



THE INFLUENCE OF EXERCISE ORDER ON LOCAL MUSCULAR ENDURANCE DURING RESISTANCE TRAINING IN WOMEN

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ABSTRACT

Purpose. The purpose of this study was to investigate the effects of different exercise orders on the local muscular endurance of trained women. **Methods.** Nineteen women with a minimum of two years experience in resistance training volunteered to participate in the study (age 27.68 ± 5.24 years; body mass 60.31 ± 7.50 kg; height 161.83 ± 7.05 cm; body mass index 22.85 ± 1.85 kg · m⁻²). Data were collected in two phases: 1) determining the one repetition maximum (1RM) for the bench press (BP), machine lat pull-down (LPD), free-weight shoulder press (SP), standing free-weight biceps curl (BC), and triceps extension (TE); 2) the completion of two resistance training sequences including 4 sets of exercise at 60% of 1RM with 2 minute rest intervals between sets with exercises performed until failure: Sequence A (SEQ A) comprised of: BP, LPD, SP, BC, TE while sequence B (SEQ B): TE, BC, SP, LPD, BP. **Results.** The mean number of repetitions per set in BP and TE presented significant reductions ($p = 0.001$ and $p = 0.026$, respectively) when they were the last exercise performed in each exercise sequence. Rating of Perceived Exertion (RPE) was not significantly different between the exercise sequences; however, increases for BC (in SEQ A) and BP (in SEQ B) were observed when they were performed later in the sequences. **Conclusion.** These data indicate that in trained women, local muscular endurance is affected by exercise sequence, with exercises performed later in a workout sequence showing decreased exercise ability due to fatigue.

Key words: strength training, performance, local muscular endurance, OMNI scale

Introduction

The American College of Sports Medicine's (ACSM) position on progression models in resistance training for healthy adults [1] is that it recommends that large-muscle group exercises generally be performed first in a training session. However, this recommendation has been based on evidence category C (evidence from outcomes of uncontrolled trials or observations). ACSM's [1] recommendations for novice, intermediate, and advanced resistance training include the following exercise sequences:

1. large-muscle group exercises before small-muscle group exercises
2. multiple-joint exercises before single-joint exercises
3. higher-intensity exercises before lower-intensity exercises
4. or rotation of upper and lower body, or agonist-antagonist, exercises, which are exercises performed for one muscle group followed by an exercise for the opposing muscle group [1].

Previous acute [2–10] and chronic studies [11–13] have all demonstrated that performing either large or small muscle group exercise at the end of a training session resulted in significantly fewer repetitions or less strength gains compared to when the same exercise was performed earlier in a workout sequence. With the results quite similar between these acute studies for either large or small muscle group exercises in relation to the number of repetitions performed [2, 5–10], it is recommended that exercises stimulating muscle groups needing maximal adaptation should be placed at the beginning of an exercise session regardless of the size of the muscle group. Recently, Bellezza et al. [2] investigated the influence of exercise order and its influence on blood lactate as well as the affective and perceptual responses to acute bouts of resistance training and suggested that a small to large exercise order may have beneficial physiological and psychological outcomes and potentially influence exercise adherence.

The ACSM's position [1] on both exercise selection and order on increasing local muscular endurance shows that the order of exercises may not be as important as fatigue is a necessary component of local muscular endurance training. To the best of the author's knowledge, no studies have examined the acute effect of exercise order on local muscular endurance. There-

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fore, the purpose of this study was to investigate the influence of exercise order on both endurance and the rating of perceived exertion (RPE) in trained women. It was hypothesized that both large- or small-muscle group exercises would be negatively affected in terms of the total number of repetitions performed to volitional fatigue when these exercises were performed later in a training session.

Material and methods

Experimental approach to the problem

In order to investigate the influence of exercise order on volume capacity and the RPE of trained women, the subjects performed two exercise sessions separated by 72 hours of rest using a counterbalanced crossover design. The two sessions were composed of the same exercises performed in different exercise order. Sequence A (SEQ A) began with exercises for large-muscle groups and progressed toward exercises for small-muscle groups. Sequence B (SEQ B) began with the exercises for small-muscle groups and progressed toward exercises for large-muscle groups. The performance of SEQ A and B was separated by 72 hours of rest. All exercises in both sequences were performed for 4 sets to volitional fatigue by using the predetermined 60% of 1 repetition maximum (1RM) for each of the exercises. The number of repetitions was recorded for each set of each exercise for both sequences. The RPE and the number of repetitions performed in each exercise as well as sequence were evaluated to examine the differences in the orders in which exercises were performed.

