BALTIC JOURNAL OF HEALTH AND PHYSICAL ACTIVITY
© Gdansk University of Physical Education and Sport in Gdansk, Volume 4, No 2, 2012, 77-83

ORIGINAL ARTICLE

DOI: 10.2478/v10131-012-0008-x

An Interaction between Exercise Order and Rest Interval during Lower-Body Resistance Exercise

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Hamid Arazi[1 (A, B, C, D, E)], Bahman Mirzaei[1 (D, E, F, G)], Morteza Sangdevini[2 (B, E, F, G)], Mohammad Reza Hossein Abadi[3 (B, C, F, G)]

[1] Department of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran.
[2] Department of Physical Education and Sport Sciences, University of Golestan, Gorgan, Iran.
[3] Department of Physical Education and Sport Sciences, Islamic Azad University Branch of Kalale, Kalale, Iran.

Key words: *recovery, resistance training, number of repetition, fatigue*

Abstract

Background: *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 and total repetitions per exercise for a lower-body workout performed in 2 different sequences.*

Material/Methods: *12 resistance trained men completed 4 experimental resistance exercise sessions. All sessions consisted of 3 sets with a 10-repetition maximum load for 4 lower-body exercises. Two different exercise sequences (i.e., A or B) were performed with either 2- or 5- minute rest between the sets and the exercises, respectively. The order of exercises for sequence A2 (SEQA2) and sequence A5 (SEQA5) was squat, leg curl, leg extension, and calf raise with 2- and 5-minute rest intervals between the sets and the exercises respectively. Conversely, for sequence B2 (SEQB2) and sequence B5 (SEQB5), the exercises were performed in the opposite order.*

Results: *The results demonstrated a significant decrease from set 1 to set 2 in 3 exercises for SEQA2 and 2 exercises for SEQB2; from set 1 to set 3 in all exercises for SEQA2 and SEQB2, 3 exercises for SEQA5, and 2 exercises for SEQB5; and from set 2 to set 3 in 3 exercises for SEQA2, 2 exercises for SEQB2, and 1 exercise for SEQB5 ($p<0.05$). In addition, the total number of completed repetitions was significantly different ($p<0.05$) between sequences for squat (SEQA5 > SEQA2 > SEQB5 > SEQB2), leg curl (SEQA5 = SEQB5 > SEQA2 = SEQB2), leg extension (SEQA5 = SEQB5 = SEQB2 > ASEQA2), and calf raise (SEQB5 > SEQB2 = SEQA5 > SEQA2).*

Conclusions: *The results indicate that during a lower-body workout reductions in the number of repetitions are greater for exercises performed at the end of the sequences, and the influence of the different rest interval lengths may depend on the position of the exercise in a sequence.*

Word count: 2,597
Tables: 1
Figures: 1
References: 26

Received: December 2011
Accepted: May 2012
Published: June 2012

Corresponding author:
Hamid Arazi, Ph.D, Assistant Professor
Exercise Physiology, Faculty of Physical Education and Sport Sciences, University of Guilan
P.O.Boxs: 1438-Rasht-Iran
Phone: +98 911 139 9207
E-mail: hamidarazi@yahoo.com

Introduction

Resistance training programs are commonly designed to promote power, absolute strength, hypertrophy, or localized muscular endurance. The exercise order and rest interval are two of the key variables in resistance training. The exercise order has been proved to affect repetition performance [1, 2, 3, 4]. The ACSM recommendations [5, 6] regarding the exercise order is to perform large muscle group exercises before small muscle group exercises, multiple-joint exercises before single-joint exercises, higher-intensity exercises before lower-intensity exercises, or rotation of upper and lower body or agonist–antagonist exercises, that is, exercise performed for a muscle group followed by an exercise for the opposing muscle group. Simão et al. [3] investigated the influence of exercise order on the number of repetitions performed during a resistance training session composed of both upper and lower-body exercises in trained women [3]. The results demonstrated that when exercises are preceded by either single-joint or multi-joint exercises, the total number of repetitions decreases.

