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Effects of rest duration between sets of resistance training on acute hormonal responses in trained women

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Summary This study investigated the acute hormonal response to three different rest periods between sets of a traditional lower body resistance training session in young women. Twelve healthy trained females (26.83 ± 3.93 years) participated in the study. On three separate sessions of a lower body resistance exercise protocol, subjects were assigned in a random order a rest interval of 30 s (P30), 60 s (P60) or 120 s (P120) between sets. The resistance exercise session consisted of four lower body exercises with three sets performed until contractile failure using 10-repetition maximum (RM) load. Blood samples were drawn for determination of serum growth hormone (GH) and cortisol concentrations before exercise (T0), immediately after each training session (T1), and after 5 min (T5), 15 min (T15), and 30 min (T30) of recovery. Statistical evaluation of the area under the time–concentration relationship for GH (GH\textsubscript{auc}) and for cortisol (C\textsubscript{auc}) were analyzed using a one-way ANOVA. There were no differences among protocols (P30, P60 and P120) in the serum GH and cortisol concentrations at baseline (T0). However, as compared to T0, all protocols led to acute increases ($p < 0.05$) in serum GH concentrations after each training session. The GH\textsubscript{auc} was greater for P30 than for both P60 and P120, however, there were no differences between P60 and P120. The C\textsubscript{auc} were not different among protocols. Thus, the magnitude of acute GH responses in previously strength-trained women appears greater with a 30-s rest interval between sets compared to longer rest periods of 60- or 120-s.

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Introduction

Resistance training has been shown to be an effective stimulus for increasing muscle strength and hypertrophy; however, the exact mechanism involved in these responses remains to be elucidated. In an attempt to evaluate the neuroendocrine mechanisms that might mediate muscle adaptations, several studies have analyzed hormonal response to resistance training with a focus on the human growth hormone (GH). GH may have an important role in postnatal skeletal muscle growth and previous studies have demonstrated a significant correlation between GH response and muscle fiber hypertrophy, suggesting that the adaptations promoted by resistance training may be related to exercise-induced alterations in this hormone.

The GH response to resistance training is influenced by different variables such as the number of repetitions performed, rest interval between sets, work output, number of sets, and training volume. The duration of the rest interval used during resistance training is considered a variable of primary importance. The amount of rest between sets has been shown to affect metabolism, cardiovascular function, and the performance of subsequent sets. With regard to endocrine responses, previous studies have shown that 1-min rest intervals are associated with higher GH response than 3-min intervals in young men and women, suggesting that shorter rest interval are associated with higher GH response. However, these studies examined relatively long rest interval durations (1 and 3 min). We are unaware of any published studies analyzing the GH response in a shorter range of rest intervals (i.e., from 30 to 120 s).

In addition, when analyzing the acute response to resistance training, it is important to consider both anabolic and catabolic responses. Adreno-cortical steroid hormones, such as cortisol, stimulate lipolysis in adipose cells and increase protein degradation and decrease protein synthesis in muscle cells. Generally, the importance of the cortisol to strength and power adaptations is related to its catabolic effects on skeletal muscle. As a result, cortisol has been the catabolic hormone most frequently analyzed after resistance training. Thus, the purpose of the present study was to examine and quantify the influence of rest interval duration on serum concentrations of GH and cortisol in young trained women after a lower body resistance training session.

Methods

Twelve women (26.83 ± 3.93 years; 58.30 ± 9.84 kg; 163.89 ± 9.11 cm) volunteered to participate in the study. All participants had at least 1 year of uninterrupted resistance training experience (mean 7 ± 4 years of experience) and performed at least three resistance training sessions per week during the previous 6 months. Women were not allowed to participate in the study if they had the following: (1) cardiovascular problem that could be aggravated by the protocol, (2) lower limb musculoskeletal injury, or (3) metabolic diseases. All participants read and signed an informed consent form, and the study was approved by an Institutional Review Board.

The test was conducted in each exercise and participants were instructed to maintain a constant velocity of 3 s per repetition during the tests. Only five attempts were allowed per testing session. The tests were repeated in all participants, and data were analyzed by Pearson product moment correlations to estimate day-to-day 10RM reliability (r = 0.99 for knee extension, r = 0.96 for hack squat, r = 0.98 for knee flexion, and r = 0.91 for leg press). The values for 10RM were 52.67 ± 6.99 kg for knee extension, 54.17 ± 13.11 kg for hack squat, 35.34 ± 5.51 kg for knee flexion, and 162.50 ± 45.35 kg for leg press.

