LONG REST INTERVAL PROMOTES DURABLE TESTOSTERONE RESPONSES IN HIGH-INTENSITY BENCH PRESS

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ABSTRACT

Scudese, E, Simão, R, Senna, G, Vingren, JL, Willardson, JM, Baffi, M, and Miranda, H. Long rest interval promotes durable testosterone responses in high-intensity bench press. J Strength Cond Res 30(5): 1275–1286, 2016—The purpose of this study was to examine the influence of rest period duration (1 vs. 3 minute between sets) on acute hormone responses to a high-intensity and equal volume bench press workout. Ten resistance-trained men (25.2 ± 5.6 years; 78.2 ± 5.7 kg; 176.7 ± 5.4 cm; bench press relative strength: 1.3 ± 0.1 kg per kilogram of body mass) performed 2 bench press workouts separated by 1 week. Each workout consisted of 5 sets of 3 repetitions performed at 85% of 1 repetition maximum, with either 1- or 3-minute rest between sets. Circulating concentrations of total testosterone (Tt), free testosterone (FT), cortisol (C), testosterone/cortisol ratio (TT/C), and growth hormone (GH) were measured at preworkout (PRE), and immediately (T0), 15 minutes (T15), and 30 minutes (T30) postworkout. Rating of perceived exertion was recorded before and after each set. For TT, both rest lengths enhanced all postexercise verifications (T0, T15, and T30) compared with PRE, with 1 minute showing decreases on T15 and T30 compared with T0. For FT, both 1- and 3-minute rest protocols triggered augmentations on distinct postexercise moments (T0 and T15 for 1 minute; T15 and T30 for 3-minute) compared with PRE. The C values did not change throughout any postexercise verification for either rests. The TT/C ratio was significantly elevated for both rests in all postexercise moments compared with PRE. Finally, GH values did not change for both rest lengths. In conclusion, although both short and long rest periods enhanced acute testosterone values, the longer rest promoted a long-lasting elevation for both TT and FT.

KEY WORDS hormones, exercise, strength training, resistance training

INTRODUCTION

Over the last several decades, resistance training has been established as an effective strategy to enhance maximal “strength,” power, and localized muscular endurance characteristics (3). The elaborated manipulation of the acute program variables such as exercise selection, exercise order, intensity, number of sets, and rest period length might improve those specific features of neuromuscular fitness (19). In a recent literature review, de Salles et al. (10) suggested that intended manipulation of the rest interval between sets could promote distinct acute responses, contributing to different chronic adaptations in neuromuscular and endocrine systems. Additionally, the American College of Sports Medicine (ACSM), in its latest position stand on progression models in resistance training for healthy adults (2), corroborated the notion that the rest interval independent of other workout variables can affect the metabolic, cardiovascular, and hormonal systems.

The ACSM position stand (2) also suggested that a program, which emphasizes maximum strength development, should incorporate load intensities varying from 1 repetition maximum (IRM) to 6RM for advanced individuals and athletes. However, most of the studies that investigated manipulation of rest intervals between sets focused on RM5 ranging from 8 to 15RM (31,35,43). Few studies have compared different rest intervals between sets in the context of high-intensity regimens (1–6RM). Weir et al. (42) and Matuszak et al. (28) examined the influence of different rest intervals between consecutive 1RM attempts for the barbell bench press (42) and barbell squat (28), respectively. However, these investigations focused on simulating 1RM testing protocols...
rather than workout scenarios aimed at maximizing muscular strength gains (2). Experiments that have examined the effect of rest period duration using intensities within the range proposed to maximize muscular strength are very scarce (34).