Rest intervals between sets also appear to be an important variable that can directly affect metabolic [7], hormonal [8, 9], cardiovascular [10], and neuromuscular [11, 12] responses during resistance exercise as well as the number of repetitions completed in subsequent sets and the total training volume [13, 14, 15, 16, 17, 18].

It has been suggested that for efficient, safe and effective training, it is important to understand the interactions between the training variables [20]. Only one study to date has examined the interaction between exercise order and rest interval length [21]. Miranda et al. [21] demonstrated that upper-body exercises involving similar muscle groups and neural recruitment patterns are negatively affected in terms of repetitions performance when performed at the end vs. beginning of a session, and the reduction in repetition performance is greater when using 1-minute vs. 3-minute rest interval between sets [21]. However, no study to date has examined the interaction between exercise order and rest interval length during lower-body resistance exercise.

Prior research demonstrated greater fatigue resistance for lower-body exercises vs. the upper-body exercises [13]; therefore, the results of the study by Miranda et al. may not apply to lower-body exercises. Therefore, the purpose of the current study was to compare the number of repetitions completed when resting 2 vs. 5 minutes between sets and exercises for a lower-body workout performed in opposite sequences.

Material and Methods

Twelve trained men volunteered for this study (age: 24 ± 2.8 years; weight: 76.5 ± 4.6 kg; height: 175 ± 3.2 cm; BMI 24.4 ± 2.8 kg/m^2). All subjects had at least 2 years' resistance training experience and performed at least 3 resistance training sessions per week during the previous year. All subjects were informed of the testing and training procedures, and then they signed an informed consent and a medical history questionnaire before the experiment. The experimental procedures were approved by the Ethics Committee of Golestan University.

Repetition Maximum Testing

The 10 repetition maximum (10RM) tests were assessed during two nonconsecutive days in the following order: squat, leg curl, leg extension, and calf raise. 10RM was determined in a maximum of three attempts for each exercise with 5-minute rest intervals between attempts and 10-minute rest between different exercises [19]. Then after 48 hours, the tests were repeated to determine test-retest reliability, and the data were analyzed by Pearson product moment correlations to estimate day-to-day 10RM reliability (r = 0.94 for squat, r = 0.94 for leg curl, r = 0.96 for leg extension, and r = 0.92 for calf raise). To minimize potential errors in the 10RM testing, the following strategies were employed: a) standardized instructions on exercise technique were given to the subjects before the test; b) all subjects received verbal encouragement during testing; c) the mass of all used weights and bars was determined using precision scales.

Experimental Sessions

48 hours after the 10-RM assessments in selected exercises, subjects performed four experimental resistance exercise sessions with two different exercise sequences and two different rest intervals between sets and exercises (sequence A2, sequence A5, sequence B2, and sequence B5) in a randomized crossover design with 48 hours between the sessions. The exercises order for sequence A2 (SEQA2) and sequence A5 (SEQA5) was squat, leg curl, leg extension, and calf raise with 2- and 5-minute rest interval between sets and exercises respectively. Conversely, for sequence B2 (SEQB2) and sequence B5 (SEQB5) the exercises order was calf raise, leg extension, leg curl, and squat with 2- and 5-minute rest interval between sets and exercises respectively.

Before the beginning of each experimental session, a warm-up was performed, with 40% of the 10RM load for 2 sets of 12 repetitions only in the first exercise (i.e., squat in SEQA2 and SEQA5; calf raise in SEQB2 and SEQB5). All exercises were performed in each experimental session for 3 consecutive sets to the point of voluntary exhaustion using the predetermined 10RM load. The total number of repetitions for the 3 consecutive sets of each exercise was recorded.

Statistical Analysis

One-way analysis of variance with repeated measures was used to test the difference in the number of repetitions between sets of each exercise in the same sequence and the total number of repetitions for each of the 4 exercises between the different sequences, and when the difference presented was significant, Tukey's post hoc test was applied for multiple comparisons. The significance level was at $p < 0.05$.

