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Research article

Effect of Different Rest Intervals, between Sets, on Muscle Performance during Leg Press Exercise, in Trained Older Women

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Abstract
The purpose of this study was to assess the effect of different rest intervals (RI) between sets on number of repetitions, sustainability of repetitions, and total volume during a leg press exercise. Seventeen resistance-trained older women (68.0 ± 5.9 years, 71.2 ± 11.7 kg, 1.58 ± 0.07 m) participated in the study. All participants performed three sets to voluntary exhaustion, with loads that corresponded to 15 maximum repetitions, in two experimental sessions (that ranged from 48 to 72 hours apart). In each session, one of two RI (one-minute: RI-1 and three minute: RI-3) was tested, employing a randomized and counterbalanced design. For both RI, significant reductions ($p < 0.05$) were observed in the number of repetitions and sustainability of repetitions, from the first to the second and third sets. Differences ($p < 0.05$) between the RI also were observed in the two final sets. The total volume for the RI-3 session was statistically higher (29.4%, $p < 0.05$) as compared to the RI-1 session. The length of the RI between sets influenced the number of repetitions, sustainability of repetitions, and total volume. The longer RI should be used, therefore, when the goal of training is to increase the total volume.

Key words: Aging, muscle fatigue, muscle endurance, recovery.

Introduction

Progressive resistance training exercises are designed to improve neuromuscular performance, physical function, quality of life, and to prevent and treat chronic diseases in older adults (Hurley et al., 2011; Katula et al., 2008; Tschopp et al., 2011). The effectiveness of a resistance training program depends on several acute variables, such as intensity, volume, weekly frequency, movement velocity, exercise order, and duration of the rest interval (RI) between sets and exercises (ACSM, 2009). The potential effect of RI, between sets, on acute muscle performance in single resistance training exercises, has been demonstrated in young and older adults (Jambassi Filho et al., 2010; Willardson and Burkett, 2006a; 2006b).

Willardson and Burkett (2006b) concluded that, in resistance-trained young adults, different RI (0.5, 1, and 2 minutes) did not promote the sustainability of repetitions in multiple sets of the squat and bench press. The longer RI promoted a greater number of repetitions as compared to the shorter RI. In resistance-trained older women, Jambassi Filho et al. (2010) observed similar behavior when comparing two RI (1.5 and 3 minutes) during an arm curl exercise. Although the results of both studies are important to the understanding of the effects of RI on number of repetitions and sustainability, such findings cannot be applied to older adults or to lower–limb performance, due to differences related to the aging process (e.g., decrease of muscle quality, fatigue, and muscle recovery) (Bottaro et al., 2010; Lynch et al., 1999).

The total volume of a resistance exercise is determined by multiplying the number of repetitions by load. Although further investigations are needed, evidence has suggested that total volume can determine increases in muscle strength and endurance in younger and older adults (Galvão and Taffe, 2005; Robbins et al., 2012). Within this context, the use of longer or shorter RI could prove to be a strategy for changing the total volume, and, hence, other variables (e.g., fatigue-related metabolites) (Ratamess et al., 2007; Willardson and Burkett, 2005).

Rest intervals of one to three minutes typically are recommended for older adults (Chodzko-Zajko et al., 2009). However, the effect of these RI on muscle performance has not been widely investigated. The purpose of this study, therefore, was to assess, in resistance-trained older women, the influence of RI of one (RI-1) and three minutes (RI-3), between sets, on number of repetitions, sustainability of repetitions, and total volume during a single resistance training exercise (leg press). It was hypothesized that 1) neither of the RI would promote the sustainability of repetitions, and 2) that the longer RI would promote the achievement of a greater total volume.

Methods

Participants

Seventeen older women (68.0 ± 5.9 years, 71.2 ± 11.7 kg, 1.58 ± 0.07 m) with resistance training experience (3.7 ± 1.8 years) participated in the study. All participants attended a fully-supervised resistance training program, with the following characteristics: a) occurred three days per week, on non-consecutive days, b) included eight exercises of alternating body segments, including the leg press, c) included three sets in which participants achieved at least 70% of 15 maximum repetitions (RM), and d) had two-minute RI between sets. Inclusion criteria for participation in the study were: age ≥ 60 years; no contraindications involving the cardiovascular system,

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muscles, joints, or bones of the lower limbs, as well as neurological limitations to the practice of resistance training. Participants were excluded if they participated in less than 80% of the resistance training program that was conducted in the eight weeks preceding the study. The study received Ethics Committee approval, according to the Declaration of Helsinki, and participants signed the appropriate informed consent form.

