Effects of Very Short Rest Periods on Hormonal Responses to Resistance Exercise in Men

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Abstract

Rahimi, R, Qaderi, M, Faraji, H, and Boroujerdi, SS. Effects of very short rest periods on hormonal responses to resistance exercise in men. *J Strength Cond Res* 24(7): 1851–1859, 2010—The effect of 3 different rest periods on the acute hormonal responses to resistance exercise (RE) was examined in 10 experienced resistance trained men (age: 20.37 ± 2.24 years, weight: 65.5 ± 26.70 kg). On 3 separate sessions of an RE protocol, subjects were assigned in a random order a rest interval of 60 seconds (P60), 90 seconds (P90), or 120 seconds (P120) between sets. The RE session consisted of 4 sets of squat and bench press to failure using 85% of 1 repetition maximum. Blood draws occurred at pre-exercise (T0), immediately post (T1), and 30 minutes post (T30) exercise for measurement of serum growth hormone (GH), testosterone (TS), and blood-lactate concentrations. Serum GH concentrations were significantly higher at T1 in P60 (64%) compared with P120. Also, serum TS concentrations were significantly higher at T1 in P120 (65%) and P90 (76%) compared to P60 ($p \leq 0.05$). Blood-lactate concentrations significantly increased at T1 for 3 protocols, but no significant protocols differences were observed. Although, training volume by using P90 and P120 was greater than that of P60, statistically a significant difference in training volume was not observed. The results of the present study support rest period in RE sets as an important variable to increase the anabolic hormone concentrations, and it should be mentioned that short rest intervals elevated greater increase in GH concentration compared with 120-second rest. However, TS response was greater in the RE protocol with a 120-second rest interval between sets.

Key Words growth hormone, testosterone, resistance training to failure, rest interval between set

Introduction

Resistance exercise (RE) stimulates the release of different anabolic hormones, especially growth hormone (GH) and testosterone (TS) (2,5,28,38). The anabolic hormones invoke the muscle protein synthesis (6,19). Therefore, RE reinforces the access to muscle strength and hypertrophy (18). Because of important functions of anabolic hormones, there have been studied different approaches to increase the interaction between sport activities and endocrine glands. Resistance exercise–induced elevations in the GH and TS concentrations have been shown to be influenced by RE variables, originally defined by Kraemer (23), including the number of training sets (15), number of repetitions (5), training intensity (32), training volume (15,42), and rest between sets (4,5,28). Among these variables, rest between sets in resistance training has a special importance that is defined as the time period between the end of a training set and commencement of the next set so that body condition of the individual approached the physiological stance before the activity. The amount of rest between sets affects the metabolism (30), cardiovascular function (11), hormonal response (4,5,28), and also the number of repetition in subsequent sets (35,40,47). Short rest periods are typically recommended for RE programs designed to maximize muscle hypertrophy because short rest periods augment the GH response when compared with long rest periods (4,27,28,42). In addition, previous research studies have shown that 1-minute rest between the sets increased GH concentration compared to 3-minute rest in young men (28) and women (26). Boroujerdi and Rahimi (4) have observed a 15% significant increase in serum GH concentration in RT with 10 repetition maximum (10RM) with 1-minute rest between sets compared with 3-minute

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rest. Also, RE with 5RM and 3-minute rest between sets led to a significant increase in TS (27).

In addition, RE to failure and not to failure have different effects on hormonal responses and training volume (21). Muscular failure can be defined as the point during an RE set when the muscles can no longer produce sufficient force to control a given load (9,37). At this point, the set is ended, and a period of rest ensues to allow for resynthesis of adenosine-3-phosphate (ATP) and clearance of fatigue-producing substances (e.g., H^+). Resistance exercise sets to failure might be most beneficial when programs are structured for increases in strength and hypertrophy (3,25,34). These adaptations attributed to greater activation of motor units that are capable of the greatest increases in strength and hypertrophy and secretion of growth-promoting hormone (9,25). Therefore, in the present study, RE protocols were performed to failure in each set.

Nonetheless, the previous research studies have examined acute hormonal response to RE with a specific number of repetitions (5RM to 10RM) and rest periods ranging from 1 to 5 minutes between resistance training sets (2,4,27,28). So, the aim of the present study was the examination of acute GH and TS responses in an RE protocol to failure with 85% of 1RM load and very short different rest intervals of 60, 90, and 120 seconds between sets.