Results

The total numbers of completed repetitions were significantly different ($p < 0.05$) between sequences for squat (SEQA5 > SEQA2 > SEQB5 > SEQB2), leg curl (SEQA5 = SEQB5 > SEQA2 = SEQB2), leg extension (SEQA5 = SEQB5 = SEQB2 > ASEQA2), and calf raise (SEQB5 > SEQB2 = SEQA5 > SEQA2) (Table 1 and Figure 1). For all exercises except leg curl in SEQA5, and leg extension and calf raise in SEQB5 there were significant differences ($p < 0.05$) in the repetitions completed between sets in each sequence.

Tab. 1. Mean (±SD) number of repetitions completed in each set

Exercise	Sequence	Set1	Set2	Set3
Squat	A2	10.0 (.0)	7.8 (1.2) *	6.5 (2.4) *†
	A5	9.8 (.6)	9.5 (.4)	8.6 (1.9) *
	B2	6.5 (.8)	5.6 (.6)	4.4 (1.2) *†
	B5	8.3 (.7)	7.5 (.9)	6.1 (1.4) *†
Leg curl	A2	8.5 (1.2)	7.6 (1.5)	6.4 (.9) *†
	A5	9.6 (.8)	9.4 (.6)	9.0 (.7)
	B2	8.5 (.4)	7.4 (.5) *	6 (1.4) *†
	B5	9.7 (.3)	9.1 (.7)	8.5 (.9) *
Leg extension	A2	8.2 (1.3)	7.0 (1.7) *	6.2 (.8) *
	A5	9.1 (.7)	8.7 (1.6)	8.1 (1.2) *
	B2	8.9 (1.4)	8.5 (1.0)	7.8 (.9) *
	B5	9.4 (.6)	9.0 (.4)	8.7 (.7)
Calf raise	A2	7.9 (.9)	6.5 (1.4) *	5.2 (1.6) *†
	A5	8.9 (.6)	8.2 (.9)	7.6 (1.1) *
	B2	9.7 (.2)	8.5 (.9) *	7.0 (1.3) *
	B5	9.8 (.4)	9.6 (.7)	9.0 (.6)

**Significant difference compared with the first set (p<0.05); † significant difference compared with the second set (p<0.05); # significant difference compared with SEQA2 (p<0.05); ‡ significant difference compared with SEQA5 (p<0.05); £ significant difference compared with SEQB2 (p<0.05).*