Experimental study design

The effects of the RI on the leg press exercise were examined using a randomized and counterbalanced within-subjects design. Muscle performance was assessed via the recording of number of repetitions, sustainability of repetitions, and total volume. The number of repetitions can vary with different movement velocities, which can affect the duration of the set (Sakamoto and Sinclair, 2006). Thus, the duration of each set also was recorded. During the experimental period of the study, each participant visited the laboratory a total of five days (separated by periods ranging from 48 to 72 hours). The goal of the first three sessions (days 1, 2, and 3) was to determine the optimum loads with which the participants could perform 15 RM. In the two experimental sessions (days 4 and 5), the dependent variables were recorded utilizing one of two different conditions (three sets with a RI of 1 minute, or of 3 minutes). All participants performed both protocols, and a counterbalanced procedure was used to determine the order of the experimental sessions. These durations of RI were chosen because they are established recommendations for older adults (Chodzko-Zajko et al., 2009). The experimental sessions took place in June. To minimize circadian variations in muscle strength, all participants performed their sessions at the same hour of the day (from 7:00 a.m. to 9:00 a.m.). The participants were instructed to maintain their food intake and hydration, and not to perform any intense physical activity or drink alcohol (for 24 and 48 hours, respectively) preceding their evaluations.

Testing of Maximum Repetitions (15 RM)

The load for 15 RM was determined over the first two days and retested on the third day. A maximum of three trials per session were performed, with a RI of 10 minutes between trials. At the onset of each session, participants performed one set of warm-ups, with 10 repetitions at 50% of the 15 RM proposed in the test trial. After 30 seconds, all participants were instructed to perform the greatest possible number of repetitions, to voluntary exhaustion, with pre-determined loads. The first load was based on the training loads. Participants were assessed through the use of a horizontal leg press (Righetto Fitness Equipment; Campinas, SP, Brazil), with adjustable weight stacks. The knee and hip angles were adjusted to 90º and 110º, respectively. The participants were asked to hold their arms parallel to the trunk, while their hands held onto support handles attached to the leg press. The position of all participants was recorded and used in the experimental sessions.

In order to reduce errors during testing, the execution of the exercise was monitored: only repetitions performed with a full range of motion were computed. No pauses were allowed between the concentric and eccentric phases of the movement, or between repetitions. Additionally, the participants were encouraged verbally to exert a maximum effort.

Experimental sessions

Forty-eight to seventy-two hours after the determination of optimum loads for 15 RM, all participants took part in two experimental sessions (separated by 48- to 72-hour periods), employing RI-1 or RI-3, in a randomized and counterbalanced design. Similar to the procedures adopted for the determination of optimum loads for 15 RM, at the onset of each experimental session participants performed one set of warm-up exercises (50% of 15 RM). After a 30-second rest, all participants performed three sets, to voluntary exhaustion, with the assigned RI. The number of repetitions performed in each set was recorded. The repetitions in the first set of each experimental session were expressed as a percentage of the repetition target (15 RM): (number of repetitions of 1^{st} set x 100) / 15. In order to calculate the percentage maintained in the number of repetitions relative to the first set (i.e., sustainability of repetitions), the following equation was used: (number of repetitions in 2^{nd} set or 3^{rd} set x 100) / number of repetitions in the 1^{st} set (Jambassi Filho et al., 2012). The total volume of each experimental session was calculated by summing the number of repetitions in all three sets, and multiplying by load (Σ repetitions x load).

The participants were instructed to complete each repetition in approximately 1 second in the concentric phase, and in 2 seconds in the eccentric phase. The duration of the set from the onset of the first repetition until voluntary exhaustion, was recorded manually with a digital timer (Herweg®, Model 8904; Timbó, SC, Brazil) (Brandenburg and Docherty, 2006). To obtain the average time for each repetition, the duration of set in each set was divided by the number of repetitions (DS/NR). The time under tension was defined as the sum of the duration of three sets.