Methods

Experimental Approach to the Problem

The acute hormonal responses of 3 resistance training protocols differing by rest periods between the sets (60, 90, and 120 seconds) were studied with 10 recreationally resistance trained men. Loading protocols were performed to failure and expected to lead to large acute hormonal responses. We hypothesized that when using short rest periods between the sets in resistance training to failure (maximum repetitions per sets), the endocrine response should be larger along with a greater metabolic stress (i.e., lactic acid) than that of long rest periods between the sets.

Subjects

Ten experienced resistance trained college-age men (age: 22 ± 2 years; weight: 84 ± 8 kg; at least 1 year of RE experience) volunteered for this study. Subjects were informed of the experimental risks, and they signed an informed consent document before the investigation. The Institutional Review Board of the University approved the research protocol. Subjects were on their ordinary diet, not permitted to use nutritional supplementation, and did not consume anabolic steroids or any other anabolic agents known to increase performance.

Experimental Design

The subjects were familiarized with the experimental testing procedures during a control day about 1 week before the actual measurements. Resistance load verification for the experimental bench press and half squat exercises was also determined. All the subjects went through 3 strength exercise trials of different rest intervals between sets. The strength exercises lasted from 09:00 to 11:00 hours and to avoid any potential carry-over effects and threats of internal validity, each of the 3 protocols was performed in a counterbalance order by all 10 participants. At least 48 hours but not more than 72 hours of recovery time was allowed between each training session. During the control day, 3 blood samples were obtained from each subject. One blood sample was drawn in the morning after 12 hours of fasting and approximately 8 hours of sleep for determination of basal serum hormone concentration. Two blood samples were also drawn within ½ hour without exercise at the same time of the day that each subject would later under tack his heavy-resistance loading protocols of normal diurnal variation of serum hormone concentration.

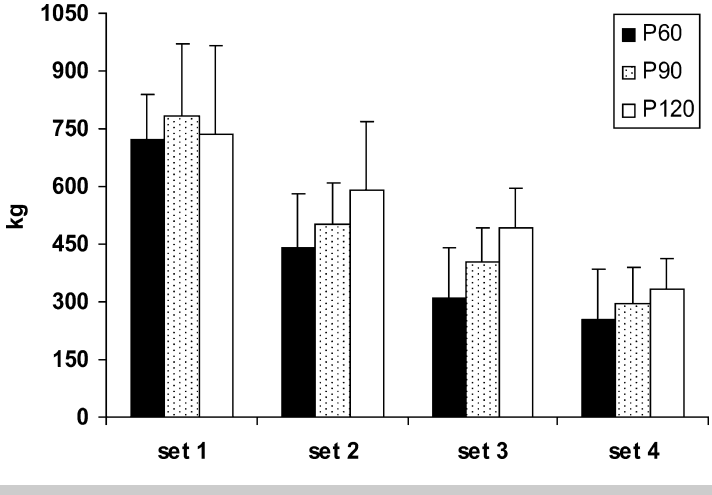

Figure 1. Training volume per set (mean ± *SD*) during 3 resistance exercise protocols to failure in bench press.

During the exercise sessions, blood samples (5 mL) were drawn from an antecubital vein into 10-mL serum vacutainer tubes at pre-exercise (T0), immediately post (T1), and 30 minutes post (T30) exercise for measurement of serum GH, TS, and blood-lactate concentrations. The experimental design comprised 3 separate sessions of an RE protocol; subjects were assigned in a random order at a rest interval of 60 seconds (P60), 90 seconds (P90), or 120 seconds (P120)

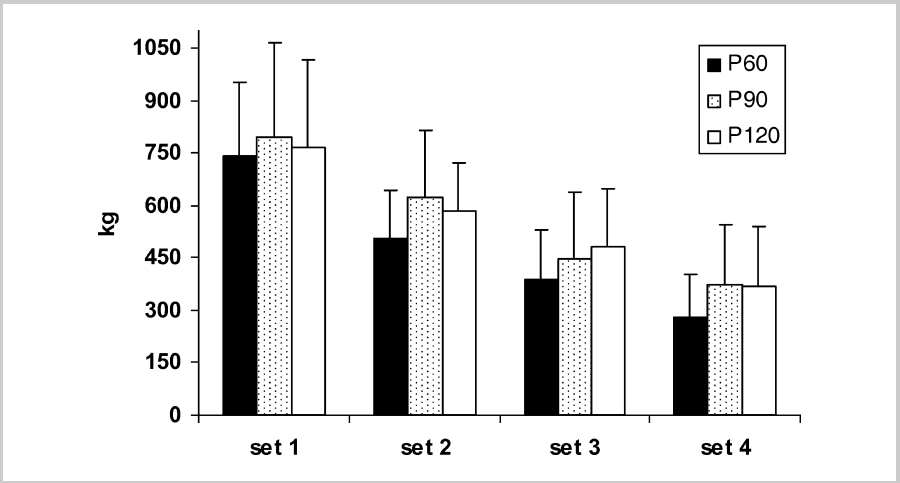

Figure 2. Training volume per set (mean ± *SD*) during 3 resistance exercise protocols to failure in squat.

