THE EFFECT OF TWO REST INTERVALS ON THE WORKOUT VOLUME COMPLETED DURING LOWER BODY RESISTANCE EXERCISE

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Abstract:

There is a lack of studies using rest intervals in the same lower muscle groups on multiple exercises volume completed. The purpose of this study was to compare the workout volume (sets × repetitions per set) completed during two lower body resistance exercise sessions that incorporated 1-minute vs. 3-minute rest intervals between the sets and exercises. For this reason, thirteen trained men completed two experimental sessions that consisted of 4 lower body exercises – leg press (LP), leg extension (LE), leg curl (LC) and parallel squat (PS), performed for three sets with 80% 1RM load. The two experimental sessions differed only in the length of the rest interval between the sets and exercises; one session with a 1-minute and the other session with a 3-minute rest interval. The results demonstrated that for each exercise a significantly greater workout volume was completed when resting interval lasted 3 minutes between the sets and exercises (LP: 48.42±3.38 vs. 58.17±3.01; LE: 47.04±2.52 vs. 57.81±2.04; LC: 38.01±2.79 vs. 53.61±2.64 and PS: 33.03±2.25 vs. 51.87±2.01 for 1-minute vs. 3-minute rest interval, respectively). These results indicate that during a resistance exercise session, if sufficient time is available, resting 3 minutes between the sets and exercises allows a greater workout volume for the lower body exercises examined.

Key words: *single exercise, multiple exercises, leg press, leg curl, recreational training, muscle groups*

Introduction

Strength training programmes can be designed to emphasize muscular strength, power, hypertrophy or endurance (Kraemer, Adams, & Fleck, 2002). The prescriptive variables are numerous, and may include: exercise order, rest intervals between sets and exercises, frequency, velocity of movement, number of sets and repetitions, and load or intensity. All of these variables can be manipulated to meet specific training goals and address individual needs (American College of Sports Medicine, 2010).

Training volume has been shown to affect neural/hormonal responses and subsequently adaptations to resistance training (Kraemer & Ratamess, 2005; Sale, 1988). The amount of rest between sets has been considered an important factor that can be manipulated to fit the goal of a programme. This factor affects the metabolic (Kraemer, Noble, Clark, & Culver, 1987) and hormonal (Boroujerdi & Rahimi, 2008) responses to an acute bout during resistance exercise, as well as training adaptations (Robinson, et al., 1995). When training for increased strength, longer rest periods of 2 and 5 minutes have been recommended to allow for greater recovery and maintenance of training volume (Kraemer, et al., 2002; Willardson & Burkett, 2005).

The effect of rest between sets on exercise volume in single exercises has been investigated by some previous studies. For example, Ratamess et al. (2007) compared the differences in workout volume (resistance x repetitions per set) over five sets of the bench press exercise when performed at two different intensities (i.e. 75% and 85% of a 1RM) and with five different rest intervals between sets (i.e. 30 seconds, 1, 2, 3, and 5 minutes). The findings demonstrated that irrespective of the intensity, the workout volume significantly decreased with each set in succession over five sets when 30-second and 1-min rest intervals were used. The workout

volume was maintained over two sets for 2 minutes, three sets for 3 minutes, and four sets for 5 minutes. Consequently, the authors recommended that if more than 2 to 3 sets of an exercise are performed, then at least 2 minutes of rest might be needed to minimize load reductions and maintain repetition performance for the sets performed at the end of a workout.

