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Research article

Influence of two different rest interval lengths in resistance training sessions for upper and lower body

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Abstract
Rest intervals between sets appear to be an important variable that can directly affect training volume and fatigue. The purpose of the present study was to compare the influence of two and five-minute rest intervals on the number of repetitions per set, per exercise and total repetitions in resistance training sessions. Fourteen trained men (23.0 ± 2.2 yrs; 74.9 ± 4.1 kg; 1.75 ± 0.03 m) completed three sets per exercise, with 10RM load in four training sessions. Two sessions involved lower body exercises (leg press, leg extension and leg curl), with two-minute (SEQA) and with five-minute interval (SEQB). The other two sessions involved upper body exercises (bench press, pec-deck and triceps pulley), with two (SEQC) and five-minute intervals (SEQD). For two-minute, five of six exercises presented reductions in the second set, compared with the first set, and for the third set compared with the first and second sets. For five-minute, three of the six exercises presented reductions in the third set, compared with the first sets, and two of the six for the third set, compared with the second sets. The total number of repetitions in SEQA (66.7 ± 4.9) was significantly smaller than in SEQB (80.9 ± 6.9). Similarly, the total repetitions was significantly lower in SEQC (71.1 ± 4.7) compared with SEQD (83.7 ± 6.1). The results indicate that the training session performance is reduced by shorter intervals, being the initial exercises less affected during the progression of the sets.

Key words: Muscle strength; weight lifting; exercise; physical fitness.

Introduction

Resistance training prescription combines a number of variables, among which the American College of Sports Medicine points out the intensity (load), number of repetitions and sets, rest period length between sets and exercises, length and type of muscle contractions, order of exercises and repetition velocity (American College of Sports Medicine, 2002). Manipulation of these training variables can alter exercise-induced adaptations and further maximize gains in muscle strength, endurance, power and hypertrophy. For example, it is well known that higher training intensities (≤11RM) lead to greater muscle strength and hypertrophy whereas lower intensities (≥20RM) are related to greater muscle endurance adaptations (Campos et al., 2002). Similarly, multiple-set regimens have shown to be superior than lower training volumes (single-set regimens) particularly in resistance-trained individuals (Peterson et al., 2005).

Rest intervals between sets appear to be an important variable that can directly affect training volume and fatigue by altering endocrinal and metabolic responses as well as the performance and completion of subsequent sets (Fleck and Kraemer, 2004). Recent studies have shown that different interval lengths result in different adaptations in the neuromuscular and endocrine systems (Hill-Hass et al., 2007; Willardson and Burkett, 2008; Bottaro et al., 2009). Nevertheless short intervals can result in significant reductions on the number of repetitions during the progression of subsequent sets (Rahimi, 2005; Ratamess et al., 2007; Willardson and Burkett, 2005; 2006a; 2006b). Additionally, Willardson and Burkett (2005; 2006b) demonstrated that the influence of the rest interval length is different between upper- (bench press) and lower-body (squat) exercises. However, results from current studies do not permit inferences regarding necessary rest interval between sets and exercises for the sustainability of repetitions' number during the progression of the sets in different exercises performed in a same training session.

To the authors' knowledge, only one study has examined the influence of different rest interval lengths on training session's strength performance. Miranda et al. (2007) reported that rest intervals between sets and exercises directly affect the total volume of a training session for upper body exercises. The results indicated that one-minute rest between sets lead to a reduction in total training volume and completion of number of repetitions in subsequent sets compared to three-minute rest intervals. Furthermore, the results also showed tendencies towards more substantial reductions in the number of repetitions of the exercises performed at the end of the sequences, indicating that the influence of the different rest interval lengths may depend on the position of the exercise in a sequence.