between sets. The RE session consisted of 4 sets of squat and bench press to failure using 85 % of 1RM with 4-minute recovery between the exercises.

Strength Testing

Lower and upper body maximal strength was assessed by using 1RM actions. Warm-up consisted of a set of 5 repetitions at the loads of 40–50% of the perceived maximum. In the half squat (1RM), the shoulders were in contact with a bar, and the starting knee angle was 90°. On command, the subject performed a concentric extension (as fast as possible) of the leg muscles starting from the flexed position to reach the full extension of 180° against the resistance. The trunk was kept as straight as possible. A security belt was used by all subjects. All of the tests were performed in a squatting apparatus in which the barbell was attached to both ends, with linear bearings on 2 vertical bars allowing only vertical movements. During the 1RM bench press test, the subject was instructed to perform from the starting position a purely concentric action maintaining the shoulders in a 90° abducted position to ensure consistency of the shoulder and elbow joints throughout the testing movement.

An attempt was considered successful when the movement was completed through a full range of motion without deviating from proper technique and form. Spotters were present to provide verbal encouragement and safety for the subjects. To ensure that all subjects were moving at approximately the same velocity for each repetition, each set was timed using a handheld stopwatch. The spotter called out a cadence for the eccentric and concentric phases of each repetition. The repetition velocity consisted of a 3-second eccentric phase followed by a 1-second concentric phase. During the next 3 testing sessions, 4 sets of the squat and bench press were performed with a 60-, 90-, or 120-second rest interval between sets. A counterbalance procedure was used to determine the order of the rest interval between sets for each testing session. Subjects were allowed to continue with their normal workouts throughout the duration of the study with the following exceptions: (a) subjects were instructed not to perform training 48 hours before the testing session and (b) subjects were instructed not to change their eating patterns during the study. The values for 1RM were 105.62 ± 18 kg for bench press and 106.31 ± 19.71 kg for squat.

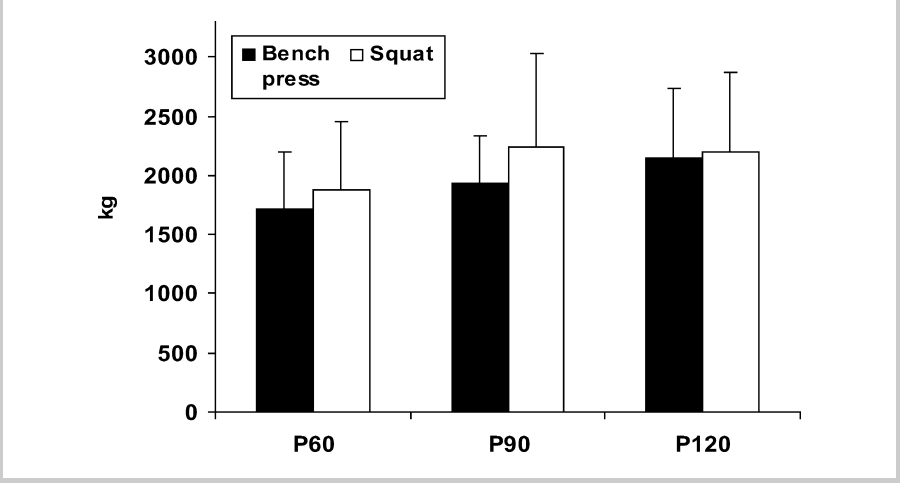

Figure 3. Total training volume (sets × repetitions × load) (mean ± *SD*) during 3 resistance exercise protocols in bench press and squat exercises.

