuge tubes and stored at −70°C for later analysis. The 22kDa immunoreactive GH was analyzed using a commercially available 125I double antibody radioimmunoassay kit (Diagnostic Products Corporation, Los Angeles, CA) in a single assay set. Intraassay variability was 5%. Assay sensitivity was 0.9 ng·mL⁻¹. Serum 17β-estradiol and progesterone were analyzed by a solid-phase, chemiluminescent enzyme immunoassay kit (Diagnostic) in single assay sets. Intraassay variability was 9.5 and 8.5%, respectively. Assay sensitivity was 44.0 pmol·L⁻¹ and 0.27 nmol·L⁻¹, respectively.

Samples were not corrected for plasma volume shifts because the uncorrected concentrations reflect what is actually occurring in the body and what the target tissue would be exposed to (5).

**Data Analysis**

All values are reported as mean ± SE, unless otherwise indicated. GH, 17β-estradiol, and progesterone data in the present investigation were analyzed over time by collapsing the temporal variable into an integrated area under the curve (AUC). The integrated AUC responses were quantified by subtracting the preexercise (baseline) concentrations and calculating the integrated AUC by the trapezoidal method (25).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Weight trained (n = 6)</th>
<th>Non-weight trained (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>26.3 ± 8.2</td>
<td>24.5 ± 5.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.1 ± 3.9</td>
<td>165.3 ± 6.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.3 ± 2.4</td>
<td>66.1 ± 9.2</td>
</tr>
<tr>
<td>Weight training (yr)</td>
<td>6.3 ± 4.0</td>
<td>0</td>
</tr>
<tr>
<td>Aerobic exercise (hrs/wk)</td>
<td>3.6 ± 2.6</td>
<td>4.7 ± 4.3</td>
</tr>
<tr>
<td>Age at menarche (yr)</td>
<td>13.0 ± 1.3</td>
<td>13.7 ± 1.9</td>
</tr>
<tr>
<td>Gynecological age (yr)</td>
<td>13.3 ± 8.6</td>
<td>10.8 ± 6.7</td>
</tr>
<tr>
<td>Menstrual cycle length (days)</td>
<td>29.2 ± 1.9</td>
<td>28.0 ± 1.7</td>
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</table>

All data were analyzed using a repeated measures ANOVA with a grouping factor to assess changes over time, and a 1-way ANOVA to compare integrated AUC between groups. For all statistical analyses, α = 0.05. Pairwise-specified contrasts were used in the post hoc analysis of the repeated measures ANOVA. Additionally, Pearson product moment correlations were used to ascertain whether a relationship existed between any of the hormonal variables at preexercise and postexercise times. The small sample sizes prompted concern that the assumption of normality may have been violated with the use of ANOVAs. As a result, significant findings were verified with a Wilcoxon Rank Sum.

**Results**

Means ± standard deviations of physical, training, and gynecological characteristics for both groups are presented in Table 2. The 2 groups were statistically similar with respect to physical and gynecological characteristics. In addition, no difference was seen in aerobic exercise (hours per week) between the 2 groups.

As established by the manufacturer, estradiol concentration in the early follicular phase ranges from 44.0–976.0 pmol·L⁻¹, and from 0.29–4.77 nmol·L⁻¹ for progesterone concentration. Preexercise (baseline) estradiol (WT 121.82 ± 18.12 pmol·L⁻¹, NWT 137.17 ± 20.88 pmol·L⁻¹) and progesterone (WT 1.12 ± 0.16 nmol·L⁻¹, NWT 1.81 ± 0.45 nmol·L⁻¹) levels for all subjects fell within the expected range for the early follicular phase of the menstrual cycle. There was no significant difference observed between WT and NWT groups.

Repeated measures ANOVA for estradiol revealed a significant time effect, but no significant group or time by group interaction. Post hoc analysis revealed a significant difference at 60 minutes post-exercise (p < 0.01). Further, the estradiol response curve (AUC) revealed no significant difference between groups.

During repeated measures, ANOVA revealed no
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Figure 1. Mean (SE) pre-exercise serum GH concentrations. Top graph; NWT (n = 6); WT (n = 6). Bottom graph; NWT (n = 5); WT (n = 5). * denotes significant difference between groups (α = .05).

Table 3. Integrated area under the GH (µg·L⁻¹) response curve with all subjects and with the removal of 2 subjects.