Regarding rest periods and acute hormone responses, Rahimi et al. (33) examined the influence of different rest intervals (60, 90, and 120 seconds) over 4 sets at 85% of 1RM squat and bench press to failure on circulating growth hormone (GH) and total testosterone (TT) concentrations. The authors found that resting 60 seconds between sets resulted in higher GH immediately after workout compared with resting 120 seconds; but in contrast, resting 90 or 120 seconds between sets resulted in higher TT concentrations immediately after workout compared with resting 60 seconds. It is important to consider that when implementing specific RM loads (e.g., 85% of 1RM), different rest period durations between sets often result in distinct outcomes for repetition number per set and thus different training volumes. In such cases, it is not possible to determine which variable (i.e., volume or rest period duration) caused differential hormone responses. In a classic study, Kraemer et al. (23) compared hormone responses after a combined upper-body and lower-body (8 different exercises) workout protocol using 5RM loads and either 1- or 3-minute rest intervals between sets while keeping total work volume, the same under both rest duration conditions. The authors found significant increases in TT and GH concentration after both rest durations, although the GH response was delayed and lasted further on postexercise for the 1-minute rest condition. Villanueva et al. (41) similarly equalized exercise volume in a combined upper-body and lower-body (4 different exercises) workout protocol applying 85% of 1RM for 3 repetitions in 1 of the methods authors claimed being of strength type characteristics. They compared 60 and 90 seconds of rest between sets and found that was a significant percentage increase in TT concentration for both rest conditions immediately after exercise. When examining the absolute TT concentrations, the authors have found increases on TT values on 15-minute postexercise compared with PRE. For the 60-second rest condition, they found elevations immediately after exercise.
after the longer 90-second rest. Cortisol (C) concentrations were not increased after either rest period protocol.

It seems that when performing a strength protocol combining upper-body and lower-body exercises, significant increases in TT and GH were observed, and although somewhat conflicting findings exist, this increase in hormone concentrations is influenced by the rest period duration and exercise selection. It remains to be determined whether rest period duration affects the hormonal response only to an upper-body strength workout protocol with low volume equated. Therefore, the purpose of this study was to examine the influence of 2 different rest conditions (1- and 3-minute rest between sets) on hormonal responses after a bench press workout conducted at a load intensity of 85% of 1RM and with equal volume of work performed under each rest condition.

**METHODS**

**Experimental Approach to the Problem**

To investigate the effect of rest period duration on the hormonal response only to an upper-body strength workout protocol, resistance-trained men completed 2 identical work volume bench press workout sessions (5 sets of 3 repetitions at 85% of 1RM) separated by 1 week. Subjects rested either 1 or 3 minutes between sets for each session. Blood was collected before the warm-up and before the first set of the bench press workout (PRE), and immediately (T0), 15 minutes (T15), and 30 minutes (T30) after the bench press workout completion. Then, the samples were analyzed for concentrations of circulating TT, free testosterone (FT), C, and GH. In addition, rating of perceived exertion (RPE) was obtained before and after each set of bench press.

**Subjects**

Ten men (25.2 ± 5.6 years; 78.2 ± 5.7 kg; 176.7 ± 5.4 cm; bench press relative strength: 1.3 ± 0.13 kg per kilogram of body weight) with a minimum of 1 year experience of specific high-intensity strength training (3–5RM) on their periodization schemes, including the bench press exercise, volunteered for this study. All subjects were required to meet the following inclusion and study criteria: (a) have a minimum resistance training frequency of 3 times per week during the previous year; (b) perform no other physical activity throughout the study duration; (c) present no medical conditions that could confound study measures; (d) attest negatively for use of anabolic steroids or any other ergogenic substances that could confound study measures; (e) present normal reference values for complete blood cell counts (red blood cells, hemoglobin, hematocrit, leukocytes, and platelets) and liver enzymes (alanine aminotransferase and aspartate aminotransferase). Before data collection, all individuals responded “no” to all questions on the PAR-Q (36). Subjects provided written informed consent in accordance with the Helsinki Declaration. The experimental procedures were approved by the Ethics Committee of the Federal University of Rio de Janeiro. The study conforms to the Code of Ethics of the World Medical Association (approved by the ethics advisory board of Swansea University) and required participants to provide informed consent before participation.

**One Repetition Maximum Testing**

After 2 familiarization sessions, subjects completed 2 bench press 1RM testing sessions (each session separated by 48 hours). The 1RM testing procedures followed the recommendations of Baechle and Earle (5). To minimize testing errors, the following strategies were adopted for all exercise sessions: (a) standardized instructions were provided to each subject; (b) proper bench press technique was explained to all subjects, and compliance with this
technique was verified for each repetition by an investigator; (c) body positioning on the bench press station (bench) was held constant and maintained throughout the experiment; (d) verbal encouragement was used during all testing sessions to encourage maximum effort from each subject; and (e) the weight of the bar and all plates was measured with a precision scale.