Statistical analysis

The statistical analysis initially was performed using the Shapiro–Wilk normality test and the Levene homogeneity test. Data were reported as means and standard deviations. The effects of different RI on number of repetitions, sustainability of repetitions, duration of set, and DS/NR of each set were examined by using a two-way analysis of variance (ANOVA) [Conditions (RI-1 and RI-3) x Sets (1^{st}, 2^{nd}, and 3^{rd})], with repeated measures on the Sets factor. The Scheffé post-hoc test for multiple comparisons was used whenever necessary. Effect sizes (partial eta square, $^{\eta}p^2$) and power were calculated. The paired Student-*t* test was used to determine differences in total volume (Σ repetitions x load) and number of repetitions, duration of set, and DS/NR totals (Σ of three sets) between RI-1 and RI-3. Intra-class correlation coefficient (ICC) was used to test the reliability of the 15 RM assessments (number of repetitions multiplied by load). In addition, paired Student-*t* test and typical error of measurement for the number of repetitions were also

Table 1. The NR, DS, and DS/NR of each set in leg press exercise, and the sum of three sets (total) for different rest intervals, in trained older women (n = 17). Values are mean ± standard deviations.

		1st set	2nd set	3rd set	Total
NR	**RI-1**	14.2 (0.8)	8.0 (1.7) *‡	7.2 (1.8) *‡	29.3 (3.6) ‡
	RI-3	14.7 (0.8)	12.4 (1.2) *	11.0 (2.2) *†	38.1 (3.9)
DS (s)	**RI-1**	36.7 (5.7)	22.6 (4.6) *	20.3 (5.6) *	79.6 (11.8) ‡
	RI-3	40.3 (5.9)	32.1 (6.5) *	29.7 (9.4) *	102.2 (21.0)
DS/NR ($s\cdot reps^{-1}$)	**RI-1**	2.6 (0.4)	2.9 (0.6) *‡	2.9 (0.6) *	8.3 (1.4)
	RI-3	2.7 (0.4)	2.6 (0.3)	2.7 (0.4)	8.0 (0.8)

NR = number of repetitions; DS = duration of set; DS/NR = average time of repetitions; RI-1 = one-minute rest interval; RI-3 = three-minute rest interval; *S tatistically significant difference when compared to the first set (p < 0.05); † Statistically significant difference when compared to the second set (p < 0.05); ‡ Statistically significant difference when compared to RI-3 (p < 0.05).

provided (Hopkins, 2000). For all analyses, the level of significance was $p < 0.05$. Statistical procedures were performed using the Statistica™ program, version 7.0.

Results

The ICC for the 15 RM assessments was 0.82 (95% CI; 0.56 to 0.93). No significant difference was observed ($p > 0.05$) in number of repetitions between the session tests-retests. Typical error of measurement was 0.97 repetitions.

The results for the number of repetitions, duration of set, and DS/NR are shown in Table 1. Significant Condition x Set interactions were found for the number of repetitions ($F_{(1,16)} = 32.17$, $p < 0.05$, power = 1.00, $^{\eta}p^2 = 0.50$), duration of set ($F_{(1,16)} = 6.98$, $p < 0.05$, power = 0.91, $^{\eta}p^2 = 0.18$), and DS/NR ($F_{(1,16)} = 12.79$, $p < 0.05$, power = 0.99, $^{\eta}p^2 = 0.29$). For both RI, the number of repetitions was significantly ($p < 0.05$) reduced for the second and third sets, as compared to the first. Significant differences ($p < 0.05$) between the RI were observed in the second and third sets. Total number of repetitions was significantly higher (30.0%, $p < 0.05$) for RI-3 when compared to RI-1. Duration of set decreased significantly for both RI in the subsequent sets; however, the total time under tension was significantly higher for RI-3 when compared to RI-1 (28.3%, $p < 0.05$). Although no difference was observed between RI in total DS/NR (Σ of three sets), only RI-1 showed a significant increase ($p < 0.05$) in the average duration of each repetition (second and third sets). A significant difference between the RI was revealed in the second set for DS/NR.

For sustainability of repetitions, significant Condition x Set interactions ($F_{(1,16)} = 23.83$, $p < 0.05$, power = 1.00, $^{\eta}p^2 = 0.43$) were observed (Figure 1). Both RI presented significant reductions in the sustainability of repetitions from the first to the second ($p < 0.05$), and to the third sets ($p < 0.05$). A significant decrease ($p < 0.05$) in the sustainability of repetitions from the second to the third set was observed only for RI-3. However, a significantly higher sustainability of repetitions ($p < 0.05$) was observed in the second and third sets when the session was performed with RI-3.

The total volume of each experimental session is shown in Figure 2. The session performed with RI-3 showed a higher total volume than the RI-1 session (29.4%, $p < 0.05$).