<table>
<thead>
<tr>
<th></th>
<th>WT (n = 6) AUC</th>
<th>NWT (n = 6) AUC</th>
<th>WT (n = 5) AUC</th>
<th>NWT (n = 5) AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>sub 1</td>
<td>107.8</td>
<td>-24.1</td>
<td>sub 1</td>
<td>-24.1</td>
</tr>
<tr>
<td>sub 2</td>
<td>132.8</td>
<td>-21.9</td>
<td>sub 2</td>
<td>-21.9</td>
</tr>
<tr>
<td>sub 3</td>
<td>255.1</td>
<td>7.8</td>
<td>sub 3</td>
<td>7.8</td>
</tr>
<tr>
<td>sub 4</td>
<td>191.6</td>
<td>-3.9</td>
<td>sub 4</td>
<td>-3.9</td>
</tr>
<tr>
<td>sub 5</td>
<td>-363.5</td>
<td>-422.4</td>
<td>sub 5</td>
<td>-15.1</td>
</tr>
<tr>
<td>sub 6</td>
<td>210.9</td>
<td>-33.6</td>
<td>sub 6</td>
<td>-33.6</td>
</tr>
<tr>
<td>mean ± SD</td>
<td>89.1 ± 228.0</td>
<td>-83.0 ± 166.9</td>
<td>*179.6 ± 59.5</td>
<td>-15.1 ± 16.7</td>
</tr>
</tbody>
</table>

* A significant difference between groups was observed (p < 0.01).
Figure 2. Mean (SE) serum GH concentration changes for various time points. NWT (n = 6); WT (n = 6). * = significant time effect. # = significant difference between groups (α = 0.05). Insets are preexercise values and AUC responses.

was analyzed with the removal of 1 subject from each group, a significant time and time by group interaction was seen (Figure 4). Subsequent post hoc analysis revealed a significant difference at immediate, 5, 15, and 60 minutes postexercise (p < 0.01). Additionally, a significant difference was observed between groups at preexercise, immediate, and 5 minutes postexercise (p < 0.01). The 1-way ANOVA revealed a significant difference between groups (p < 0.01) for the integrated area under the GH response curve (Figure 3).

No significant correlation was found between estrogen and GH in either the WT or NWT group, or with both groups combined.

Discussion

The present investigation resulted in 2 significant findings: (a) the resistance exercise protocol elicited a greater overall serum GH response in the WT group, and (b) the WT women demonstrated lower baseline serum GH levels than their NWT counterparts. Conclusions regarding GH production or tissue responsiveness to GH should be made with caution since the present study measured only circulating levels of immunoassay GH. Recent data demonstrated that after days of bed rest, the ambulatory state influenced the release of bioassay GH, but not immunoassay GH (26). Circulating levels of the 22kDa GH is the most commonly measured isoform using an immunoassay; however, recent research indicates other isoforms of GH with varying molecular weights (14). Therefore, consideration must be given to the specific assay system used when examining circulating concentrations of GH.

A variety of stressors are known to stimulate GH release, including some, but not all, resistance-exercise protocols (18, 22). A threshold of exercise intensity has been suggested to be necessary to sufficiently stimulate a rise in GH (17, 31). An exercise protocol that emphasizes anaerobic glycolysis will result in a large increase in serum GH (12, 21, 23, 25), suggesting that regulatory control of GH secretion is related to anaerobic metabolism, particularly the increase in hydrogen ion concentrations associated with increased lactate
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Figure 4. Mean (SE) serum GH concentration changes for various time points. NWT (n = 5); WT (n = 5). * denotes significant time effect. # denotes significant difference between groups (α = 0.05). Insets are preexercise values and AUC responses.

concentrations (12). Vanhelder et al. (31) reported a variable response of GH to 2 weight-lifting exercises with equal total work output, total duration, and work-rest cycle. The heavier load (85% of 7RM), lower-frequency exercise induced an increase in GH, while the lower load (28% of 7RM) and higher-frequency exercise had no such response. Observations from the present investigation extend the results of Vanhelder et al. (31), as well as Kraemer et al. (21, 23, 25), in demonstrating that a resistance exercise protocol combining short rest periods (1 minute), moderate resistance (10RM), and the use of large muscle groups elicits a significant increase in serum GH concentration above baseline, irrespective of resistance-training status.

A resistance exercise stimulus provides a unique physiological environment for significant adaptive responses that result in enhanced muscular strength, size, and power (20, 23). Like other physical activities, resistance exercise is a potent stimulator of hormone secretion. Unlike other modes of activity, such as endurance exercise, resistance exercise activates high-threshold motor units through the preferential recruitment of type II muscle fibers to produce great amounts of force (29, 30). Heavy external loads activate the motor units of the muscle fibers being stimulated, which in turn stresses the sarcolemma, consequently increasing anabolic hormonal levels (21, 23). Muscle hypertrophy, as seen with progressive heavy resistance training, induces specific increases in type II fibers (7, 29, 30). The magnitude of a hormonal response therefore depends on the amount of muscle tissue stimulated and the amount of repair and remodeling induced by resistance exercise (20). In summary, it is the production of force in the activated high-threshold motor units, along with receptor and membrane binding of anabolic factors, which result in changes in muscle growth, strength, and power.

Much of the available research concerning women, resistance training, and serum hormone responses have focused primarily on testosterone. In men, the higher concentration of testosterone has been shown to be an important anabolic hormone for the development of muscle strength and hypertrophy (7, 32). However, women display a general lack of testosterone responsiveness to various resistance exercise protocols (9, 21, 23, 24, 32), yet they experience similar relative training adaptations (6, 7, 29, 30). A recent investigation by Kraemer et al. (21) documented the rise in serum GH levels in women following a heavy resistance exercise protocol with no concomitant rise in testosterone concentrations, indicating that GH may play a larger role in the physiological adaptations to resistance exercise.