Subjects

Nineteen women (age 27.68 ± 5.24 years; body mass 60.31 ± 7.50 kg; height 161.83 ± 7.05 cm; body mass index 22.85 ± 1.85 kg · m⁻²) with at least two years of recreational resistance training experience participated in the study. The inclusion criteria consisted of the following: a) all of the subjects must have experience performing all of the selected exercises; b) the subjects did not have any medical conditions that might be aggravated by participation in resistance training; and c) subjects did not use any nutritional supplements or ergogenic aids. All subjects read and signed an informed consent document and were asked to not participate in any resistance training during the study period other than that prescribed as part of this study. The experimental procedures were in accordance to the Declaration of Helsinki and the study protocol was approved by the Research Ethics Committee of the institution where the experiment was performed.

1RM testing

After two weeks of a resistance training familiarization period (comprised of 4 sessions), all participants completed 1RM tests performed on two non-consecutive days for all the exercises using a counterbalanced order. On day one the first trial of 1RM tests were performed and then after 72 hours of rest the 1RM retests were repeated to determine test retest reliability. The heaviest load achieved on either of the test days was considered to be the 1RM. No exercise was allowed in the 72 hours between 1RM tests so as not to interfere with the test retest reliability results. To minimize error during 1RM tests, the following strategies were adopted: a) standardized instructions concerning the testing procedure were given to participants before the test; b) participants received standardized instructions on exercise technique; c) verbal encouragement was provided during the testing procedure; d) the mass of all weights and bars used were determined using a precision scale. The 1RM was determined in fewer than three attempts with a rest interval of 5 minutes between each of the 1RM attempts including 10 minutes of rest was allowed before starting the next exercise test. The range of motion for each of the exercises used was similar to Simão et al. [7]. 1RM testing on both attempts, separated by 72 hours of rest, showed intraclass correlation coefficients of BP, $r = 0.95$; LPD, $r = 0.91$; SP, $r = 0.92$; BC, $r = 0.95$; TE, $r = 0.97$.

Exercise sessions

72 hours after the 1RM loads were determined for each exercise, the subjects performed one of the two exercise sessions in a counterbalanced crossover design. The second session was performed 72 hours after the first session. The two sessions were composed of the same exercises performed in two different exercise orders. SEQ A began with exercises for large-muscle groups and progressed toward exercises for small-muscle groups. The exercise order of SEQ A was free-weight bench press (BP), machine lat pull-down (LPD), free-weight shoulder press (SP), standing free-weight biceps curl (BC) with a straight bar, and seated machine triceps extension (TE). SEQ B began with exercises for small-muscle groups and progressed toward exercises for large-muscle groups. The exercise order for SEQ B was TE, BC, SP, LPD, and BP. Warm-up before each exercise sequence consisted of 10 repetitions of the first exercise of the session (BP for SEQ A and TE for SEQ B) at 40% of the 1RM load. A 2-minute rest interval was allowed after the warm-up before subjects performed the assigned exercise sequence. Both exercise sequences consisted of 4 sets of each exercise (60% of 1RM load) with 2-minute intervals between sets and exercises. During the exercise sessions, subjects were verbally encouraged to perform

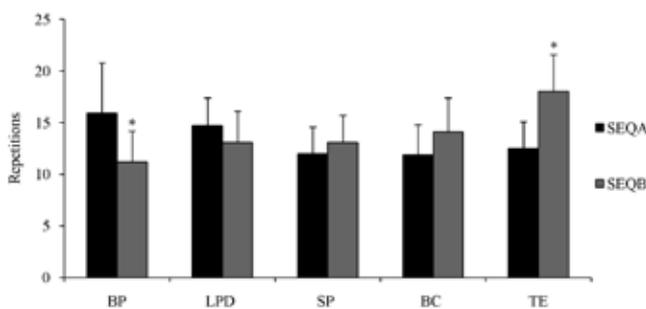
all sets to concentric failure, and the same definitions of a complete range of motion used during 1RM testing were used to define the completion of a successful repetition. No attempt was made to control the velocity in which the repetitions were performed. The total number of repetitions for each set of each exercise was determined. Immediately after completion of the fourth set of each exercise and exercise sequences, the OMNI Scale was used to assess the RPE with emphasis on local fatigue [14].

Statistical analyses

Two-way analyses of variance (ANOVAs) were used to test differences in the mean number of repetitions per exercise and the repetitions per set between sequences. A 1-way ANOVA was used to compare the number of repetitions per set within each sequence. A Tukey post-hoc test was performed where indicated. The RPE at the end of each exercise and exercise sequences was analyzed by a Wilcoxon test. The level of significance was set at $p \leq 0.05$ for all statistical procedures. Statsoft statistical software (version 6.0) was used for all analyses (Statsoft, Tulsa, USA).

Results

The mean number of repetitions of each exercise for the 4 sets varied significantly between sequences only for BP ($p = 0.001$) and TE ($p = 0.026$). The LPD, SP and BC presented no significant difference between sequences, as defined by $p > 0.05$. (Fig. 1).