For the 1RM bench press determination, a progressive loading scheme was adopted, so that the load was increased by 2 kg after every successful attempt. After warm-up, a maximum of 5 attempts were allotted for each 1RM testing session, with a minimum of 5- to 10-minute recovery between maximum attempts. Thus, the greatest load successfully lifted over the 2 testing sessions was considered as the 1RM load.

Bench Press Workout Session
Seventy-two hours after the second 1RM test session, subjects completed a bench press workout session, which consisted of 5 sets of 3 repetitions at 85% of 1RM with either 1- or 3-minute rest between sets. One week later, subjects completed the same bench press workout protocol (i.e., a total of 15 repetitions [5 sets × 3 repetitions per set] at 85% 1RM) but with the other rest condition (i.e., 1 or 3-minute of rest between sets); in this manner, a particular subject performed exactly the same exercise volume for each bench press workout (Figure 1). The Omni-Res (25) RPE scale was used to record subjective responses before (preset) and after (post-set) completion of each workout set. The order of rest period conditions (1- or 3-minute rest between sets) was counterbalanced and assigned using randomization. Before each bench press workout, a standardized warm-up was performed consisting of 2 sets of 12 repetitions with 40% of an 8RM load that was pre-estimated based on each subject’s personal workout journal. A 2-minute rest interval was observed after the warm-up and before the workout sets (34). No attempt was made to control repetition speed.

To avoid any potential confounding effects of the circadian cycle on hormonal responses, all workout sessions were conducted between 06:00 and 08:00 hours, and the time of data collection for a particular subject was held constant for each bench press workout session (24,41).

Blood Collection and Analysis
At PRE, T0, T15, and T30 blood samples were collected by venipuncture from an antecubital vein for subsequent determination of concentrations of circulating TT, FT, C, and GH (22 and 20 kDa isoforms). Blood samples were collected in 5-milliliter evacuated tubes (Vacutainer; Becton, Dickinson and Company, Franklin Lakes, NJ, USA). After coagulation at 15–20°C, samples were centrifuged at 3,000 RPM and resultant serum divided into several aliquots and frozen at −80°C until analysis. Hormone concentrations were analyzed using the Access 2 Immunoassay System (Beckman Coulter, Inc., Chaska, MN, USA) through dioxetane-based chemiluminescent (Lumi-Phos). The sensitivity and coefficient of variance, respectively, for each assay were as follows: TT: 0.01 ng·ml⁻¹ and 10%; FT: 0.1 ng·ml⁻¹ and 7%; C: 0.4 μg·dl⁻¹ and 6%; and GH: 0.003 μg·ml⁻¹ and 20%. After obtaining values of TT and C, testosterone/cortisol ratio (TT/C) was calculated.

Figure 4. Free testosterone (FT) concentrations at pre-exercise (PRE), and immediately (T0), 15 minutes (T15), and 30 minutes (T30) after completing of 5 sets of bench press exercise with 1- or 3-minute rest between sets. *Significant differences corresponding PRE. #Significant differences corresponding T0. †Significant differences corresponding T15.
Nutritional Control

On the day before the first bench press workout session, subjects recorded their dietary intake by a food questionnaire (PDFQ-3). Subjects received a copy of this diet record and were instructed to reproduce, as closely as possible, this diet on the day before the second bench press workout. Subjects arrived to the laboratory after an overnight fast and were fed with a standard breakfast 1 hour before the onset of each bench press workout to standardize the nutrient conditions (24). The breakfast consisted of 40 g of carbohydrates, 8 g of protein, 6 g of fat, and 5 g of fiber, and contained a total of 256 kcal. The standardized meal was prepared to provide recommended amounts of macronutrient proportions as recommended according to the ACSM position stand on nutrition and athletic performance (1). To help ensure that subjects arrived in a euhydrated state, they were instructed to ingest 5 to 7 milliliters of water per kilogram of body weight immediately on awakening on bench press workout days (1).