However, a limitation of Ratamess et al. (2007) and similarly designed studies (Kraemer, 1997; Richmond & Godard, 2004; Rahimi, 2005; Willardson & Burkett, 2005, 2006a,b; Mirzaei, Arazi, & Saberi, 2008a; Mirzaei, Rahmani-Nia, & Saberi, 2008b) was the examination of a single exercise, when typical resistance sessions consist of multiple exercises for the same muscle groups (American College of Sports Medicine, 2010; Kraemer & Ratamess, 2005). On the other hand, Senna, Salles, Prestes, Mello and Simão (2009) showed that the total number of repetitions in resistance exercise with a 2-minute rest interval was fewer than with a 5-minute rest interval (at 10RM) for multiple exercise. However, there is a great need for further research to compare the volume of work completed over an entire resistance exercise session aimed at training the same muscle groups with different rest intervals between sets. Therefore, to our knowledge, the impact of 1- or 3-minute rest interval on the lower muscle groups multiple exercises volume completed with 80% 1RM load has not been reported, and resistance--trained athletes, such as bodybuilders or power--lifters, must perform exercises at maximal or near maximal intensities with repeated efforts in order to enhance muscular hypertrophy and/or strength (Rahimi, 2005). Therefore, the purpose of the current study was to compare the workout volume completed during two lower body resistance exercise sessions that incorporated 1-minute vs. 3-minute rest intervals between the sets and exercises.

Methods

Experimental approach to the problem

In order to examine the effect of two different rest intervals on the workout volume completed (sets × number of repetitions per set), a 1RM was assessed on four nonconsecutive days randomly for the *leg press* (LP), *leg extension* (LE), *leg curl* (LC), and *parallel squat* (PS) to design the two exercises sessions. Following the 1RM assessments, the subjects completed two experimental resistance exercise sessions with either 1- or 3-minute rests between the sets and exercises in a randomized design. The workout volume completed (sets × repetitions per set) was recorded for each exercise during each session and later compared between the rest interval conditions.

Subjects

Thirteen healthy men (age 21.74±2.25 years; height 172±1,87 cm; body mass 76.57±8.51 kg), with at least two years of recreational resistance training experience, volunteered to participate in the current study. The subjects were informed of the purpose, procedures and possible risks of the investigation before they gave the written informed consent to participate in the study. The Institutional Review Board of the Islamic Azad University Marivan, Iran, approved the research protocol.

1RM testing

The 1RM assessments were conducted in the following order: LP, LE, LC, and PS. In order to increase the reliability of the 1RM assessments, the following strategies were employed: 1) before the test, all subjects underwent two familiarization sessions (3 sets, 20 repetitions of each exercise with the minimum weight allowed by the machines) on non-consecutive days; 2) all subjects received standard instructions on the exercise technique prior to testing; 3) the exercise technique was monitored and corrected as needed; 4) all subjects received verbal encouragement during testing. LP, LE and LC were performed using a universal weight machine station. The PS was performed in a power cage. The pins in the power cage were adjusted to allow the subject to descend to the point where the tops of the thighs were parallel to the floor. A successful PS required descending by flexing the knees and hips until the proximal head of the femur reached the same horizontal plane as the superior border of the patella. No pause was allowed between the eccentric and concentric phases of each repetition and a complete range of motion (as normally defined) had to be completed.

Experimental resistance exercise sessions

In both experimental sessions, three sets of each exercise (repetitions to voluntary exhaustion) were performed. On experimental day 1, the subjects performed all exercises with the 1-minute rest, then they did all the exercises with the 3-minute rest on test day 2 (48-72 hours later). Warm-up prior to each session consisted of 2 sets of 12 repetitions of the first exercise (LP) at 40% of the 1RM load and then 80% of the 1RM load was selected to purpose the load used in testing. The subjects were verbally encouraged to perform all sets to exhaustion. No attempt was made to control the repetition velocity; however, the subjects were required to utilize a smooth and controlled motion with no pause between repetitions. The workout volume completed (sets × repetitions per set) was recorded for each exercise during each session and later compared between the rest conditions.

Statistical analyses

Values from the different sessions were compared using a 3-way ANOVA and Benferroni's *post-hoc* test. The level of significance for this investigation was set at $p<.05$. All the data were reported as mean±SD.

Results

The total workout volume completed (sets × repetitions per set) for all exercises was significantly greater for the 3-minute-lasting rest condition vs. the 1-minute-lasting rest condition ($p<.05$; see Table 1). Within each rest condition, there were significant differences in the number of repetitions completed for each exercise set ($p<.05$; see Table 2). Furthermore, there were significant differences between rest conditions in the repetitions completed for most exercise sets ($p<.05$; see Figure 1).