Hormonal Analysis

Blood samples (5 mL) were drawn from an antecubital vein into 10-mL serum Vacutainer tubes, and after approximately 45 minutes, serum tubes were centrifuged at 3,000 rpm (5,000*g*) for 10 minutes at room temperature. Serum was separated from blood cells and stored at −20° C until analyzed. Serum TS and GH concentrations were determined using enzyme-linked

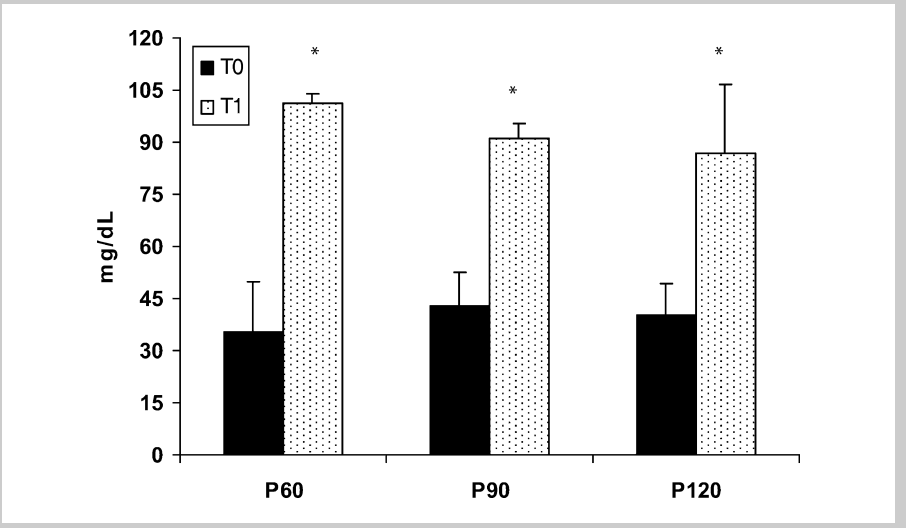

Figure 4. Blood-lactate levels (mean ± *SD*) during pre-exercise (T0), immediately post (T1) exercise with the 60-second (P60), 90-second (P90), and 120-second (P120) protocols. *$p \leq 0.05$ (between T0 and T1).

immunosorbent assay (DRG Instruments GmbH, Germany; Division of DRG International, Inc., Hamburg, Germany) and immunoenzymometric assay (RADIM SpA-Via del Mare, 125-00040 Pomezia, Rome, Italy), respectively. To eliminate inter-assay variance, all samples for a particular assay thawed once and analyzed in the same assay run. All samples were run in duplicate with a mean inter and intraassay coefficients of variances of 9.94 and 4.16% for serum TS and 4.9 and 5.6% for serum GH. The detection limits of the TS and GH assays were 0.15 and 0.083 ng·mL^{-1}, respectively. Lactate in plasma was analyzed enzymatically using a YSI 1500 Sport (Yellow Springs, OH, USA). The CV for lactate was <5%. All samples from each subject were analyzed on the same day.

Statistical Analyses

Statistical evaluation of the data was accomplished by a repeated-measures analysis of variance. In the event of a significant *F* ratio, least significant difference post hoc tests were used for pairwise comparisons. A criterion α level of $p \leq 0.05$ was used to determine statistical significance. All data are reported as mean ± *SD*.

Results

The volume of exercise per set for squat and bench press is shown in Figures 1 and 2, respectively. Training volume performed during the 4 sets of squat and bench press decreased over sets during 3 protocols. Total work performed comparison between groups (P30, P60, and P120) revealed no significant differences ($p > 0.05$) in P60 (3,603.81 ± 816.05 kg), P90 (4,175.50 ± 939.89 kg), and P120 (4,352.06 ± 996.87 kg) (Figure 3). Blood-lactate concentrations were significantly increased at T1 for 3 protocols, but no significant protocol differences were observed (Figure 4).

The acute GH response to the exercise protocol can be seen in Figure 5. Comparison within protocols revealed that during P60, GH concentrations were significantly higher at T1 and T30 when compared with T0 ($p \leq 0.05$). During P90, GH concentrations were significantly higher at T1 when compared to T0, and during P120, the GH concentrations at T30 were higher than T0 ($p \leq 0.05$). The GH comparison between protocols (P30, P60, and P120) revealed that GH response was higher for P60 than for P120 ($p \leq 0.05$), but no difference was found between P90 and P120 ($p > 0.05$).