Statistical Analyses

Data were presented as mean ± SD. A 2-way analysis of variance with repeated measures on both factors (rest condition × time point) was conducted for each hormone and ratio (TT, FT, TT/C, C, and GH). When necessary, Fisher’s least significant difference (LSD) corrected was used to identify pairwise differences. Effect sizes (ES) for changes from PRE to T0, T15, and T30 were calculated. To interpret the magnitude of the ES, limits proposed by Cohen (7) were adopted. For hormonal data, the area under the curve was calculated using the trapezoidal method and
compared between rest conditions using a paired mean t-test. The Friedman test was used to investigate nonparametric data for RPE (Omni-Res) to compare differences in values between the distinct sets and rest protocols. When appropriate, Dunn's Post hoc analysis was applied for multiple comparisons. Additionally, the Wilcoxon test was used for comparisons between different rest RPE values. The level of significance was set as \( p \leq 0.05 \). All analyses were performed using the Statistica Software (version 10.0; StatSoft, Tulsa, OK, USA).

**RESULTS**

Excellent test-retest reliability was demonstrated by the intraclass correlation coefficient \( (r = 0.98) \) for the bench press 1RM test. In addition, a paired student t-test did not show any significant differences between test-retest 1RM loads.

For TT concentration (Figure 2), a significant interaction (rest condition \( \times \) time point) effect was observed \( (p = 0.02) \). Specifically the main effect for time point \( (p = 0.001) \) the Fisher's LSD Post hoc analysis revealed that both rest protocols resulted in significant increases in TT compared with PRE for all post-exercise time points for both 1- and 3-minute rest protocol (T0, T15, and T30). In addition, the 1-minute rest triggered a significant reduction in TT for T15 and T30 when comparing with the previous peak found at early T0. However, there was no significant main effect \( (p = 0.194) \) between rest conditions. The area under the curve did not differ \( (p = 0.240) \) between the 1-minute \( (199.33 \pm 34.43 \, \text{ng} \cdot \text{ml}^{-1} \cdot \text{min}^{-1}) \) and 3-minute \( (209.37 \pm 29.07 \, \text{ng} \cdot \text{ml}^{-1} \cdot \text{min}^{-1}) \) rest conditions (Figure 3).
For FT concentrations (Figure 4), a significant interaction (rest condition × time point) effect (p = 0.001) and a significant main effect was observed for time point (p = 0.001). Fisher’s LSD Post hoc analysis revealed that the 1-minute rest protocol resulted in significant increases in FT at T0 and T15, and a significant reduction at T30 compared with PRE; whereas, for 3-minute rest length, FT was significantly increased compared with PRE at T15 and T30. In addition, the 3-minute rest triggered a subsequent increase at T30 when compared with T15. No difference (p = 0.452) was found between rest conditions. The area under the curve did not differ (p = 0.150) between 1-minute (199.35 ± 23.54 ng·ml⁻¹·min⁻¹) and 3-minute (203.20 ± 20.28 ng·ml⁻¹·min⁻¹) rest conditions (Figure 5).

For C concentrations (Figure 6), no significant interaction (rest condition × time point) effect was observed (p = 0.902). The area under the curve did not differ (p = 0.08) between the 1-minute (583.39 ± 79.07 μg·dl⁻¹·min⁻¹) and 3-minute (527.66 ± 88.86 μg·dl⁻¹·min⁻¹) rest conditions (Figure 7).

For TT/C concentration (Figure 8), a significant interaction (rest condition × time point) effect was observed (p = 0.02). Specifically on the main effect for time point (p = 0.001), Fisher’s LSD Post hoc analysis revealed that both rest protocols resulted in significant increases in TT/C compared with PRE for all rest periods (1 and 3 minutes) and postexercise time points (T0, T15, and T30). However, there was no significant main effect (p = 0.212) between rest conditions. Additionally, the area under the curve did not show any significant difference (p = 0.31) between 1-minute (14.64 ± 4.01 TT/C·min) and 3-minute (17.87 ± 5.08 TT/C·min) rest conditions (Figure 9).

For GH concentrations (Figure 10), no significant
interaction (rest condition × time point) effect was observed ($p = 0.686$). Moreover, the area under the curve did not show any significant difference ($p = 0.20$) between 1-minute ($2.12 \pm 1.01 \text{ ng}\cdot\text{ml}^{-1}\cdot\text{min}^{-1}$) and 3-minute ($1.83 \pm 0.91 \text{ ng}\cdot\text{ml}^{-1}\cdot\text{min}^{-1}$) rest conditions (Figure 11).