However, Miranda et al. (2007) study only analyzed exercises for trunk and upper body and used 1 and 3 minutes intervals, showing the necessity of further investigations involving different exercises and rest intervals. Trying to extend those findings for different muscle groups exercises and rest interval conditions, the aim of this study was to investigate the effects of longer rest interval between sets (two versus five-minute) undertaken in separate sessions for upper and lower body exercises on completion of repetitions across subsequent sets and total training session volume. The reason for the choice of these rest intervals in the present study was the general recommendation when training for maximal strength has been to rest two to five-minute between sets (American College of Sports Medicine, 2002), and the paucity of studies that analyzed a daily practice session with multiple exercises. It was hypothesized that performance would

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be negatively affected with the shorter rest interval condition, and in the exercises performed late in a training session irrespective of the rest interval.

Methods

Subjects

Fourteen trained men participated in this study (23 ± 2.2 yrs; 74.9 ± 4.1 kg; 1.75 ± 0.03 m). The inclusion criteria for the study were that all participants had to be habitually physically active, having performed a resistance training program for at least one year with a minimum training frequency of three times per week, had no functional limitations concerning the resistance training program or any of the testing procedures and were not using anabolic-androgenic steroids or other ergogenic substances. Prior to data collection, all the participants filled the PAR-Q questionnaire (Shephard, 1988). All participants read and signed an informed consent document after being informed of the testing and training procedures to be performed during the study according to the Declaration of Helsinki. Training experience and habitual physical activity were determined by the use of questionnaire and interview. The experimental procedures were approved by the Ethics Committee of Universidade Federal do Rio de Janeiro. The present research procedures were in accordance with guidelines for use of human subjects set forth by the American College of Sports Medicine.

Strength testing

After two familiarization sessions, the 10 repetition-maximum (10RM) tests were assessed during two non-consecutive days in the same sequence: leg press (LP), bench press (BP), leg extension (LE), pec-deck (PD), leg curl (LC) and triceps pushdown (TP). During the 10RM test, each subject preformed a maximum of three 10RM attempts for each exercise with five-minute rest intervals between attempts. After the 10RM load in a specific exercise was determined, an interval not shorter than 10 minutes was allowed before the 10RM determination for the next exercise. Standard exercise techniques were followed for each exercise (Baechle and Earle, 2000). Then after 48 hours, the 10RM tests were repeated to determine test-retest reliability. Excellent day-to-day 10RM reliability for each exercise was obtained with intraclass correlation coefficients of LP r = 0.92; BP r = 0.94; LE r = 0.98; PD r = 0.96; LC r = 0.96 and TP r = 0.94. Additionally, a paired student t-test showed no significant differences between the 10RM tests for any of the exercises in both days. The greatest load lifted over two days was considered the 10RM and posterior used.

The 10RM testing protocol has been described previously (Simão et al., 2005). Briefly, in order to minimize the errors, the following strategies were adopted: a) standardized instructions concerning the testing procedure were given to the participants before the test; b) the participants received standardized instructions about exercise technique; c) body position was held constant (i.e. hand width during BP and foot position during the LP test); d) verbal encouragement was provided during the testing procedure; e) the mass of all weights and bars used were determined using a precision scale.

Experimental procedure

Forty-eight hours after the loads were obtained for the 10RM test in each selected exercise, Latin Square design was used to determine the inclusion of the participants in the sequences. Sequence A (SEQA) was comprised of exercises for lower body (LP, LE and LC) with two-minute rest interval between sets and exercises. Sequence B (SEQB) was similar to SEQA, however with five-minute rest interval. Sequence C (SEQC) was comprised of exercises for upper body (BP, PD and TP) with two-minute rest interval between sets and exercises. Sequence D (SEQD) was similar to SEQC, however, with five-minute rest interval. The training sessions were comprised by 10RM loads and the participants were instructed to perform the maximum number of repetitions in each set. The exercises were interrupted in concentric failure, when the subjects could no longer produce sufficient force to move the resistance in the concentric phase, staying in isometric contraction for more than two seconds. Before the beginning of each training session, a warm-up was performed, with 40% of the 10RM load for 12 repetitions only in the first exercise. Subjects were required to utilize a smooth and controlled motion. Pauses were not allowed between the concentric and eccentric phases and the movement had self-selected velocity. No attempt was made to control the movement velocity during each repetition of the exercises. All sessions were supervised individually by an experienced resistance training professional.