Discussion and conclusions

The rest interval between sets is an important variable that affects both acute responses and chronic adaptations to resistance exercise programmes (Salles, et al., 2009). The previous findings recommended that if more than 2 to 3 sets of an exercise are performed, then at least 2 minutes of rest might be needed to minimize load reductions and maintain repetition performance for the sets performed at the end of a workout (Salles, et al., 2009). However, these findings are based upon the examination of single exercises, whereas typical resistance sessions consist of multiple exercises for the same muscle groups and multiple exercises for the same muscle groups are prescribed based on the training goal, that is, for example, strength, power, hypertrophy and neural responses (American College of Sports Medicine, 2010; Kraemer & Ratamess, 2005). Therefore, there was a great need for a research to compare the workout volume completed over an entire resistance exercise session with different rest intervals between sets on multiple exercises aimed at the same muscle groups. For this need, we compared the workout volume completed during two lower body resistance exercise sessions that incorporated 1-minute vs. 3-minute rest intervals between sets and exercises.

The main finding of the present study was that a significantly greater workout volume (sets × repetitions per set) was completed for each exercise when resting 3 minutes between sets and exercises (Table 1). Because the resistance was constant in all three sets of each exercise, these differences in workout volume, due to the greater repetitions completed per set, could be accounted for the 3-minute rest condition (Figure 1). The 3-minute rest condition allowed for greater consistency in repetitions over all three sets, whereas the 1-minute rest condition did not allow sufficient recovery time. For example, there were no significant differences in the repetitions completed between the first and second sets for any exercise when resting 3 minutes between the sets; however, there were significant

Table 1. Total workout volume (sets × repetitions per set) for 1-minute vs. 3-minute rest intervals; data are means±SD

Session	LP	LE	LC	PS
1-minute rest interval	48.42 (3.38)	47.04 (2.52)	38.01 (2.79)	33.03 (2.25)
3-minute rest interval	58.17 (3.01)*	57.81 (2.04)*	53.61 (2.64)*	51.87 (2.01)*

LP-leg press, LE-leg extension, LC-leg curl, PS-parallel squat

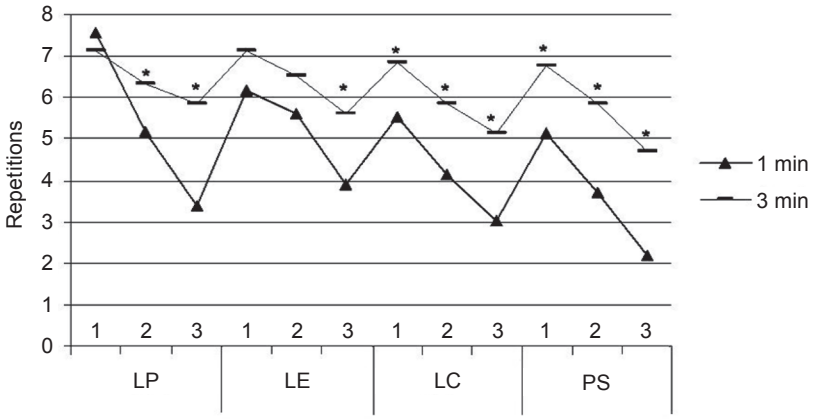
*Significant difference in total workout volume for 1-minute vs. 3-minute rest interval ($p<.05$).

