INTER-SET REST PERIODS AND PERFORMANCE REST PERIOD OPTIMIZATION IN NEAR-MAXIMUM TRAINING ZONES FOR TRAINED WOMEN: IMPLICATIONS FOR PERFORMANCE IN LEG EXTENSION AND LEG PRESS EXERCISES

Abstract

Introduction: The inter-set rest periods are important to understand how the manipulation works and are fundamental to correct description. Objective: The aim was to investigate the acute effects of resistance exercise (RE) inter-set rest intervals on the repetition performance and perceived exertion in multi- and single-joint exercises with near-maximal loads in women. Methods: Fifteen trained women performed eight sessions (2 exercises, 4 inter-set rest periods); each consisting of 5 sets with a 3-RM load for each exercise. The exercises tested were leg extension (LE) for the single-joint exercise and the leg press (LP) for the multi-joint exercise with 1-, 2-, 3- and 5-minute conditions. Results: The total number of repetitions in LP was significantly higher for the 3- (14.63±0.67 reps; p= 0.0002) and 5-minute conditions (14.90±0.32 reps; p= 0.0001) vs. the 1-minute condition (12.90±0.83 reps); and, similarly, the 3- (p= 0.0014) and 5-minute conditions (p= 0.0002) vs the 2-minute condition (13.54±1.13 reps), however, to 1- and 2-minute rest conditions no significant differences were found. For the LE, a significantly higher total number of repetitions was completed for 3- (14.91±0.30 reps; p= 0.0004) and 5-minute conditions (14.90±0.31 reps; p= 0.0005) vs. the 1-minute condition (13.18±1.72 reps). Conclusions: Both exercises showed decreasing repetition performance with all rest protocols over the last three sets. Regardless of exercise type, 1- and 2-minute rests led to higher perceived exertion. To enhance repetition consistency in women, prioritize longer rests (3 and 5 minutes) for multi-joint exercises like LP, and 2 minutes for single-joint exercises like LE.

Key Words *Weightlifting, Muscular strength, Physical fitness, Health promotion.*

Introduction

The specific arrangement of resistance exercises (RE) variables such as volume, intensity, inter-set rest periods, and exercise order, can optimize RE adaptations regarding strength, power, endurance, and muscle hypertrophy. In the last 20 years, inter-set rest periods have received considerable attention from researchers and have become an important RE variable to be included in training programs [2-4]. Previous studies have highlighted both acute and sub-acute variations on neuromuscular [5-7], endocrine [8,9], cardiorespiratory [10], and inflammatory responses [11,12] resulting from the rest interval manipulation. Over two decades, there have been several studies conducted to examine the ideal rest duration to maintain repetition performance [2,5,6,12-14] . Recent studies show that longer rest periods (such as 5-minutes) allow for better consistency in the repetition performance with 8- to 15-RM loads [5,12,15-17]. However, it is recommended for individuals with specific muscle strength development goals to train with loads ranging from 1- to 6-RM [1]. Thus, Scudese et al. [9] were the first to investigate the effects of manipulating rest periods with near maximal loads in the bench press exercise and observed that a 3-minute condition allowed sufficient recovery to maintain consistency in the repetition performance. Later, Senna et al. [7] found that to sustain repetition performance, a 2-minute rest period inter-sets was

sufficient for a single-joint exercise and 3 to 5 minutes was necessary for a multi-joint exercise. Scientific knowledge seems to be limited regarding this RE methodological variable in women.

More specifically, Ratamess et al. [10] investigated the performance of the bench press in individuals of both sexes. Two samples of subjects performed three protocols in the bench press, consisting of 3 sets of up to 10 repetitions with 75% of 1-RM using intervals of 1-, 2- or 3-minute inter-sets. For this, 22 men and women were analyzed to investigate any gender influence on RE. The number of repetitions performed, average power, and speed for each set was recorded. Women performed significantly more repetitions than men at 1-, 2- and 3-minute, thus demonstrating a greater tolerance to fatigue with the same intensity. In addition, the magnitude of the decline in mean speed and power was significantly greater in men than in women. The data from this experiment suggest that shorter intervals may be sufficient in women to achieve a high volume of training [10].