Statistical analyses

All data were presented as mean ± standard deviation of the Mean (SD). The statistical analysis was initially done by the Shapiro-Wilk normality test and by the homocedasticity test (Bartlett criterion). All variables presented normal distribution and homocedasticity, so ANOVA two-way was used to verify if there were differences in the number of repetitions between sets of each exercise in the same session and between the training sessions, and when the difference presented was significant, the Tukey's post hoc test was applied for multiple comparisons. Student's test-t was used to verify differences in the total number of repetitions per session, as well as in the total number of repetitions for a same exercise between the two and five-minute rest intervals. The significance level adopted was $p < 0.05$. Statistica version 7.0 (Statsoft, Inc., Tulsa, OK) software was used for all statistical analyses.

Results

Table 1 and 2 shows the number of repetitions in each set and the total number of repetitions in each exercise for lower and upper body with rest intervals of two and five-minute.

The total number of repetitions (total number of repetitions in all session's sets and exercises) in SEQA (66.7 ± 4.9 repetitions) was significantly smaller than in SEQB (80.9 ± 6.9 repetitions). Similarly, the total number of repetitions was significantly lower in SEQC (71.1 ± 4.7 repetitions) compared with SEQD (83.7 ± 6.1 repetitions).

Table 1. Total number of repetitions in each set and the total number of repetitions in each exercise for lower body with the rest intervals of two and five minutes. Data are means (± standard deviation).

	1st set	2nd set	3rd set	Repetitions
Leg press				
2 min	9.7 (.5)	7.7 (.7) *	6.7 (2.1) *†	24.1 (2.5)
5 min	10.0 (.0)	9.6 (.8) ‡	8.0 (1.9) *	27.6 (2.0) ‡
Leg extension				
2 min	8.3 (1.5)	7.3 (1.6) *	6.6 (.5) *	22.1 (3.3)
5 min	9.0 (1.4)	8.7 (1.6)	8.3 (1.7)	26.0 (4.2) ‡
Leg curl				
2 min	8.0 (1.3)	7.0 (1.7) *	5.4 (1.0) *†	20.4 (3.5)
5 min	9.7 (.5)	9.1 (.7) ‡	8.4 (1.1) *†‡	27.3 (2.0) ‡

Values are expressed in repetitions maximum (RM); * $p < 0.05$ compared with the 1st set; † $p < 0.05$ compared with the 2nd set; ‡ compared with 2 min.

Discussion

The main finding of the present study was that two-minute rest intervals resulted in significantly lower repetitions performed for all the exercises in the second set compared with the first one, except for PD, and for the third set compared to the first and second set, except for LE. For five-minute, the declines in repetitions were only significant for LP, LC and TP exercises in the third set. Additionally, the total number of repetitions for all the exercises and the total number of the repetitions in the sessions showed significantly reduced values in SEQA and SEQC (sessions with two-minute intervals between sets and exercises).

Miranda et al. (2007) found similar results to the present study when comparing the effects of one and three-minute rest intervals on the number of repetitions per sets, total volume of each exercise and total volume of the training session. In the above-mentioned study, 14 trained men performed two training sessions, consisting of three sets with 8RM loads, in six exercises for upper body, in the following order: lat pull-down with a wide grip, lat pull-down with a close grip, machine seated row, barbell row lying on a bench, dumbbell seated arm curl and machine seated arm curl. The two experimental sessions differed only in the rest interval between sets and exercises (one and three-minute). For all the exercises, the results showed a lower total number of repetitions when one-minute intervals were used. Both protocols resulted in significant reductions in the third set compared with the first set, in four of the six exercises. Moreover, the protocol that used one-minute also showed reductions in the second set compared with the first set, in two of the six exercises. Although using different intervals and exercises, the results of this study are similar to ours, by showing that shorter rest intervals between sets and exercises can result in declines on the total volume of repetitions of a training session. Additionally, the results of Miranda et al. (2007) showed tendencies towards more substantial reductions in the number of repetitions of the exercises performed at the end of the sequences, which can also be observed in our results