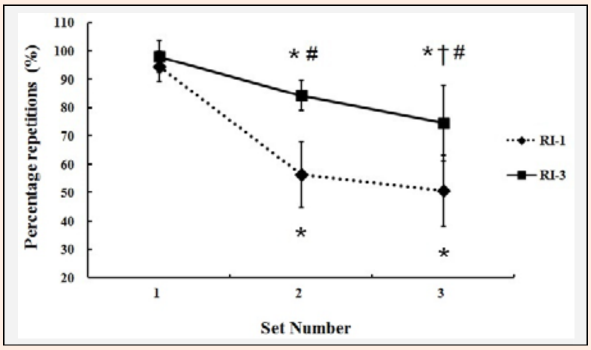

Figure 1. Percentage of repetitions per set with rest intervals of one (RI-1) or three (RI-3) minutes, in trained older women (n = 17). All values are presented in mean ± standard deviations. * Statistically significant difference when compared to the first set (p < 0.05); † Statistically significant difference when compared to the second set (p < 0.05); # Statistically significant difference when compared to RI-1 (p < 0.05).

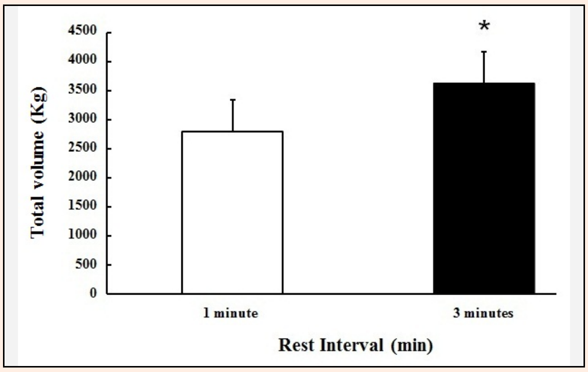

Figure 2. Total volume (load x repetitions) of experimental sessions performed with rest intervals of one or three minutes, in trained older women (n = 17). All values are presented in mean ± standard deviations. * Statistically significant (p < 0.05) difference when compared to rest intervals of one minute.

Discussion

The purpose of this study was to analyze the influence of two different RI (1 and 3 minutes), between sets, on number of repetitions, sustainability of repetitions, and total volume during a leg press exercise performed by resistance-trained older women. The results show that neither RI was sufficient to maintain the number of repetitions in relation to the first set (Table 1). However, greater sustainability of number of repetitions was observed for RI-3 in comparison to RI-1 (Figure 1), leading to a significant difference in total volume (Figure 2).

It has been established that resistance training with moderate to heavy loads and different movement speeds leads to increases in muscle strength and functional performance (Gurjão et al., 2012; Tschopp et al., 2011). Additionally, it has been shown that training protocols involving low to moderate loads and higher number of repetitions are effective for increasing muscle size, oxidative capacity, mitochondrial volume density, and muscle strength (Harris et al., 2004; Jubrias et al., 2001). Harris et al. (2004), for example, performed resistance training protocols with different intensities, but similar volumes (2 x 15 RM, 3 x 9 RM, 4 x 6 RM), in the older adults. These authors reported no significant difference in increases in muscle strength between protocols after 18 weeks of training. In this context, training protocols designed to increase local muscular endurance can be a strategy for *variation* (or periodization) in order to help older adults improve their performance of daily living activities (e.g., submaximal work and recreational activities) (Chodzko-Zajko et al., 2009; Kraemer and Ratamess, 2004).

Systematic literature reviews indicate that the performance of multiple sets is the most effective method for developing muscular strength in resistance-trained individuals (Peterson et al., 2005; Rhea et al., 2002). When multiple sets are performed to voluntary exhaustion, with the maintenance of a constant load throughout all sets, the RI plays a key role in the performance of subsequent sets and in total volume (García-López et al., 2008; Miranda et al., 2007; 2009; Rahimi, 2005; Senna et al., 2008; Willardson and Burkett, 2006a; 2006b).