The acute TS response to the exercise protocol can be seen in Figure 6. During P120, TS levels were significantly higher at T1 and T30 in comparison to

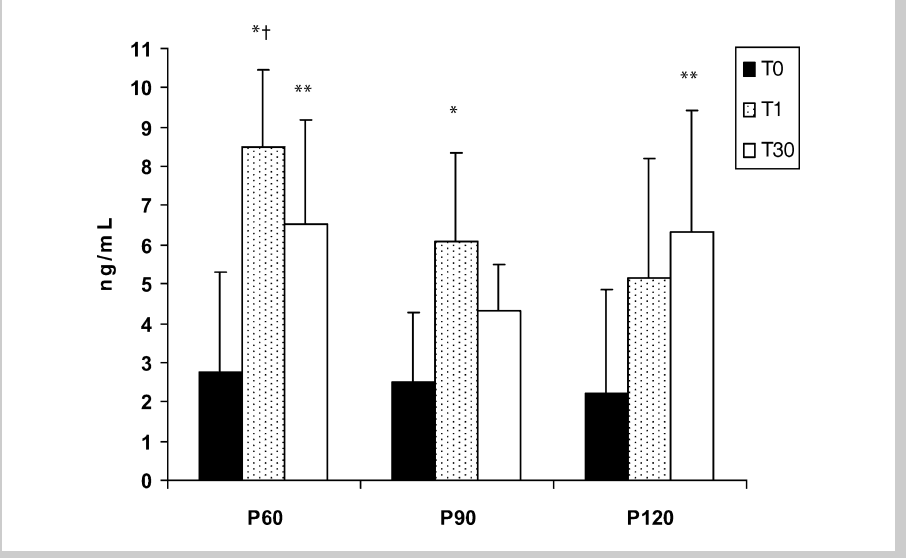

Figure 5. Growth hormone levels (mean ± *SD*) during pre-exercise (T0), immediately post (T1), and 30 minutes post (T30) exercise with the 60-second (P60), 90-second (P90), and 120-second (P120) protocols. *$p \leq 0.05$ (between T0 and T1); **$p \leq 0.05$ (T0 and T30), †$p \leq 0.05$ (between P60 and P120).

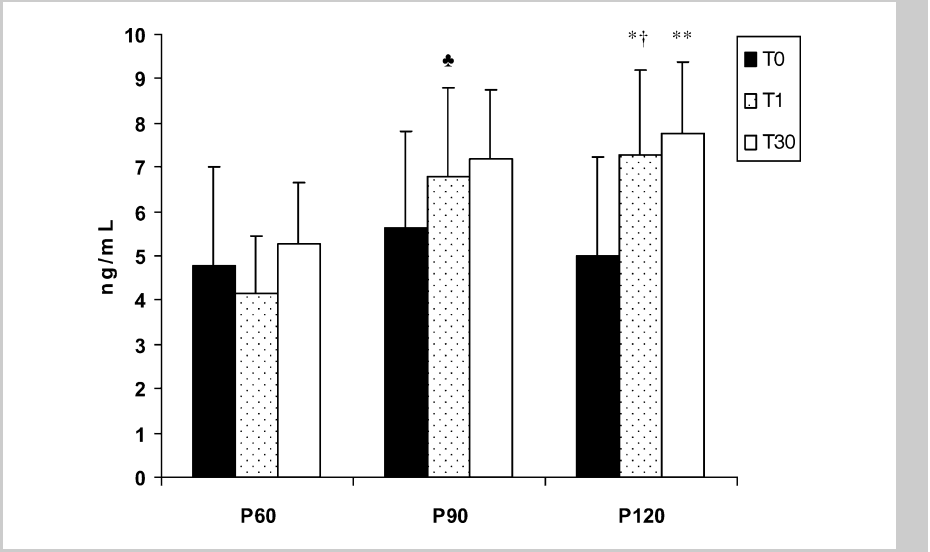

Figure 6. Testosterone levels (mean ± *SD*) during pre-exercise (T0), immediately post (T1), and 30 minutes post (T30) exercise with the 60-second (P60), 90-second (P90), and 120-second (P120) protocols. *$p \leq 0.05$ (between T0 and T1); **$p \leq 0.05$ (T0 and T30); †$p \leq 0.05$ (between P60 and P120). ♣$p \leq 0.05$ (between P60 and P120).

T0 ($p \leq 0.05$). There were no differences among time points during P60 or P90. The TS comparison between groups (P30, P60, and P120) revealed that TS response was higher for P90 and P120 than for P60 ($p \leq 0.05$), but no difference was found between P90 and 120 ($p > 0.05$).