However, there is a persistent gap in the literature regarding the effect of different inter-set rest periods on repetition performance for multi- and single-joint exercise, and more specifically, with near maximal loads (such as 3-RM) in women. Thus, more knowledge on this subject can increase the efficacy in the prescription of RE for subsequent adaptations of strength over time. Therefore, the purpose of this study was to investigate the acute effects of different rest periods (1-, 2-, 3- and 5-minute) on the repetition performance of multi- and single-joint exercises with near maximal loads in women. The multi- and single-joint exercises selected for this study were the leg press (LP) and the leg extension (LE), respectively.

Material & methods

Experimental Approach to The Problem

Forty-eight to 72-hours after the familiarization and determination of the 3-RM loads for LP and LE, subjects performed eight different training sessions with 48 hours between sessions. The sessions were conducted in random order with a specific combination of exercise (LP or LE) and rest conditions (1-, 2-, 3-, or 5-minute). Five sets were performed for maximum repetitions with the pre-determined 3-RM load. The total number of repetitions and the rate of perceived exertion (RPE) were recorded after each set for all sessions.

Subjects

Fifteen trained women (29.86±3.37 years; 65.39±2.64 kg; 1.65±0.04 cm; 22.50±2.23% body fat) with a six-months minimum experience in RE participated in the study. The inclusion criteria adopted were: (a) the non-use of ergogenic resources to increase performance; (b) absence of chronic or acute injuries that would affect the LP and LE exercises performance; (c) not performing intense activities on the test days. All subjects were assessed within the luteal phase of the menstrual cycle. Before data collection, subjects answered “no” to all questions to the PAR-Q questionnaire [18]. The study procedures were analyzed by the ethics committee of the Catholic University of Petrópolis. Subjects read and signed the informed consent form when informed of the test procedures under Helsinki Declaration.

Determination of Three Repetition Maximum (3-RM)

After two familiarization visits, subjects performed four tests to determine the LP and LE exercises load. Subjects performed only one exercise per visit, in alternate order

on non-consecutive days for both test and retest. The following strategies were adopted to minimize measurement errors: (a) standardized instructions concerning test procedures and techniques for exercises performance were provided before each test; (b) body position was standardized; and (c) use of verbal encouragement [19]. The 3-RM test procedures were previously described elsewhere [7,9]. The definition of the initial loads for the 3-RM tests was estimated from the loads used by each subject in their daily routine. Thereafter, the load variation for each attempt was 5 kg for the LP and 2.5 for LE exercises. The last successful repetition was considered, and the highest load raised in the two test sessions was stipulated as the subject 3-RM load. Subjects performed a maximum of 5 sets per visit, with 10 minutes of passive rest period between each set [5]. Training sessions were separated by an interval of at least 48 hours. To minimize possible errors in the 3-RM tests, the following strategies were adopted: (a) participants were instructed regarding the exercise technique standardization, (b) participants' exercise technique throughout the test session was monitored and corrected, if necessary, (c) participants received verbal stimuli during all tests, and (d) all plates were determined with a precision scale [20,21].

Rate of Perceived Exertion Procedures (RPE)

The OMNI-Res scale for adults [22] was implemented to obtain the RPE values. Subjects were familiarized with the OMNI scale in the week before the load tests. Each subject determined a number based on their subjective perception of exertion, discomfort, and fatigue during the exercise session. The LP and LE exercises were performed during the familiarization sessions of 3 sets with 15 repetitions with 3 minutes of rest between sets with loads estimated in the daily training routines of each subject. Immediately after each exercise set, subjects were asked to classify their RPE, identifying a corresponding measure of the effort level.

Experimental Procedures

Forty-eight to 72 hours after the last 3-RM test, subjects completed the first of 8 different visits (2 sessions per week). In each session, subjects performed five sets with 3-RM loads in a randomized format that was implemented to combine each exercise (LP or LE) with a rest period condition (1-, 2-, 3- or 5-minute). Before each protocol, subjects performed a warm-up, which consisted of 2 sets of 12 repetitions with 40% of the 10-RM load (according to their daily training) for the exercise chosen for that session [7]. Then, a 2-minute rest was allowed between the warm-up and experimental procedures. Subjects were verbally encouraged [19] to perform five sets until voluntary fatigue. Each subject was instructed to perform a controlled and fluid movement. Besides, the total number of repetitions completed, and the values of the OMNI-Res scale were recorded after each set for both exercises.