Simão et al. (2005) investigated the influence of different exercise sequences on the number of repetitions performed in a group composed of both trained men and women. The exercise sessions, consisted of performing three sets of each exercise with a resistance of 10RM and two-minute rest periods between sets and exercises. The results demonstrated performing either large or small group exercises for the upper-body at the end of an exercise sequence resulted in significantly fewer repetitions, compared to when the same exercises were performed early in an exercise sequence. A more recent study by Simão et al. (2007) demonstrated a similar phenomenon in trained women when both upper and lower-body exercises were performed in the same exercise session. Like described by Simão et al. (2005; 2007), utilized 2-minute rest are used, reduced numbers of repetitions (approximately eight) were observed even at the first set of the exercises performed last (LE, LC and PD). These results can be associated to the progressive fatigue accumulation during the progression of the sets and exercises in the training session, as observed in previous studies (Simão et al., 2005; 2007).

Previous studies seem to be convergent regarding the rest interval influence between sets on the number of repetitions during the progression of the sets in the same exercise (Rahimi, 2005; Willardson and Burkett, 2005;

Table 2. Total number of repetitions in each set and the total number of repetitions in each exercise for upper body with the rest intervals of two and five minutes. Data are means (± standard deviation).

	1st set	2nd set	3rd set	Repetitions
Bench press				
2 min	10.0 (0.0)	9.0 (1.3) *	7.1 (1.3) *†	26.1 (2.2)
5 min	10.0 (0.0)	9.7 (.9)	9.1 (1.1) ‡	28.9 (1.8) ‡
Pec-deck				
2 min	8.3 (.7)	7.7 (1.1)	6.1 (.7) *†	22.1 (1.8)
5 min	8.8 (1.5)	9.7 (.9) ‡	9.3 (1.2) ‡	27.9 (2.7) ‡
Triceps pulley				
2 min	9.3 (.5)	7.7 (1.1) *	5.9 (1.1) *†	22.9 (1.7)
5 min	9.8 (.7)	9.5 (1.3) ‡	8.4 (1.4) *†‡	27.7 (2.6) ‡

Values are expressed in repetitions maximum (RM); * $p < 0.05$ compared with the 1st set; † $p < 0.05$ compared with the 2nd set; ‡ compared with 2 min.

2006a; 2006b). Ratamess et al. (2007) examined the effects of different rest intervals on the intensity, volume, and metabolic responses to the bench press exercise. Eight trained men performed 10 randomized protocols [five bench press sets at 75% or 85% of 1RM for 10 repetitions and five repetitions, respectively, using different intervals between sets (30 seconds, one-, two-, three, five-minute)]. The oxygen consumption was measured during exercise and for 30 minutes thereafter. For the 30 second and 1 minute rest intervals, 15-55% reductions in intensity and volume were observed (sets five < four < three < two < one). For the two-minute rest interval, the performance was maintained during the first two sets, but declined 8-29% during the third, fourth and fifth sets. For the three-minute rest interval, a volume reduction was noted for the fourth and fifth sets, (approximately 21% lower than the first, second, and third sets). At five-minute, a reduction was observed only for the fifth set. Overall, the greatest reductions in performance occurred with very short rest intervals (< one-minute), and performance was maintained during the first three to four sets when three to five-minute rest intervals were utilized.

Confirming this, our results showed that longer rest intervals of five-minute enabled a significantly increased number of repetitions per exercise, when compared with two-minute. Abdessemed et al. (1999) associate the decrease in the total number of repetitions with the concomitant effects of the lactate accumulation and insufficient time for a complete creatine phosphate (CP) store resynthesis. Knowing that the strength performance is highly dependent of the anaerobic energetic metabolism (especially ATP-PC), rest interval length in each exercise or session, determines fatigue development. Thus, it can be stated that periods with varied lengths between sets and exercises effectively result in different physiological responses, which causes an impact in resistance training programs, according to the aimed objective (Abdessemed et al., 1999).