Discussion

Resistance exercise is the most effective way for achieving acute increase in the concentration of anabolic hormones, which in turn stimulates strength and muscle hypertrophy (4,42). High-intensity hypertrophic REs when performed in multiple sets (3–5 sets for each exercise), with short rest intervals (60–120 seconds) and high repetition (8–12 repetition) lead to acute hormonal responses (17,26,27). The amount or time of acute hormonal responses after RE may be related to gain of muscle strength and hypertrophy (1,24). The role of acute hormonal responses is very important because anabolic hormones such as TS (10) and GH (12) will increase protein synthesis in muscle cells. Therefore, instigation of endocrine gland through exercise activity may be a stimulant for the compatibility process of skeletal muscle cells and leads to an increase of contractile proteins. There has been a more acute increase of GH and TS in a multiple-set resistance training program (3 sets per training) than in a single-set RE program (15). Also, an RE protocol with average intensity (with 10RM load), high volume (3 sets of 10RM for each exercise), and with a short rest interval (1 minute) between the sets caused an increase in GH and cortisol concentration (31).

It is inferred from the previous research that acute hormonal response related to RE is dependent on the kind of RE protocol that is affected by variables such as number of repetitions and sets, rest period between sets, load or intensity, frequency, and muscle volume involved. In present research, the young athletes have performed a 3-RE protocol (4 set × 85% of 1RM) to failure (maximum repetition per sets) with different rest intervals of 60, 90, and 120 seconds between the sets. Therefore, the difference in programs was in the different rest intervals between sets, and because of using resistance training sets to failure (RE to failure), we expected a different training volume related to the rest intervals. Also, different metabolic needs, which these 3 RE protocols have, are expected to cause different acute hormonal responses. The findings of the present study showed that total training volume in the RE programs with rest intervals of 90 and 120 seconds between sets increased 20 and 15% more than that of the protocol with rest intervals of 60 seconds between sets. Although, these differences were not statistically significant, they cannot be neglected because these differences might affect measured physiological responses.

Growth hormone and TS have been known as hormones involved in anabolic processes in muscle cells. Therefore, these hormones may instigate an increase of muscle mass. Binding of GH to its membrane-bound receptor initiates janus kinase 2 signaling. Janus kinase 2 signaling activates phosphatidylinositol-3 kinase (PI-3K). Because PI-3K is proximal to the protein kinase B–mammalian target of rapmycin (Akt-mTOR) signaling, it is likely that the GH response to RE promotes translational efficiency and muscle anabolism by eIF2B activity and 4E-BP1 phosphorylation, resulting in enhanced translational efficiency and protein synthesis (for a review see Spiering et al. [42]). The result showed that GH responses are different from the RE programs with rest intervals of 60, 90, and 120 seconds between sets. Serum GH concentration immediately after heavy RE to failure with a rest interval of 60 seconds between sets was higher than RE to failure with a rest interval of 120 seconds between sets. However, 30 minutes after the training, no significant difference between these 2 protocols was observed. A greater increase was also observed in GH concentration immediately after the RE protocol with a 60-second rest interval compared with a 90-second rest interval, but statistically it was not significant. No significant difference was also observed in the concentration

of this hormone between 2 programs with rest intervals of 90 and 120 seconds. These findings are in accordance with those of Botaro et al. (5). They observed a significant increase in GH concentration in the RE protocol with a 30-second rest interval compared to 60- and 120-second rest intervals. Although in the present study the maximum increase in GH concentration was observed in the RE protocol with 60-second rest, this difference may emanate from the difference in training intensity (load) in these 2 investigations, because in the present research has been used 85% 1RM, which is heavier than the loadused in Bottaro et al. (5).

In addition, our findings are in accordance with Boroujerdi and Rahimi (4) who observed a 15% meaningful increase in GH concentrations during an RE program (5 sets with 10RM load in squat and bench press exercises) with 60-second rest between sets compared with 180-second rest. Corroborating these findings, Kraemer et al. (28) reported that performing the training with 10RM with a 60-second rest interval between the sets led to a large increase in serum GH concentration compared to RE protocol with 180-second rest. In the same research, Kraemer et al. (28) reported that GH concentration immediately, 5, and 15 minutes after RE was greater in the protocol with 60-second rest between sets than in that with 180-second rest between sets.