Table 2. Comparison of repetitions per set (mean±SD) under the 1-minute and 3-minute rest interval conditions; data are means±SD

Exercise	Time rest (min)	Set 1	Set 2	Set 3
LP	1	7.56 (.80)*§	5.18 (1.11) †	3.40 (1.21)
	3	7.14 (.92) §	6.34 (.99)	5.85 (1.12)
LE	1	6.17 (.68) §	5.62 (.44) †	3.89 (.97)
	3	7.13 (.81) §	6.53 (.75)	5.61 (.86)
LC	1	5.54 (.77)*§	4.14 (1.02) †	3.02 (1.18)
	3	6.85 (.85) §	5.87 (.83)	5.15 (.84)
PS	1	5.12 (.82)*§	3.72 (1.25) †	2.17 (1.08)
	3	6.75 (.97) §	5.85 (1.03)	4.69 (.73)

LP-leg press, LE-leg extension, LC-leg curl, PS-parallel squat

*Significant difference in repetitions of set 1 vs. set 2; § Significant difference in repetitions of set 1 vs. set 3; †Significant difference in repetitions of set 2 vs. set 3. ($p<.05$)



LP-leg press, LE-leg extension, LC-leg curl, PS-parallel squat.
*Significant difference in repetitions between 1-minute and 3-minute rest intervals (p<.05)

Figure 1. Comparison of repetitions per set between 1-minute vs. 3-minute rest interval conditions.

reductions between the first and second sets for three out of the four exercises when resting 1 minute between sets (Table 2).

These results were consistent with the related studies that compared repetition performance and the volume of work completed during the performance of single exercises (Kraemer, 1997; Richmond & Godard, 2004; Rahimi, 2005; Willardson & Burkett, 2005, 2006a,b; Ratamess et al., 2007; Mirzaei, et al., 2008a,b). A study by Rahimi (2005) compared 1-, 2- or 5-minute rest intervals with 85% of a 1RM and on 4 sets of the squat volume completed (total number of repetitions completed over 4 sets for each rest condition) during a workout. The 5-minute rest condition resulted in the highest volume of work completed (6.17±1.39), followed in the descending order by the 2- (5.10±1.84) and 1-minute (4.55±2.25) rest conditions.

Another study by Mirzaei et al. (2008a) compared the sustainability of bench press repetitions with different rest intervals. During each session from 7 testing sessions, 4 consecutive sets of the bench press were performed with a 60% or 90% of 1RM and with a 90-, 150- or 240-second rest interval between sets. The results demonstrated that for each load, a significant decline in repetition occurred between the first and fourth set and the 240-second rest between sets resulted in sustainable greater total of repetitions vs. 90- or 150-second rest between sets.

A limitation of these (Rahimi, 2005; Mirzaei, et al., 2008a) and related studies (Kraemer, 1997; Richmond & Godard, 2004; Willardson & Burkett, 2006a,b; Ratamess, et al., 2007; Mirzaei 2008b) was the evaluation of single exercises. Miranda et al. (2007: 09) compared different rest intervals in the context of a typical resistance exercise session consisting of multiple exercises, but they compared repetition performance during upper body resistance exercise muscle groups. The exercises sessions were performed with 8RM loads for three sets with either 1-minute or 3-minute rests between sets and exercises; similar to the finding of the current study, significantly more repetitions were completed for all exercises when resting 3 minutes between sets. The findings of the current study, when combined with the findings of Miranda et al. (2007), suggest similar results to the impact of 1- or 3-minute rest interval on multiple exercises volume of work completed for different muscle groups (upper body vs. lower body) in recreationally trained men. However, it should be noted that the findings of the current study are not applicable to a sequence of combinations with the upper body resistance exercises, which should be examined in combination with the upper body resistance exercises in future research.

Weir, Wagner and Housh (1994), however, showed no differences in the ability to repeat a maximal bench press following 1-, 3-, 5- or 10-minute rest intervals between sets. A limitation of this study was that subjects performed only 2 sets with 1RM load. Had more than 2 sets been attempted, longer rest intervals may have resulted in superior performance. In the current study, the subjects were able to maintain a training volume to the greatest extent when resting 3 minutes between sets.