Our results or the results obtained by Miranda et al. (2007) showed that longer intervals allow the sustainability of the number of repetitions in sets and subsequent exercises performed in a same training session, exerting direct effect on the total training volume (Willardson and Burkett, 2008). On the other hand, shorter rest intervals can result in favorable hormonal and metabolic responses to a training session (Bottaro et al., 2009). Bottaro et al. (2009) investigated the acute hormonal responses to three distinct intervals between sets in similar resistance training sessions involving exercises for lower body. This study composed three resistance training sessions performed by 12 trained women, with 30, 60 and 120 seconds intervals between sets and exercises. The training sessions consisted of four exercises for lower body, performed up to muscular concentric failure, in three sets with 10RM loads. No difference was found between the protocols for growth hormone and cortisol concentrations before the training sessions. However, in comparison with the value presented before the exercise sessions, all the protocols induced an acute elevation in the growth hormone concentrations, while no differences for cortisol were presented. Growth hormone concentrations were shown to be higher for 30 seconds intervals, when compared to the other rest intervals, however, the total work (total number of repetitions x load) was significantly lower for the session that used 30 seconds interval, compared with those sessions using 60 and 120 seconds.

However, in the training for the strength development, longer rest intervals will be necessary to avoid significant declines in the number of repetitions, therefore the capacity to maintain the number with a constant intensity can result in greater muscular strength gains (Willardson, 2006; Willardson and Burkett, 2008). Our results are in accordance with this statement, suggesting that when training for muscular strength, resting five-minute might be advantageous to accumulate a higher training volume while also maintaining the intensity of the load lifted for upper- and lower-body. Additionally, it has been shown that training not to failure may be more advantageous for maximal strength gains than training to failure, so longer rest intervals (five-minute) would be necessary (Peterson et al., 2005).

In other previously conducted experiments of the influence of distinct intervals between sets, the movement velocity of the exercises was controlled (Willardson and Burkett, 2005; 2006a; 2006b). In our experiment that was not possible, due to the fact that there was a constant decrease in cadence from the first to the last repetition to failure, and one of the indicators of the concentric failure utilized was the reduction in the movement velocity and the consequent pause at concentric phase. Nevertheless, the first repetitions were performed at high velocity and, when fatigue was established, there was a significant decline in velocity, until the exercise was finish. This may be a limiting methodological factor of our experiment, since it may affect the number of repetitions, fatigue and type of strength being trained.

Conclusion

To maintain resistance training goals intensity and volume are important variables to be manipulated. Moreover, the present study showed that the rest interval time between sets and exercises is also a critical variable to meet different training goals; therefore it directly affects the number of repetitions during the progression of the sets, the total number of repetitions per exercise and the total number of repetitions of the session. These results indicate that these values can be reduced by the use of shorter intervals (two versus five-minute), and these reductions are less evident during the progression of the sets in the initial exercises. However, the influence of the rest intervals between sets and exercises in a training session is still a controversial issue in the literature, since it is highly related with the order in which a certain exercise is placed in the session. This way, studies that further investigate the influence of the relationship between different rest intervals and exercises orders for the same training session are recommended, especially in daily practical sessions, where frequently more than one exercise for the same or distinct muscle group are used.

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Key points

- Shorter rest interval between the sets and exercise in resistance training sessions for upper and lower body resulted in significant declines on the number of repetitions during the progression of the sets and exercises.
- Longer rest intervals seem to be necessary to avoid significant declines in the number of repetitions during the progression of sets and exercises during a resistance training sequence, principally for the exercises performed last.
- An important variable when maximal strength is desired is the volume of repetitions or total work. To achieve specific volumes longer rest interval is necessary
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