Although the relative share of adjusting mechanisms for the increases in serum GH concentrations during heavy RE with very short rest period is unknown, it may be affected by glycolytic metabolism increase and acid–base changes (13,14,27). Previous research suggests that factors related to anaerobic metabolism are involved adjusting control GH and that these factors may respond much to an intense resistance training program with short rest intervals between sets. Häkkinen and Pakarinen (17) observed a significant correlation between individual changes in lactate accumulation and GH response when 2 different strength exercises were combined. We did not measure changes in blood pH, but changes in blood-lactate concentration could explain differences in GH responses during 3 protocols. Also, previous research with restriction of blood flow during exercise has shown that local accumulation of metabolic intermediaries such as lactate and hydrogen ion stimulate the increase of GH (45). Corroborating this hypothesis, Gordon et al. (13) showed that alkalosis stimulated by sodium bicarbonate ingestion has decreased GH response during resistance training. Although the real mechanism through which the acid–base changes stimulates GH secretion is not known correctly, it has been suggested that the hypothalamic–hypophysial axis is activated by muscle metabolic receptors signals (13,43). In line with the findings for GH, blood-lactate concentrations increased during all 3 kinds of RE to failure protocols with greater responses observed in protocol with 60-second rest between sets than in 120-second rest between sets.

Growth hormones are actually a 'family of hormones' because >100 different variant forms exist in circulation (46). The specific biological activity of each GH variant awaits complete elucidation; however, acute RE dramatically affects concentrations of these GH variants (20,36). Additionally, Kraemer et al. (29) recently demonstrated that long-term training increases the biological activity of circulating GH molecular weight variants. Although our results showed that RE with a very short rest period instigates 20-kD GH monomer levels (the most frequently studied form), they are not solely responsible for adaptations to RE. In addition, GH exerts its function by eliciting IGF-1 production from the liver and/or muscle, which stimulate muscle hypertrophy via PI3K and Akt-mTOR signaling. Additionally, IGF-1 stimulates the proliferation and differentiation of satellite cells (42).

The findings of the present and previous research studies (4,5,12,28) suggest that GH response to RE is dependent on short rest intervals between the training sets. Heretofore, it was suggested that training volume (number of sets × number of repetitions × amount of load) is one of the determining factors of GH response (7,15,35). However, the findings of the present investigation do not confirm this suggestion because the RE protocol with 60-second rest between sets has led to the largest increase in serum GH concentration while it has had the least training volume. Moreover, Bottaro et al. (5) observed that the RE protocol with 30-second rest between sets elicited higher GH levels despite resulting in the lowest training volume compared to 60- and 120-second rest protocols. In the present investigation, the maximum training volume has been observed in the training program with 120-second rest. These results are in accordance with those of Bottaro et al.'s (5), Rahimi's (39), Rahimi et al.'s (40), Wilardson and Burkett's (47) investigations, and it has been shown in these studies that with an increase of rest between the resistance training sets, training volume has been increased meaningfully.

The results presented here indicate several conclusions concerning the number of repetitions possible in an exercise session and consecutive sets of the same exercise to failure when rest periods between sets are 60, 90, or 120 seconds in length. A rest period of 60 seconds results in less total training volume than a rest period of 120 seconds because of a greater decrease in the number of repetitions to failure in consecutive sets with a 60-second rest period. This decrease in training volume in the 60-second rest periods is probably related to insufficient time to replenish anaerobic energy sources and neural drive and higher blood-lactate concentrations, all of which result in fatigue (34).

According to the results, the TS concentration was higher immediately after protocols with 120- and 90-second rest than after a protocol with 60-second rest between sets, but 30 minutes postexercise, no meaningful difference was observed in TS concentrations among the protocols. In addition, meaningful differences in TS concentration during RE

protocols with 90- and 120-second rest periods between sets were not observed. These findings are in accordance with those of Kraemer et al. (27,28) who showed that high-intensity RE (5RM) with large muscle groups and with 3-minute rest between sets elevates TS concentrations.

Although circulating hormone concentration is one of the symptoms of hormone function, they are not solely responsible for adaptations to RE, and there are factors such as number of receptors and affinity of receptors that affect hormone function and subsequent adaptations in body tissues. Testosterone exerts its influence on skeletal muscle protein synthesis via androgen receptors (ARs). Testosterone binds to and converts AR to a transcription factor capable of translocating to the nucleus and associating with DNA to regulate androgen-specific gene expression. Previous studies reported that training influences the number of androgen binding sites in skeletal muscles. The increase in ARs would lead to an enhancement of the sensitivity of muscles to circulating androgens. A significant increase in the number of ARs has been shown to occur after endurance and strength training and electrical stimulation in animal studies (46). Because the subjects were male resistance trained athletes, and they prevalently trained with submaximal load, high repetitions, and short rest period between sets, upregulation of ARs may have occurred in fast-twitch fibers, and this led to low TS concentration in a very short rest protocol. Additionally, like IGF-1, TS exerts some influence on muscle growth via satellite cells. Supraphysiological doses of TS increase satellite cell number in a dose-dependent manner (41) and stimulate satellite cell proliferation and differentiation (19).