Statistical Analyses

An alpha value of $p \leq 0.05$ was used to establish the significance of comparisons. To verify the reproducibility between the test and the retest, a paired t-test was followed by the intraclass correlation coefficient. One-way ANOVA was conducted to analyze the differences in the total number of repetitions completed for each exercise. Also, two-way ANOVA was performed to determine the repetitions completed in each set and under different rest period conditions. If necessary, additional comparisons were made using Tukey's post-hoc test. The Friedman test was used to analyze the RPE scores and compare differences after each set of each exercise, and between distinct rest period protocols. If necessary, a multiple comparisons test was applied (Dunn post-hoc). Version 21.0 of the SPSS software was used for the analysis (IBM, Inc).

Results

An excellent test/retest correlation was found for the 3-RM loads using the ICC (LP, r = 0.988; LE, r = 0.993), and no difference was found between the test/retest loads using the paired t-test ($p < 0.05$) for both cases.

The results indicated that for the LP, a significantly higher total number of repetitions was completed for, 3- (14.63±0.67 reps; p= 0.0002) and 5-minute (14.90±0.32 reps; p= 0.0001) vs. the 1-minute protocol (12.90±0.83 reps), and similarly, 3- (p= 0.0014) and 5-minute (p= 0.0002) vs. 2-minute (13.54±1.13 reps). There were no differences for the total number of repetitions between the 1- and 2-minute rest conditions. For the LE, the total number of repetitions completed was significantly higher in 3- (14.91±0.30 reps; p= 0.0004) and 5-minute (14.90±0.31 reps; p= 0,0005) vs. the 1-minute condition (13.18±1.72 reps). There were no significant differences between the 2-minute (14.27±1.27 reps) and the other rest conditions ($p > 0.11$). All performance data are presented in Figures 1A and 1B.

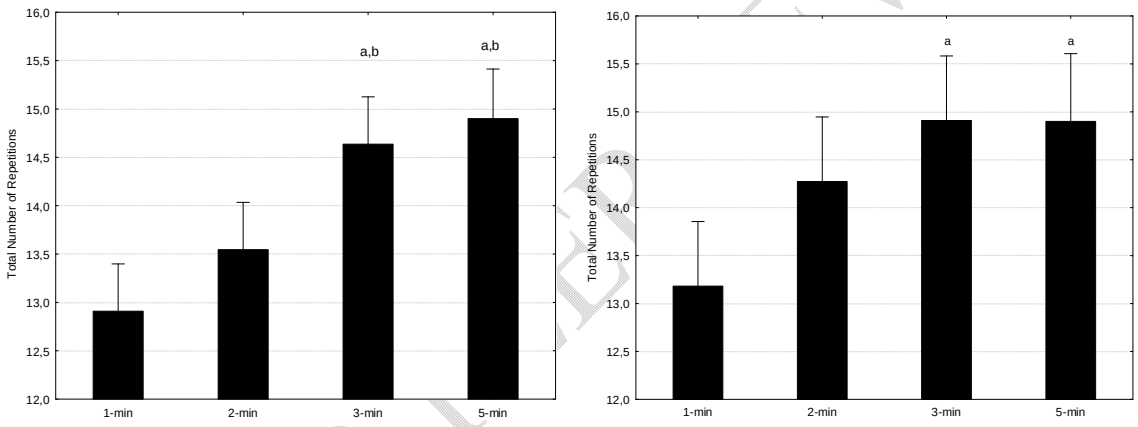

Figure 1. (A) Total number of repetitions in the LP for each interval condition (1-, 2-, 3-, and 5-minute). a Significant difference for the 1-minute rest inteval. b Significant difference for the 2-minute rest interval. (B) Total number of repetitions in the LE exercise for each interval condition (1-, 2-, 3-, and 5-minute). a Significant difference for the 1-minute rest interval.