In the present study, the level of resistance-training experience may explain the greater overall GH response of the WT group, as well as the difference seen in resting serum GH concentrations. Although there is no reported examination of the relationship between an acute GH response and level of resistance training in women, Kraemer et al. (22) examined the acute responses of serum testosterone and GH in elite junior weightlifting men. The authors found that the weightlifters with >2 years training exhibited an exercise-induced increase in testosterone, but weightlifters with ≤2 years training showed no such increase. Conversely, serum GH significantly increased above baseline in both groups, but did not appear to be influenced by training status.

In our investigation, both groups exhibited acute increases in serum GH concentrations. However, the response of the WT group was sustained over a longer time period, resulting in a greater magnitude of GH response. What is it about training status that would elicit a greater GH response? As previously stated, resistance exercise variables of intensity, load, rest intervals, and the amount of muscle mass utilized contribute to GH release (6, 7, 29, 30). Both groups in the present investigation used the same exercise protocol of intensity (70–80% of 1RM), load (10RM), and rest intervals (1 minute), suggesting that the difference may stem from the amount of muscle tissue involved.

The WT women had an average of 6.3 years of resistance-training experience (Table 2) and demonstrated greater absolute strength (Table 1). It is well documented that resistance exercise results in an increase in lean body mass (LBM) (6, 7, 29, 30). Although LBM was not assessed in the present investigation, it is rea-
sonable to assume that through chronic exposure to resistance training, the WT group would have a higher LBM than the NWT group. Additionally, chronic exposure to resistance training allows for higher levels of force production through the recruitment of a larger percentage of the motor unit pool. It has been shown that trained individuals can activate a greater percentage of high-threshold motor units during a contraction, whereas this is not possible for untrained individuals (23). Further study is needed to fully describe the relationship between hormonal responses and resistance-training experience in women.

Numerous investigations have reported that baseline serum GH concentrations range from 3–8 μg·L⁻¹ in women in the early follicular phase of their menstrual cycle (4, 16, 21, 23, 24), and that these levels are higher than the baseline concentrations of men (4, 22, 25, 31). In particular, Kraemer et al. (17) examined the hormonal response to heavy resistance exercise in both men and women and found marked differences in resting serum GH concentrations. Baseline values for women ranged from 3–7 μg·L⁻¹, while men’s values ranged from 1.0–1.5 μg·L⁻¹. These levels of serum GH at rest are further supported by Bunt et al. (4), who found women to have higher resting levels than men. In the present investigation, baseline serum GH concentrations of NWT females (4.99 ± 1.23 μg·L⁻¹) are in agreement with those found in previous studies (21, 23, 24). Interestingly, the baseline concentrations of the WT females (2.47 ± 1.27 μg·L⁻¹) appear to reflect serum GH levels typically reported for men (22, 25, 31).

The gender difference in resting serum GH concentrations has been partially explained by the relationship between GH and estrogen. The intermittent, pulsatile secretory pattern of GH is tightly controlled by neurotransmitters of the brain (dopamine, serotonin, acetylcholine, and norepinephrine), as well as levels of glucose, GH, and estrogen (16, 20, 23, 27). Some authors have suggested that women demonstrate higher resting levels of GH (4, 21, 23) because of greater frequency and amplitude of GH secretion (20), possibly because of estrogen sensitization of somatotrophs (28). In fact, Ho et al. (16) found that estradiol concentrations strongly correlated with indices of total and pulsatile GH secretion. These results are further supported by the findings of Franz and Rabkin (11), who observed that exogenous estradiol administration increased basal GH levels after ambulation in men. Conversely, Bonen et al. (1) found similar GH responses irrespective of a menstrual phase. Despite the correlative evidence for the influence of estrogen on GH, however, the mechanism responsible for different resting GH levels between men and women has not been well described.

The present study found no significant relationship between resting levels of estradiol and serum GH in either group, probably because of testing in the early follicular phase, which minimizes the estradiol environment. Therefore, it appears that estrogen plays little role in the current study in the lower resting GH concentrations of the WT women as compared to their NWT counterparts.

In conclusion, the resistance exercise protocol design of moderate resistance (10RM), short rest periods (1 minute), and involvement of large muscle groups elicited a response in serum GH in both WT and NWT women. Overall, however, the WT group exhibited a greater magnitude of GH response. In addition, WT women demonstrated lower baseline serum GH concentrations at levels similar to those of men. These results prompt several questions for future studies: the relationship between training status and an exercise-induced serum GH response, as well as the mechanism by which anabolic hormones mediate physiological adaptations of muscular strength and development in women.

Practical Applications

The results of the present study suggest that a periodized model of strength training for women athletes should include a hypertrophy cycle to bring about adaptive responses that may lead to improved performance. Given the importance of strength and power on athletic performance, utilizing a program of moderate resistance (75–80% of 1RM) with short rest periods will increase the potential for significant gains in muscular strength, size, and power. Women should continue to be encouraged to engage in strength training, since there may be a greater magnitude of GH response in women athletes with chronic training experience, thus resulting in greater development of strength and power.

References

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