Unfortunately, studies focusing on the effects of different rest periods between sets on TS concentration, in resistance trained men, are lacking, making it difficult to compare our results. However, in terms of RE intensity, Raastad et al. (38) showed that the acute responses of TS was greater during the high-intensity protocol as compared to the moderate-intensity protocol, and no meaningful difference was observed in luteinizing hormone (LH), follicle stimulating hormone, and GHs (38). Linnamo et al. (32) examined acute hormonal responses to maximal heavy RE, submaximal heavy RE, and explosive RE. They observed greater increase in GH and TS concentrations in maximal heavy RE compared with submaximal and explosive RE.

Our findings showed that the RE protocol with a long rest period between sets and greater training volume elicited an increase in TS concentration, but the possible mechanisms responsible for these changes were not measured in this study. However, previous studies suggest that exercise-induced elevations in TS are caused by mechanisms other than the normal LH stimulation of Leydig cells (38,44). Stress related to RE (32,38), reduced clearance (44), adrenergic-stimulated secretion (8,16,22) and lactate-stimulated secretion (33) and hemoconcentration have been suggested as other mechanisms for exercise-induced increases in TS concentration.

Lactate stimulates TS secretion in Leydig cells from rats in vitro, and lactate infusions, resulting in similar elevations in plasma TS concentrations as seen during exercise, have been shown to elevate TS concentrations in rats in vivo (33). In the present study, significant differences were observed in mean blood lactate from pre to postexercise within protocols but not between each protocol. Also, there was no correlation between individual changes in lactate and TS concentrations for either protocol. Therefore, this hypothesis that lactate-stimulated secretion of TS was not confirmed by the results of the present study because the greater lactate accumulation observed during the 60-second protocol which has the least TS concentrations as compared to the 120-second protocol. The possible role of lactate in stimulating TS secretion during exercise in men requires further investigation.

In summary, the results of this investigation indicate that serum GH and TS concentrations were dependent on the length of the rest interval between sets in heavy RE protocols to failure. The primary finding of this study was that the patterns of GH and TS responses were dramatically different from the length of rest interval between sets in heavy RE (4 sets of squat and bench press to failure using 85% of 1RM). An RE protocol with a short rest interval between sets elicited greater increase in serum GH concentration compared to a long rest period, but acute TS responses were greater in the protocol with a long rest period and high training volume.

There are few limitations of this study that warrant discussion. First, manipulation of the acute RE program variables (i.e., exercise choice, load, volume, rest periods, and exercise order) dramatically influences the signaling responses and subsequent adaptations to RE (42). The direct influence of rest periods on mediating RE-induced muscle signaling responses is largely unexplored. Therefore, it is recommended that future studies evaluate the effect of different rest periods on signaling response. Second, these findings are related to few numbers of anabolic hormones. Further investigations are necessary to determine more anabolic hormones and growth factor. Third, these findings are specific to the RE protocol that was performed to failure. Further investigations are necessary to determine if these findings are generalizable to the RE protocol not to failure. Fourth, our findings are specific to the RE protocol performed at 85% of 1RM. It is unknown whether similar findings exist during RE protocols performed at different intensities. Additionally, our findings are specific to healthy resistance trained men. Further investigations are necessary to determine if these findings are generalizable to other populations.

Practical Applications

In this study, we demonstrated that the rest interval between sets affects GH and TS responses and so could influence hypertrophy gains over time. During an RE session, a rest period of 60 seconds results in greater serum GH levels and less total training volume than a rest period of

90 and 120 seconds, but the TS response was greater in the RE sessions with long rest periods (90–120 seconds) and higher training volume. Short rest periods are typically recommended for RE protocols designed to maximize muscle hypertrophy because short rest periods augment the GH response when compared with long rest periods (40). However, short rest periods impair physical performance during subsequent sets (39,40) and, over several weeks, attenuate strength increase when compared with long rest periods (42). Of particular importance to the RE practitioner is that specific combinations of RE variables must be used to optimize the desired functional outcome (muscle strength, muscle power, muscle size, or muscle endurance). Therefore, it is recommended that short rest periods can be used to stimulate hypertrophy and that long rest periods are used to maximize strength gains.

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