Both exercises showed similar and progressive reductions in repetition performance for all resting conditions over the final two sets, starting in the third sets for the 1-minute rest condition. In both exercises, the interaction (rest x set conditions) showed significant differences (LP, p= 0.0001; LE, p= 0.008); similarly, the main effects (main-effect) of different rest conditions (LP, p= 0.0001; LE, p= 0.002); and for the main effects of different sets (LP, p= 0.0001; CE, p= 0.0001). Briefly, significant reductions in the numbers of repetitions were evident from the fourth set on 1- and 2-minute rest conditions for LP exercise. For the 3- and 5-minute rest conditions, there were no significant reductions between the sets. Also, for LP, significant differences were observed between the 1- and 2-minute rest conditions, in the fourth and fifth sets, compared to long (3- and 5-minute) rest conditions. For the LE exercise, significant reductions in repetition numbers appeared in the fourth set for a 5-minute rest condition.

There were no significant differences between each set for the 1-, 2- and 3-minute conditions. The data are shown in Figures 2A and 2B.

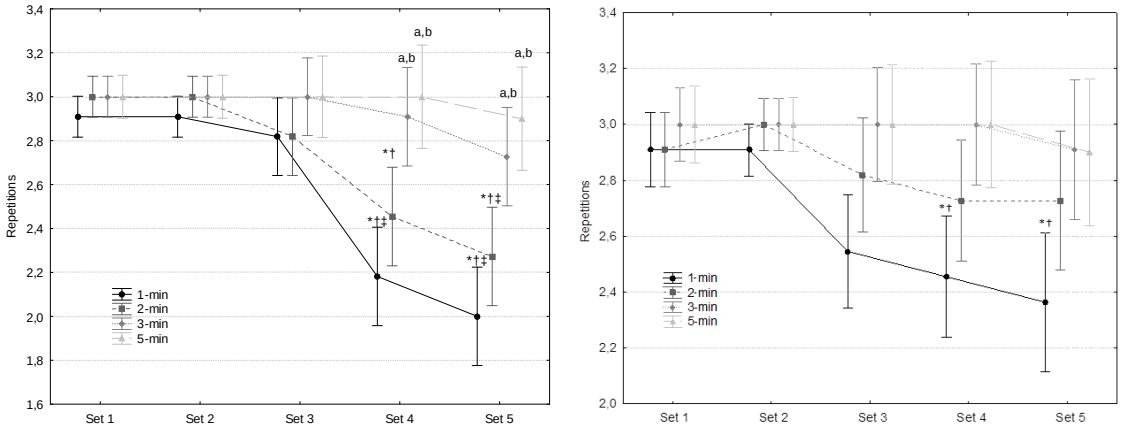

Figure 2. (A) Number of repetitions in the LP exercise for each set with rest intervals of 1-, 2-, 3- and 5-minute. * Significant difference for the set 1. † Significant difference for the set 2. ‡ Significant difference for the set 3. a Significant difference for the 5-minute rest interval. b Significant difference for the 3-minute rest interval. (B) Number of repetitions in the LE for each set with rest intervals of 1-, 2-, 3- and 5-minute. * Significant difference for the set 1. † Significant difference for the set 2.

For LP, the 1- and 2-minute rest protocol showed significantly higher RPE values compared to the other rest conditions (i.e., 3- and 5-minute) in the fourth and fifth sets, as statistically higher values in the fourth and fifth sets concerning the two initial sets. Partially similar, the LE presented higher values for RPE in the 1-minute interval rest protocol compared to the 5-minute interval in the fourth; and in the 3- and 5-minutes rest in the fifth sets. For the 1- and 2-minute rest conditions, the fourth and fifth sets showed higher values compared to the longer rest condition. The results of the RPE are shown in Table 1.

Table 1. Rate of perceived exertion for each set in both exercises with 1-, 2-, 3- and 5-minute of rest periods. (Data according to the median [25% - 75% of the frequency]).