Table 1 represents the magnitude of each ES for hormone concentrations at each corresponding rest period and post-exercise time point compared with PRE.

A significant increase in preset RPE was evident by the fourth set for the 1-minute condition ($p < 0.0001$) and only at the fifth set for the 3-minute condition ($p = 0.0002$). Also for preset RPE, higher values were found for the 1-minute condition compared with the 3-minute condition starting at the third set ($p < 0.007$).

Significantly higher values of postset RPE were evident from the fourth set for both conditions compared with the first set ($p < 0.0001$). Additionally, significant differences were also observed in postset RPE values, with increments appearing early on the second set for postset RPE for the 1-minute condition when compared with the 3-minute condition ($p < 0.01$). All RPE data are presented in Table 2.

![Figure 11. Spaghetti graph of growth hormone (GH) concentrations at pre-exercise (PRE), and immediately (T0), 15 minutes (T15), and 30 minutes (T30) after completing of 5 sets of bench press exercise with 1- or 3-minute rest between sets.](image)

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<th>Table 1. Effect size of the change from PRE in hormone concentration for each rest period and post-exercise time point.*</th>
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*TT = total testosterone; FT = free testosterone; C = cortisol; TT/C = total testosterone/cortisol ratio; GH = growth hormone.
DISCUSSION

The key experiment findings regard that TT was sensible to a strength characteristic model with both 1- and 3-minute rest, triggering significant elevations on TT values occurred after 5 sets of only 1 exercise performance for all postexercise verifications. However, with some peculiarities, for instance, the 1-minute rest triggered a significant reduction in TT for T15 and T30 when comparing with the previous peak found at early T0 while the same peak occurred for 3-minute at T0, but it was maintained augmented until as far as T30. In addition, noticeable FT augmentations were found for both rest protocols on distinct postworkout moments. The acute TT elevations with unnoticeable changes in C promoted a higher TT/C ratio for all postexercise verifications on both rest analyzed. Additionally, it, perhaps, that the strength characteristic method applied, did not change GH values for any posterior moment compared with PRE. To the authors' knowledge, this is the first study to equalize load and number of repetitions for each set in addition to total work volume (load × total repetitions) for the bench press exercise and thus allowing for examination of isolated effect of the rest interval variable. Nonetheless, other studies have focused on the impact of rest interval manipulation on hormone concentrations. However, great variation in methods used regarding exercise selection, populations, nonequalized vs. equalized volume and exercise schemes, workout duration, relative loads, and nutritional controls provided very divergent results preventing a consensus regarding postexercise hormone response patterns in response to rest period durations.

Testosterone may be an important and rapid signaling molecule to trigger the distinct mechanisms that would lead for strength and muscle hypertrophy adaptations from resistance training in men (30,38). It also known that resistance exercise could acutely increase TT concentrations in men (24). Increases on TT values might be related to reduced plasma volume, acute blood lactate augmentation (26), and adrenergic stimulation (18), or even adaptations in testosterone synthesis and/or secretory capacity of the Leydig cells in the testes (11). It seems that increases on TT values are related to augments on other hormonal mechanisms (e.g., GH and insulin-like growth factor-1) that could enhance muscle anabolism (12). Also, some studies have shown that greater TT values would have a positive impact on nervous system adaptations such as higher amount of neurotransmitters released, regenerate nerves, increase cell body size, and dendrite length/diameter (6,32). These processes directly related to strength adaptations and are from most interest of observation to comprehend and optimize resistance training prescriptions.