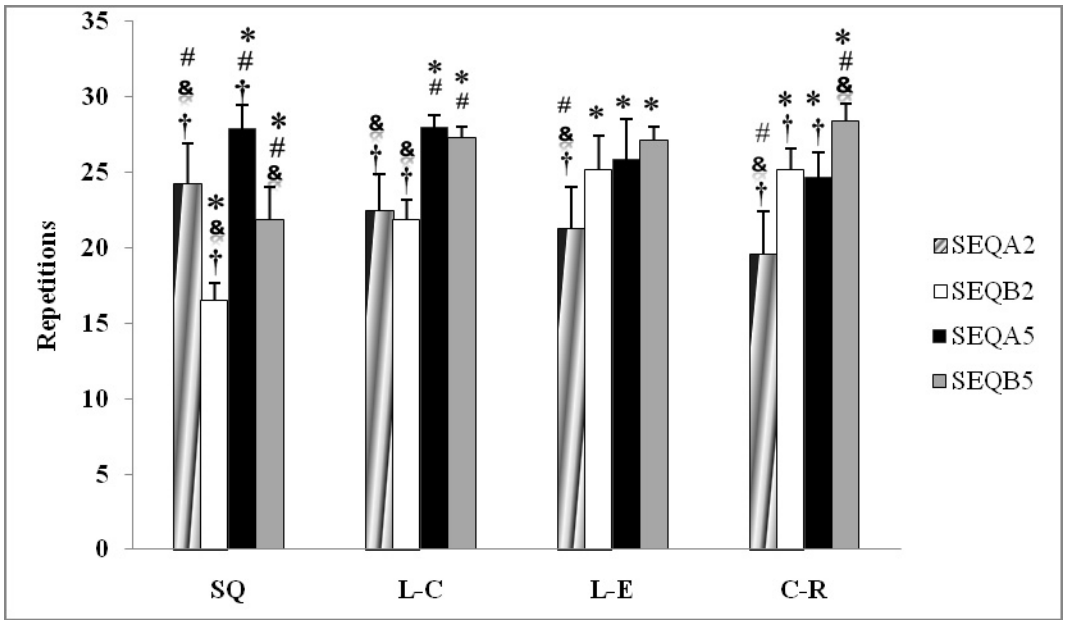

Fig. 1. Total number of repetitions completed in SEQA2, SEQB2, SEQA5, and SEQB5 (mean ± SD). SQ: squat; L-C: leg curl; L-E: leg extension; C-R: calf raise. * Significant difference compared with SEQA2; # significant difference compared with SEQB2; & significant difference compared with SEQA5; † significant difference compared with SEQB5

Discussion

The purpose of this study was to compare the number of repetitions when resting 2 minutes vs. 5 minutes between sets and exercises for a lower body workout performed in 2 different sequences. The results demonstrated that the total number of completed repetitions was greater for the squat and calf raise when performing these exercises at the beginning of a session than when performing these exercises at the end of a session. For the leg curl that was the second exercise performed during SEQA and the third exercise performed during SEQB. There were significant differences in the total number of completed repetitions based on the rest interval but not based on the exercise order (SEQA5 = SEQB5 > SEQA2 = SEQB2). Additionally, for the leg extension that was the third exercise performed during SEQA and the second exercise performed during SEQB. The lowest number of completed repetitions was observed during SEQA2 (21.3 ± 2.1); however, no significant differences were observed in the total number of completed repetitions between SEQA5 (25.9 ± 2.6), SEQB5 (27.1 ± 0.9), and SEQB2 (25.2 ± 2.2).

A recent study by Miranda et al. [21] compared repetition performance during a resistance training session composed of upper body exercises when performed in 2 opposite sequences and with 2 different rest intervals between the sets and exercises. In the mentioned study, 16 recreationally trained men performed 4 experimental resistance exercise sessions, consisting of three sets with 8RM loads, in 6 upper-body exercises. Two different exercise sequences (i.e., A or B) were performed with either 1- or 3-minute rest between sets and exercises, respectively. For sequence A1 (SEQA1) and sequence A3 (SEQA3), resistance exercises were performed in the following order: lat pull-down with a wide grip (LPD-WG), lat pull-down with a close grip (LPD-CG), machine sitted row (SR-M), barbell row lying on a bench (BR-B), dumbbell seated arm curl (SAC-DB), and machine seated arm curl (SAC-M). Conversely, for sequence B1 (SEQB1) and sequence B3 (SEQB3), the exercises were performed in the opposite order. The key finding was that the effect of exercise order was stronger than the effect of rest interval length for the LPD-WG and the SAC-M, whereas the effect of rest interval length was stronger than the effect of exercise order for the LPD-CG, SR-M, BR-B, and SACDB. The authors concluded that upper-body exercises involving similar muscle groups and neural recruitment patterns are negatively affected in terms of repetitions performance when performed at the end vs. the beginning of a session, and the reduction in repetition performance is greater when using 1-minute vs. 3-minute rest interval between sets [21].