	Set 1	**Set 2**	**Set 3**	**Set 4**	**Set 5**
LP					
1-min	7 (7-8)	8 (7-8)	8 (8-9)	9 (9-9)*†	9 (9-10)*†‡
2-min	7 (7-8)	7 (7-8)	8 (7-9)	8 (8-9) *†	9 (8-10) *†
3-min	7 (6-8)	7 (6-8)	7 (6-8)	7 (6-8)[a,b]	8 (7-9)[a]
5-min	7 (6-8)	7 (6-8)	7 (6-8)	7 (6-8)[a,b]	7 (7-8)[a,b]
LE					
1-min	7 (6-8)	8 (7-8)	8 (7-9)	9 (8-9)*†	9 (8-10)*†
2-min	7 (6-8)	7 (6-8)	7 (6-9)	8 (7-9)*†	8 (7-9)*†
3-min	7 (6-8)	7 (6-8)	8 (6-8)	8 (7-8)	8 (7-8)[a]
5-min	6 (6-8)	7 (6-8)	7 (6-8)[a]	8 (6-8)[a]	8 (6-8)[a]

*** Significant difference for the set 1; † Significant difference for the set 2; ‡ Significant difference for the set 3; [a] Significant difference for 1-min condition; [b] Significant difference for 2-min condition.**

Discussion

The key findings of the present study indicated that when implementing a 3-RM load for LP and LE in women, a 1-minute rest period between sets resulted in a significant reduction in the total repetitions completed over 5 consecutive sets. The results (for 1-minute) showed a significant decrease in contrast to the total number of repetitions completed for longer rest intervals between sets (3- and 5-minute), regardless of the exercise mode (multi and single-joint). However, the repetition reductions observed for the LP were more evident in comparison to LE with 2-, 3- and 5-minute between sets. Additionally, it appears that the longer rest periods have acute response patterns similar to 2-minute rest between sets for single-joint exercise, which does not seem to occur with multi-joint exercise. From a practical point of view, this study suggests that when 5 sets are performed, 2-minute rest seems to be sufficient for single-joint exercise (LE); while a rest period of at least 3-minute is adequate for multi-joint exercise with near-maximal load (3-RM) in women.

According to the American College of Sports Medicine [1], to optimize the development of muscle strength, the ideal load intensity should vary between 1 and 6-RM. In addition, the most recent recommendations suggest that, for the purpose of developing muscle strength, the rest period between sets should be 1- to 2-minute for single-joint exercises, and 2- to 3-minute for multi-joint exercises [1,22]. However, the present study is the first to assess the acute response in women on the repetition's performance for multi (i.e., LP) and single-joint (i.e., LE) exercises with near-maximal loads (i.e., 3-RM). Thus, we can affirm, based on our findings, that the current recommendations can be supported by our data [1]. Our findings suggest that to maximize repetition's performance, it appears that 2-minute is sufficient for single-joint exercise and at least 3-minutes is required for multi-joint exercise in trained women.

These data corroborate the previous study conducted by Senna et al. [7] with men. In this study, investigated the acute effects of different rest periods between sets on the repetition performance of multi- and single-joint exercise with near-maximum loads. For this, fifteen trained men were selected to carry out eight sessions (2 exercises and 4 different rest periods); each session consisted of 5 sets with a 3-RM load. The exercises tested were the machine chest fly as the single-joint exercise and the bench press as the multi-joint exercise. All rest periods were similar to those covered in our experiment. In conclusion, to maintain the best consistency in repetition performance, 2- minute rest periods between sets were sufficient for the machine chest fly (single-joint) and 3- to 5-minutes for the bench press (multi-joint exercise).

Corroborating in part to this experiment, Senna et al. [5] compared the repetition performance and RPE with a 1-, 3- or 5-minute rest period between sets in multi- and single-joint exercise. Fifteen trained men completed twelve sessions (4 exercises and 3 rest conditions), with each session involving 5 sets with loads compatible with the hypertrophy training zone (10-RM) on the bench press, machine chest fly, LP, and LE. The results indicated that for both multi- and single-joint exercises, there were similar patterns of repetition performance regardless of the length of the rest period between sets.

Comparing our results with previous studies [5,7], we observed similar patterns for both genders in repetition performance with 3-RM loads with different rest conditions between the sets. However, it seems that the training loads might be the primary factor for the differences between rest conditions on repetition performance. For instance, with load zones designed for muscle hypertrophy, like 10-RM range, differences were not observed between exercise types. However, the literature has not yet made clear the complete understanding of the different length of the rest period for hypertrophy or

strength zones in women. In a study previously conducted by Ratamess et al. [10], it was demonstrated that for women, that the results for repetition performance were higher in comparison with the men independent of the rest period with 75% of 1-RM loads. This data is not supported by our findings with near-maximum loads, due to similar responses in repetition performance observed in both the present [7].