For instance, our findings have shown that TT was sensible to strength characteristic protocol on both rest periods models (1 and 3 minutes). We have found that 1-minute rest period triggered significant elevations on TT for T0, T15, and T30 when compared with PRE status. However, T15 and T30 were significantly reduced when compared with the peak obtained for T0. As for the longer rest period (3 minutes), there was a significant elevation on TT concentration in all postworkout verification (T0, T15, and T30) compared with PRE, and TT value presented a sustainable lasting elevation until as far as T30. Our data corroborate partially to previous findings (33,41). For instance, Villanueva et al. (41) implemented a series of distinct strength training intensities and have found significant elevations of TT for what the authors called a strength characteristic (8 sets of 85% of 1RM for upper and lower body), only at immediately after exercise verification compared with pre-exercise for the longer (90 seconds) of rest between sets. In addition, they found increases only at 15-minute postexercise for the shorter (60 seconds) rest. In another experiment, Rahimi et al. (33) implemented a distinct strength training method (4 sets of 85% of IRM to failure for back squat and bench press) and did not found any TT elevation for the short rest (1 minute) for any postworkout verification (immediately after and after 30-minute postexercise). However, the authors have found significant TT augmentations for the longer rest period (2 minutes) for both immediately after and 30-minute post-exercise verification. It is important to note that our experiment was the first investigating the rest variable applying only 1 exercise for high-intensity/low-volume method, and we still found a strong TT sensibility for the postworkout window.
Free testosterone is a portion of testosterone not bound to the sex hormone-binding globulin protein and is considerably biologically active, able to interact with androgen receptors, and its expression has been shown to hold some relation to TT values (24). Previous studies have shown acute increases on FT values after strength exercise routines (22,39). Additionally, the previous data suggest that strength-trained men would present higher sensibility to an acute bout of a strength session, indicating a positive adaptation effect on FT expression. In parallel with these findings, we observed that strength-trained men (bench press relative strength: $1.3 \pm 0.1$ kg per kilogram of body mass) were sensible to a single exercise protocol with 5 sets for both 1- and 3-minute rest protocols. For instance, resting 1 minute produced an augmentation on FT values for T0 and T15 when compared with PRE. However, there was an abrupt decrease for T30 compared with both T0 and T15 increases, and even for the PRE state. In contrast with those findings, the 3-minute rest period triggered significant elevations late at the T15 compared with PRE state, and a very high elevation at T30 compared with PRE, T0, and even compared with the T15 increase. These findings suggest that the longer rest (3 minutes) could be an efficient strategy for dramatically increasing FT values in a postworkout window. To the author’s knowledge, this is the first experiment that compared rest periods and analyzed acute postexercise FT values.

Acute increases in C values during and after resistance training are generally attributed to metabolically demanding protocols. It has been shown that high-volume, moderate to high-intensity, and short rest periods have elicited the greatest acute lactate and C response (24). However, some strength protocols have failed to elicit a significant C response, whereas hypertrophy and endurance protocols performed by the same group of subjects elicited more substantial acute elevations through 30-minute postexercise (37,44). For instance, Smilios et al. (37) have shown that 4–6 sets of a resistance session elicited a significantly larger C response than 2 sets. Our investigation is in parallel with these findings once it was implemented by a strength characteristic protocol with low volume (5 sets of only 1 exercise). After the acute bouts, we did not observe any differences in C values between PRE and all other postexercise verifications (T0, T15, and T30). In parallel with our data, Villanueva et al. (41) also did not find any differences on C values over neither different strength training protocols (strength and hypertrophy type) nor rest periods (60 and 90 seconds) for any postworkout verifications.

The TT/C ratio has been suggested by some as an indicator of the anabolic/catabolic status of skeletal muscle during resistance training (14). However, in animals, when the TT/C ratio was manipulated to investigate muscle hypertrophy, no correlation was able to be established. Therefore, it is not possible to ensure that the TT/C ratio alone would be a useful indicator of tissue anabolism (9). In our investigation, we observed that both resting protocols (1 and 5 minutes) were able to efficiently elevate the TT/C ratio as soon as the T0 and were able to sustain this increase as late as T30 for postworkout window. Although the relation between TT/C ratio and chronic tissue adaptations remains questionable, its analysis could add important data when interpreting the data from a broader perspective. To the author’s knowledge, this is the first investigation that has compared distinct rest protocols and analyzed TT/C ratio variations on acute postexercise verifications.