The findings of this study are consistent with those reported in previous studies involving young and older adults performing single exercises. Willardson and Burkett (2006b) demonstrated that longer RI result in greater sustainability of number of repetitions, as compared to shorter RI. For a 1-minute RI during the squat exercise (between five sets of 15 RM), the authors found a decrease of approximately 50% in number of repetitions from the first to the third set. In resistance-trained older women, Jambassi Filho et al. (2010) compared the effect of two RI, 1.5 minutes (RI-1.5) and 3 minutes (RI-3), on muscle performance during an arm curl exercise (three sets of 10-12 RM). The number of repetitions showed a greater decrease from the first to the third sets in RI-1.5, as compared to RI-3 (49.5% vs. 29.7%, respectively). In addition, the total volume accrued in the experimental session with RI-1.5 was significantly lower than for the RI-3. In accordance with recommendations for older adults (Chodzko-Zajko et al., 2009), a RI of 1-3 minutes can be used to improve strength and hypertrophy. However, the differences between RI-1 and RI-3, which were observed in the number of repetitions, sustainability of repetitions, and total volume, should be considered in the design of a resistance training program.

When considering long-term resistance training, the performance of sets until voluntary exhaustion has a marked influence upon the muscular environment, and provides an important metabolic stimulus for neuromuscular adaptations (Crewther et al., 2006). In this condition, the use of shorter RI between sets, practiced to failure, as compared to those with longer RI, can increase the metabolic stimulus. On the other hand, longer RI can improve the mechanical stimulus to resistance training adaptations by increasing the time under tension, yet without modifying load training.

In association with other variables (e.g., magnitude of muscle tension and fatigue-related metabolites), time under tension is an important variable for the development of strength and hypertrophy (Drinkwater et al., 2005; Fry, 2004). In the present investigation, the RI-3 allowed for a greater total time under tension (28.3%; Table 1) as a consequence of increased number of repetitions in subsequent sets (total volume) (Machado et al., 2011). Machado et al. (2011) indicated that a higher volume is the primary determinant of muscle damage in resistance-trained individuals, which can provide higher acute neuromuscular responses.

It has been suggested that older adults have a higher metabolic economy than their younger counterparts and a preference for oxidative pathways (Kent-Braun, 2009). However a lower RI may generate a greater accumulation of different ions (e.g., H^+ Na^+, K^+, Ca^{2+} Mg^{2+}, Cl^-), resulting in a decrease in intracellular pH and a maximal velocity of cellular shortening (De Salles et al., 2009). The lower sustainability of repetitions observed in RI-1 may be associated with higher fatigue levels (Ratamess et al., 2007). A significant increase in the DS/NR relationship was observed only for RI-1, indicating an increase in the average duration of each repetition. However, this measure does not distinguish the point at which the repetition velocity is significantly reduced within the set. García-López et al. (2008) showed that RI-1 was insufficient to maintain the average repetition velocity during subsequent sets in a resistance training exercise. No significant changes were seen in RI-3.

A limitation of our study was the use of a single exercise in the experimental design. In older adults, a resistance training program with multiple exercises (major muscle groups) is recommended in order to provide an overall conditioning stimulus (Chodzko-Zajko et al., 2009). However, a single exercise can be used to assess the effects of resistance training on muscle performance (Izquierdo et al., 2009), while avoiding the effects of the order of multiple exercises on number of repetitions (Miranda et al., 2010). Recently, Miranda et al. (2010) demonstrated that a smaller number of repetitions is obtained when the exercise is performed at the end of, rather than at the onset of, a session. In addition, the effect of exercise order on number of repetitions was stronger when compared with RI.

The leg press is an exercise that is commonly prescribed in resistance training programs for older adults. In order to attend to the general principles of *progression*, the proper manipulation of different resistance training program variables is necessary (Kraemer and Ratamess, 2004). In resistance-trained older women, the length of the RI may be used as a strategy for increasing the total volume, without modifying load training or number of sets. Additionally, the RI can easily be changed by practitioners to provide higher acute neuromuscular responses. Future studies are needed to analyze the effects of multiple exercises and different intensities, and to determine the mechanisms associated with a decrease in muscle performance during the use of different RI, between sets.

Conclusion

The number of repetitions, sustainability of repetitions, and total volume of experimental sessions were significantly influenced by the RI, between sets, in resistance-trained older women. Neither RI appeared to help the women maintain sustainability of repetitions in subsequent sets. However, the sessions with RI-3 reflected a greater ability for the participants to maintain number of repetitions, time of tension, and total volume.

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Key points

- This study examined the influence of rest intervals, between sets, on muscle performance during leg press exercise, in trained older women.
- When multiple sets were performed to voluntary exhaustion, neither short and long rest interval (1 and 3 minutes, respectively) promoted the sustainability of repetitions in subsequent sets.
- A longer rest interval seems to be necessary for a higher number of repetitions in subsequent sets, and with increase in time of tension and total volume.

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