The accumulation of lactic acid has been shown to lower intracellular pH through the dissociation of hydrogen ions (H^+), which results in muscle fatigue (Westerblad, Allen, & Lännergren, 2002). However, Robergs, Ghiasvand and Parker (2004) demonstrated that there is no biochemical support for lactate production causing acidosis. Lactate production retards, not causes, acidosis. Similarly, there is a wealth of research evidence to show that acidosis is caused by reactions other than lactate production (Corey, 2003). When the rate of H^+ production exceeds the rate of the capacity to buffer or remove protons from skeletal muscle, or when there is not enough time to buffer or remove H^+

production, metabolic acidosis ensues and results in muscle fatigue (Rahimi, 2005). Short rest intervals of 1 minute or less have been shown to significantly increase lactic acid levels during heavy strength training exercise (Kraemer et al., 1987). In the current study, the 3-minute rest condition was most likely the necessary time to uptake H^+ and delayed fatigue which allowed subjects to complete a higher volume of training vs. the 1-minute rest conditions.

In conclusion, our data suggest if sufficient time is available, instituting longer rest intervals (e.g. 3 minutes) allows for a greater number of repetitions and workout volume vs. shorter rest intervals (e.g. 1 minute). This performance enhancement has been demonstrated across a wide variety of exercises and muscle groups. Regarding the series of resistance exercises examined in the current study, it is not known whether resting more than 3 minutes between sets would further increase the workout volume completed. There might be a point of diminishing returns at which the rest interval between sets would become excessive, and yield no further increases (Miranda, et al., 2009). Future research should examine strength gains resulting from long-term training with shorter vs. longer rest intervals between the sets for the same or distinct muscle group. The results of the current study may have the greatest relevance to programmes designed for maximal strength for the maintenance of the load and repetitions per set.

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UTJECAJ DVAJU RAZLIČITIH PERIODA ODMORA NA VOLUMEN TRENINGA U VJEŽBAMA S OTPOROM ZA DONJE EKSTREMITETE

U znanstvenoj literaturi trenutačno postoji nedostatak istraživanja u kojima bi se testirao utjecaj različitih intervala odmora istih mišićnih skupina donjih ekstremiteta na ukupni volumen treninga u kojemu se izvode različite vježbe. Cilj ovoga istraživanja bio je usporediti ukupni trenažni volumen (broj serija × broj ponavljanja) izveden tijekom dva treninga s opterećenjem za donje ekstremitete, koji su uključivali odmore od 1 minute odnosno od 3 minute između serija i vježbi. U tu svrhu trinaest je aktivnih muškaraca provelo dva eksperimentalna treninga koji su se sastojali od četiri vježbe donjih ekstremiteta: nožni potisak, opružanje potkoljenica, pregib potkoljenica i paralelni čučanj izvedene u tri serije s opterećenjem od 80% 1RM. Dva eksperimentalna treninga razlikovala su se samo po trajanju odmora između serija i vježbi; u jednom treningu korišten je odmor u trajanju od jedne minute, dok je u drugom trening korišten odmor u trajanju od tri minute. Rezultati su pokazali da je za svaku vježbu u kojoj je korišten 3-minutni odmor između serija i vježbi izvršen statistički značajno veći ukupni volumen treninga (nožni potisak: 48,42±3,38 pri 1-minutnom odmoru nasuprot 58,17±3,01 pri 3-minutnom odmoru; opružanje potkoljenica: 47,04±2,52 pri 1-minutnom odmoru nasuprot 57,81±2,04 pri 3-minutnom odmoru; pregib potkoljenica: 38,01±2,79 pri 1-minutnom odmoru nasuprot 53,61±2,64 pri 3-minutnom odmoru te paralelni čučanj: 33,03±2,25 pri 1-minutnom odmoru nasuprot 51,87±2,01 pri 3-minutnom odmoru. Ovi rezultati pokazuju da tijekom treninga s opterećenjem, ako je dovoljno vremena na raspolaganju, 3-minutni odmor između serija omogućuje veći volumen trenažnoga rada u analiziranim vježbama za donje ekstremitete.

Ključne riječi: *pojedinačna vježba, višestruke vježbe, rekreacijski trening, mišićne grupe*