Growth hormone is a polypeptide produced by the anterior pituitary gland, and it is regulated by 2 hypothalamic hormones: GH-releasing hormone that triggers its production and somatostatin that inhibits. In the bloodstream, GH is presented in different isoforms as follows: dimers, monomers, and acidified and glycosylated forms. The major circulating isoform is the 22 kDa and its fractions (20 kDa) corresponding approximately 90% of total circulating molecules. The hormone circulates in free form and approximately 40% is bound to a GH-binding protein. Its secretion is pulsatile, with several daily peaks of greater magnitude and frequency during sleep, increasing during puberty and decreasing with advanced age (20). The potential role of GH for repairing and remodeling of skeletal muscle and connective tissue has led to several studies of GH responses to acute resistance exercise (20). Although it is well known that functional roles of GH include tissue anabolism, metabolism, and endocrine signaling (20), elevations in the anabolic hormones such as GH are believed to be advantageous for muscle growth but are still controversial (24). Previous studies have widely investigated GH responses to resistance training. Perhaps that the manipulation of training variables such as intensity (4,24), volume (14), muscle mass involved (21), rest periods (30), and multiple vs. single set protocols (8,14) can directly change the GH outcome values in postworkout.

Particularly in our experiment, we focused on investigating a low volume with only 1 exercise, and we have found that the GH is not acutely sensible to this training approach regardless of the distinct rest periods interventions. This finding is in parallel to the literature that indicates GH elevations are sensible to metabolic demanding training protocols such as those with moderate-to-higher intensity and high volume (24,27,33). The phenomena in which GH responds acutely to exercise seem to be influenced by changes in homeostasis caused by metabolic stress (13,15–17,40). Our data seem to show that a single exercise independently of the rest period has no GH and C elevation potential, probably because of the low metabolic stress that our designed training scheme promoted. These outcomes seem to be in parallel with those found by Mangine et al. (27). The discrepancy between the known signaling properties of GH and its anabolic effects may be explained by the apparently low biological activity of GH monomeric 22 kDa molecule (20). One limitation of our experiment was that we did not verify the specific activity of the binding molecules, and we
did not dose the blood lactate in order to make any correlation with the metabolic stress. Thus, our study leaves unclear important questions about GH expression and the possibility of further muscle growth. Our study only verified that low-volume resistance exercises do not promote significant changes in GH hormone.

Additionally, resting 1 minute between sets elicited significantly higher RPE values vs. resting 3 minutes between sets. The RPE values were assessed before and after each set; when considering the preset RPE values, a significant increase was observed before fourth set vs. before second set when resting 1 minute between sets. Conversely, when resting 3 minutes between sets, the preset RPE value was only evident by the fifth (and final) set. Moreover, resting 1 minute between sets produced a higher preset RPE value as early as the third set. The short 1-minute rest also presented higher postset RPE values vs. resting 3 minutes between sets, and this was observed as early as the second set, consistent with another recent scientific investigation (35). These data indicate that even on a load-equalized and volume-equalized scheme, rest interval alone can directly result on different perceived exertion sensations.

Traditionally, the prescription of high-intensity 1–6RM loads are intended to increase muscle strength and have not been shown to stimulate large systemic elevations in hormones (29). However, this study demonstrated that a high-intensity/low-volume bench press protocol with both 1- and 3-minute rest intervals between sets could trigger significant and extended acute responses. Both rest periods (1 and 3 minutes) resulted in significant increases in acute TT, FT without significantly increasing C. This outcome sparked elevations of the TT/C ratio making the postworkout window an opportune hormonal status for those aiming to develop strength and tissue adaptations.

**Practical Applications**

Traditionally, professionals prescribe longer rests between sets (e.g., 3–5 minutes) for strength-developing purposes. This experiment is on parallel to this practice once we have found that although both rest protocols (1 and 3 minutes) enhanced testosterone values, the longer rest (3 minutes) provided a long-lasting elevation for both TT and FT. It seems that because of the strength and low volume characteristics of the model applied, neither C nor GH presented significant variations on a postexercise window for both rest conditions. Based on the findings of a durable testosterone augmentation with the longer rest period, practitioners with strength development goals should consider implementing this type of rest between sets for this type of training method. Although, it is important to highlight that short rest periods also inflicted significant testosterone elevations and must not be discarded as part of a strength program elaboration. This experiment supports the previous findings that the manipulation of the acute program variables, including rest interval, can provide distinct effects on the acute hormone response to exercise and thus, such manipulations of the variables should be applied according to the specific training goals. However, it is important to observe that these results apply to the specific conditions (bench press exercise, 5 sets of 3 repetitions performed at 85% of 1RM, ingestion of a pre-exercise meal, and resistance-trained young men) involved in this study and might not be transferable to other conditions.

**References**

Durable Testosterone Responses