Additionally, the results of the present study demonstrated that for squat, leg curl, and calf raise in both SEQA and SEQB and for leg extension in SEQA, as the rest interval between sets and exercises increased, the total number of completed repetitions also increased. In this study we also showed a significant decrease in the number of completed repetitions from set 1 to set 2 in 3 exercises for SEQA2 and 2 exercises for SEQB2; from set 1 to set 3 in all exercises for SEQA2 and SEQB2, 3 exercises for SEQA5, and 2 exercises for SEQB5; and from set 2 to set 3 in 3 exercises for SEQA2, 2 exercises for SEQB2, and 1 exercise for SEQB5. The possible reason for a decreasing number of repetitions completed in subsequent sets is progressive fatigue accumulation during the progression of the sets and exercises in the training session. These findings are in agreement with previous studies that compared the effect of different rest intervals on the repetition performance and the volume completed during the performance of single exercises [7, 13, 14, 15, 16, 22, 23, 24] and other studies that compared repetition performance during resistance training session composed of multiple exercises [17, 18, 19]. These studies demonstrated a decrease in the number of repetitions completed in subsequent sets, especially by shorter rest intervals. For example, Senna et al. [19] compared the influence of 2- and 5-minute rest intervals on the number of repetitions per set, per exercise and the total number of repetitions in resistance training sessions. Fourteen trained men 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 intervals (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 intervals, five out of six exercises presented reductions in the second set, compared with the first set, and for the third set compared with the first and the second sets. For five-minute intervals, three out of the six exercises presented reductions in the second set, compared with the first set, and two out of the six for the third set, compared with the second set. The total number of repetitions in SEQA (66.7 ± 4.9) was significantly smaller than in SEQB (80.9 ± 6.9). Similarly, the total number of 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, with the initial exercises less affected during the progression of the sets [19].

Interestingly, in the current study no significant difference was observed in the number of repetitions completed for leg extension between SEQB2 (25.2 ± 2.2) and SEQB5 (27.1 ± 0.9). It has been reported that the length of the rest interval between sets and exercises may vary based on several factors (e.g., goal training, muscle mass involved, exercise order, or type of muscle action). Therefore, exercises such as the squat which involve both isotonic (e.g., hip extensors, knee extensors) and isometric (e.g., wrist flexors, abdominals) muscle actions, require longer rest intervals between sets [25]. Willardson et al. [26] compared the effect of load reductions over consecutive sets on repetition performance during a lower-body workout consisting of squat, leg curl, and leg extension exercises. 12 trained men performed 4 workouts under the following load conditions: (a) constant load for all sets, (b) 5% load reduction after each set, (c) 10% load reduction after each set, and (d) 15% load reduction after each set. The results showed a significant decrease in the number of repetitions completed for the back squat and leg curl within the constant condition vs. the 15% condition. However, for the leg extension, there were no significant differences in the number of repetitions completed between these conditions. The authors concluded that subjects have relatively greater fatigue resistance for the leg extension vs. the back squat and leg curl [26]. In this study, we show when the leg extension is performed before the squat and leg curl during a workout, 2-minute rest interval might be sufficient to maintain the number of repetitions.

Conclusions

The ability to maintain repetitions and to perform a higher volume of training has been shown to be essential for stimulating greater strength and hypertrophy adaptations [5, 6]. The results of the present study showed that reductions in the number of completed repetitions is more pronounced for exercises performed at the end vs. the beginning of a workout and the reduction is greater

when using shorter rest intervals between sets especially in large muscle groups of lower body exercises. Interestingly, no significant difference in the number of repetitions was observed between 2-minute and 5-minute rest intervals for the leg extension when performed before squat and leg curl exercises. These findings showed the importance of understanding the interaction among the order of exercises and the rest interval between sets and exercises to minimize fatigue-related reductions in the number of repetitions completed during a lower-body resistance training session. The findings of the current study are applicable for the examined resistance exercises. However, because of the few data on interactions between the order of exercise and rest intervals on repetition performance during resistance exercise, further research that examines different muscle groups and especially in a sequence composed of both upper and lower body exercises is necessary.

Acknowledgments

We would like to thank subjects for their participation in this study. In addition, we would like to thank the National Strength and Conditioning Association for funding this study.

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