Another pioneer experiment was conducted by Scudese et al.. [7] who compared the effects of different rest periods on bench press performance with 3-RM loads. Sixteen trained men made 4 visits for rest periods with 1-, 2-, 3- and 5-minute between 5 consecutive sets. In their results, Scudese et al. [9] found a higher total number of repetitions with 2-, 3- and 5-minutes vs. 1-minute rest conditions. Performance declines (in relation to the first set) were observed from the second set with 1-minute and only in the fifth set in all other rest conditions (2-, 3- and 5-minute) in trained men. The present study found similar results in the implemented load zone (3-RM); however, we went further and verified the repetition performance in trained women, with multi- and single-joint exercise for the lower limbs, and load zones compatible with the adaptations in muscle strength [1].

The present study showed a distinct difference between LP and LE, specifically in the 2-minute rest condition, in which declines appear to have been less evident for LE vs. the LP. In another study, Senna et al. [6] compared the effects of different rest conditions in repetition performance of the multi- and single-joint exercise, RPE, and blood lactate. Twelve trained men completed 5 sets of bench press and machine chest fly with 10-RM loads until failure with 1- and 3-minute rest periods. It was found that significantly higher total repetitions were completed for the 3-minute vs. 1-minute rest protocol for both exercises. For blood lactate concentrations, the multi-joint exercise demonstrated significant increases immediately and fifteen minutes post-exercise vs. the baseline for both conditions (1- and 3-minute). Although this experiment showed us a small difference between the different exercise types (multi- and single-joint) the fact is that this was not performed with near-maximal loads (like 3-RM).

The RPE values have been used to assess the relative intensity of the RE and its response to fatigue for different experiments that investigated the methodological variable of rest periods [5,-7,9,23]. Previous studies [5-7] reported that RPE increased over consecutive sets when comparing 1-minute vs. 3- or 5-minute rest when loads of 10-RM are used. More recently, Scudese et al. [9] found that the RPE was also lower when the longest rest was applied between the series with a 3-RM load. Significant increases in RPE for the 1-minute rest condition from the third to the fifth set for multi- and single-joint exercise were noted [7]. For the other rest conditions (2-, 3- and 5-minute), multi-joint exercises triggered significant increases from the third set to the fifth set. For the single-joint exercise, this increase was observed only in the fifth set for 3- and 5-minute rest conditions in trained men.

Similarly, the present study showed increases in RPE from the fourth set for the 1- and 2-minute intervals regardless of the type of exercise. Thus, 1- and 2-minute conditions can emphasize anaerobic glycolysis to a greater extent to compensate for incomplete phosphocreatine resynthesis. The greater dependence on anaerobic glycolysis is associated with the accumulation of H+ which decreases the pH of intracellular fluid. The resulting effect is afferent feedback from chemoreceptors and muscle nociceptors that are associated with an increase in perceived exertion [22]. The complex physiology involved on muscle recovery can somehow be evaluated using this type of scale, and when well familiarized by the user, it has the potential give immediate feedback between RE practitioners and strength coaches that can use this study data to make adjustments in the prescription of rest periods between sets.

Conclusions

Or logical consequent. Your conclusion is your chance to have the last word on the subject. The conclusion allows you to have the f This study contributes to the growing body of knowledge regarding the importance of programming the rest period between sets in near-maximum training zones for trained women. Our results indicate that for the leg extension exercise, 2-minutes between sets seems to be sufficient for excellent performance over 5 sets. However, the leg press exercise requires rest periods of 3- to 5-minutes between sets to allow a proper recovery for women. Strength coaches can apply the results of this study to improve the efficiency and effectiveness of a training program. From a practical perspective, the main lower extremity exercises (multi-joint exercise) should have longer intervals between sets for experienced women. However, 2-minutes between sets might be sufficient to allow an adequate recovery for the leg extension in this population with a 3RM load.inal say on the issues you have raised in your paper, to summarize your thoughts, to demonstrate the importance of your ideas, and to propel your reader to a new view of the subject. It is also your opportunity to make a good final impression and to end on a positive note.

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