Participants refrained from ingesting caffeine and alcohol for 24 h before all tests, and no other strenuous exercise was performed for 48 h before the experimental sessions. The tests were conducted at the same facility at 02:00 pm. Two hours before the tests, all participants were provided with a 300 ml liquid meal containing ~287 kcal (23 g carbohydrate, 42 g proteins, 3 g fat and 3 g fiber). Participants performed three sets of the following exercises: knee extension, hack squat, knee flexion, and leg press (Cybex, Medway, MA).

To avoid any potential carry-over effects and threats of internal validity, each of the three protocols was performed in a counterbalance order by all 12 participants. At least 48 h but not more than 72 h of recovery time was allowed between each training session. Since estrogen is known to stimulate GH secretion, it was selected only participants currently under oral contraceptive therapy. The oral contraceptive administration schedule consisted of 21 days of oral contraceptive ingestion followed by a non-use period of 7 days. The exercise sessions were performed during the oral contraceptive ingestion. Rest interval durations were 30 s (P30), 60 s (P60) and 120 s (P120).

Blood samples (5 ml) were collected at rest (T0); immediately after (T1); and at 5 min (T5), 15 min (T15), and 30 min (T30) after the end
of the session. The percent changes in plasma volume were calculated according to the equations of Dill and Costill. Hormone concentrations were measured by radio immunoassays. Concentrations of GH were measured with a liquid-phase radio immunoassay with double-antibody technique. Cortisol concentration was analyzed with a solid-phase radio immunoassay technique. Coefficient of variances for duplicate samples was calculated to be 3.6% intra-assay and 5.2% inter-assay for GH, and 2.1 and 3.8% for cortisol, respectively.

Standard statistical procedures were used to calculate means and standard deviations (S.D.). Differences in hormonal responses among time point for each trial were evaluated using a one-way ANOVA with repeated measures. The resulting integrated area under the response curve for GH (GHauc) and cortisol (Cauc) were computed using a trapezoidal method after pre-exercise values were subtracted from each time point. Differences among GHauc and among Cauc rest intervals (30, 60, and 120 s) were analyzed using a one-way ANOVA with repeated measures. Multiple comparisons with confidence interval adjustment by the LSD (Least Significant Difference) method were used as post hoc when necessary. The significance level was set at $p < 0.05$. The SPSS 14.0 (SPSS, Chicago, IL) was used in the current analyses.

Results

Fig. 1 presents the acute changes in GH concentrations at different time points. Comparison within protocols revealed that during P30, GH concentrations were significantly higher at T1, T5, and T15 when compared to T0 ($p < 0.05$). During P60, GH concentrations were significantly higher at T1 and T5 when compared to T0, and during P120 the GH concentrations at T1 were higher than T0 ($p < 0.05$). The GHauc comparison between protocols (P30, P60, and P120) revealed that GH response was higher for P30 than both P60 and P120 ($p < 0.05$), but no difference were found between P60 and 120 ($p > 0.05$).

Fig. 2 shows the serum cortisol responses within protocols. During P60, cortisol levels were significantly higher at T5, T15, and T30 in comparison to T0 ($p < 0.05$). There were no differences among time points during P30 or P120. The Cauc comparison between groups (P30, P60, and P120) revealed no significant differences ($p > 0.05$) in cortisol concentration among protocols.

Total work performed during P30 (8957.82 ± 1999.78 kg) was significantly lower than P60 (9328.68 ± 2132.68 kg) and P120 (9475.96 ± 2076.31 kg); however, there was no difference between total work performed during P60 and P120.

Discussion

To match training volume when investigate the effects of short rest intervals between sets is very difficult without the manipulation of exercise intensity. Thus, the major limitation of the present study was the powerlessness of matching training volume. Moreover, it may be possible that the relation between GH and muscle response to resistance training is not a cause—effect relationship, since previous evidence suggest a limited effect of systemic GH in muscle strength and hypertrophy. However, the same stimuli related to GH response may also trigger muscle adaptation, which explains...
the correlation between GH response to training and skeletal muscle adaptation to resistance training.\(^4\)

The primary finding of this investigation was that resistance exercise protocols with different rest-interval duration elicited different increases in peripheral concentrations of growth hormone in trained women. According to the results, GH level was higher after P30 than P60 and P120, confirming a higher response of these hormones with short interval durations, in agreement with previous studies in young men\(^3\) and women.\(^2\) Although the difference between P60 and P120 were apparently large, it did not achieve significance, which could be due to the high inter-individual variations in the GH response. However, every effort was made to normalize as many factors as possible given the effect of circadian rhythms and the high inter-individual variability inherent in GH levels.

Kraemer et al.\(^3\) evaluated the hormonal response to different resistance training protocols in young men and found that the performance of 10RM with a 60-s between-set rest interval resulted in greater GH response than a 180-s between-set rest interval. In a similar study, Kraemer et al.\(^2\) analyzed the hormonal response to different resistance training protocols in young women. When comparing sets of 10RM with 60 or 180 s of rest between sets, it was reported that GH response was higher with 60 s of rest, immediately after, and 5 and 15 min after the end of the session. These studies and the present results suggest that shorter rest intervals are related to greater GH response.

It was previously suggested that training volume is a determinant for GH response\(^6,16–18\) but the present findings did not confirm this suggestion, since P30 elicited higher GH levels despite resulting in lowest training volume. Although the relative contributions of various regulatory mechanisms for GH remains unclear, the increases might have been affected by an increase in glycolytic metabolism, and acid–base shifts.\(^18–20\) Previous studies suggested that factors related to anaerobic metabolism are involved in the regulatory control of GH\(^2,3,21\); these may have led to a higher response after sessions with shorter rest intervals between sets. It has been suggested that local accumulation of metabolic intermediaries such as lactate and hydrogen ions stimulates GH response, as shown by studies that induced restriction of blood flow during exercise.\(^22,23\) Corroborating this hypothesis, previous studies have demonstrated that alkalosis, inducted by sodium bicarbonate ingestion, attenuate GH response to exercise.\(^19,20\) Although the exact mechanism by which acid–base changes stimulate GH secretion is not fully understood, it has been suggested that the hypothalamic-hypophysial axis is activated by muscle metabolic receptors signals.\(^13,19,22\)

In the present study, cortisol levels were not different from rest (T0) at any time point after P30 and P120. After P60, cortisol concentrations at T5 (22%), T15 (26%), and T30 (21%) were significantly higher than T0. When comparing different protocols, Cauc concentration was not different among interval durations. However, contrary to our findings, other studies\(^2,24,25\) have demonstrated that shorter rest intervals are associated with an increased cortisol response after resistance training. Although blood Cauc tended to be lower as rest intervals increased, large inter-individual variation responses may have prevented the appearance of statistical significant differences in the present study. Also, cortisol is secreted in response to physiological or psychological stress.\(^6\) Thus, higher levels of blood cortisol during P30, as compared to T0, maybe due to an increase in physiological stress in response to a very short rest interval.

In agreement with previous studies showing that longer rest intervals are related with more total work\(^10,26\) the present results demonstrated that total work performed during P30 was significantly lower than P60 and P120; however, there was no difference between P60 and P120. Willardson and Burkett\(^11\) reported a significant difference in the ability of trained young men to sustain repetitions between the 30- and 120-s rest conditions. However, there were no differences between 30- and 60-s rest condition and 60- and 120-s rest conditions. The difference between our results and the results of Willardson and Burkett\(^11\) may be related to total training volume; in the present study, participants performed three sets of four exercises (a total of 12 sets) while only five sets of one exercise were performed by the participants in the study of Willardson and Burkett.\(^11\) Therefore, the differences between 30- and 60-s rest conditions may be only evident in longer training sessions.

**Conclusion**

The present results show a higher GH response with shorter rest interval durations. The adaptational importance of an augmented growth hormone response to a resistance exercise protocol remains to be determined.\(^5\) Previous studies have demonstrated a significant correlation between GH response to resistance training and muscle fiber hypertrophy,\(^4\) suggesting that increases in mus-
cle size due to resistance training may be related to exercise-induced alterations on this hormone. However, there is evidence suggesting that systemic GH has negligible effects on muscle fiber hypertrophy. Therefore, the nature of the relation between GH and muscle adaptation may be only mathematical rather than biological.

Also, earlier studies have indicated that resistance exercise with 30 s interset rest period is substantially effective in inducing muscular hypertrophy and concomitant increase in strength. However, it is important to report that previous studies have shown that the use of short rest intervals may compromise the increases in muscle strength. Therefore, the use of rest intervals as short as 30 s may not be recommended when the training purpose is to achieve strength gains due to decrease in total work volume.

**Practical implications**

- During resistance training, shorter rest intervals can be used to promote skeletal muscle hypertrophy. Long rest intervals can be used to increase muscle strength.
- Short rest intervals, during resistance training, mean that less time is spent in the gym.
- Short rest intervals of 30 s are efficient for increasing growth hormone response to resistance training.

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