SEQ A – sequence A, SEQ B – sequence B, BP – bench press, LPD – lat pull-down, SP – shoulder press, BC – biceps curl, TE – triceps extension, * significant difference found when compared to SEQ A

Figure 1. Mean number of repetitions per exercise in both exercise sequences (mean ± SD)

Comparison between SEQ A and the corresponding SEQ B sets did not demonstrate significant differences for the number of repetitions performed. However, within each sequence, significant differences were observed with the progression of the sets in all of the exercises, with more significant differences found in SEQ A which began with large muscle group exercises (Tab. 1).

The RPE median was not significantly different between exercise sequences (SEQ A: 9 and SEQ B: 9). Increases in RPE for BP (SEQ A: 8 and SEQ B: 9) and BC (SEQ A: 9 and SEQ B: 8) were observed when they were performed later in the sequences (Tab. 2).

Discussion

An important finding from this study was that exercise order did influence the number of repetitions in the last exercise in each of the sequences, the large muscle group (BP) or a small muscle group (TE), with loads equal to 60% of 1RM. Results found that local fatigue can reduce performance (the mean number of repetitions in 4 sets) in the last exercise of each sequence. For example, the mean repetitions of 4 sets of BP decreased 29% in sequence B when it was at the end of the sequence. Similarly, the mean number of repetitions of TE decreased 30% when it was performed at the end of SEQ A compared to SEQ B when it was performed first in the sequence. This pattern of significant decrease in the mean number of repetitions of the 4 sets, when an exercise was preceded by exercises for the same general body part (the upper-body), was true only in the last exercise of both SEQ A and SEQ B. Additionally, within each of the sequences, significant reductions in repetitions performed per set were found from the first exercise to the end of the exercise sequence. This decrease in the number of repetitions in the successive sets of an exercise appears to be, in part, the result of increasing fatigue as the exercise session progresses.

Two previous studies done by our research group [7, 8] corroborate with the results of this study. Simão et al. [7] compared the effects of exercise order on the number of repetitions and RPE in 14 men and 4 women with 6 months of resistance training experience. The exercise sessions consisted of 3 sets of 10RM for the same exercises that were performed in this study. In that study there were two training sessions, one training session began with large muscle group exercises and progressed to small-muscle group exercises (exercise order: BP, LPD, SP, BC and TE) while the other session first began with small group exercises (exercise order: TE, BC, SP, LPD and BP). Simão et al. [8] also conducted a study that compared two exercise orders in a sample group composed of only trained women. The exercise sequence utilized was BP, SP, TE, leg press, leg extension and leg curl in one sequence, and the exact opposite order in the second exercise sequence. The results of both studies [7, 8] found that performing either large or small muscle group exercises at the end of a training session resulted in significantly fewer repetitions compared to when the same exercises were performed earlier in a workout sequence.

In the present study, the exercises and the sequences adopted are similar to that utilized by Simão et al.

Table 1. Number of repetitions per set in both exercise sequences (mean \pm SD)

		BP	LPD	SP	BC	TE
SEQ A	First set	22.0 \pm 5.2	18.7 \pm 2.8	15.8 \pm 3.1	16.2 \pm 3.6	16.2 \pm 3.6
	Second set	17.4 \pm 4.1*	14.3 \pm 2.1*	12.2 \pm 1.6*	11.6 \pm 2.8*	12.6 \pm 3.1*
	Third set	14.1 \pm 4.0*†	13.3 \pm 2.1*	10.3 \pm 1.8*	10.3 \pm 1.8*	10.5 \pm 2.4*
	Forth set	10.5 \pm 2.4*†#	12.7 \pm 2.1*	9.9 \pm 2.0*†	9.5 \pm 2.2*	10.8 \pm 3.4*
SEQ B	First set	15.5 \pm 4.4	17.3 \pm 4.6	16.7 \pm 3.5	18.9 \pm 4.1	23.0 \pm 3.0
	Second set	11.1 \pm 3.2*	13.2 \pm 2.5*	13.4 \pm 2.2	14.2 \pm 3.5	18.3 \pm 3.2
	Third set	9.6 \pm 2.5*	11.7 \pm 1.9*	11.8 \pm 2.1*	12.2 \pm 3.1*	16.1 \pm 2.7*
	Forth set	8.6 \pm 2.3*†	10.2 \pm 1.9*†	10.7 \pm 2.2*	11.3 \pm 2.2*†	14.7 \pm 3.1*†
SEQ A – sequence A	SP – shoulder press	* significant difference found from the first set of the same sequence				
SEQ B – sequence B	BC – biceps curl	† significant difference found from the second set of the same sequence				
BP – bench press	TE – triceps extension	# significant difference found from the third set of the same sequence				
LPD – lat pull-down						

Table 2. Rating of Perceived Exertion (RPE) per exercise in both exercise sequences (median)

		BP	LPD	SP	BC	TE
SEQ A	Median 4 sets	8	9	8	9	9
SEQ B	Median 4 sets	9	9	8	8	9
SEQ A – sequence A	SP – shoulder press					
SEQ B – sequence B	BC – biceps curl					
BP – bench press	TE – triceps extension					
LPD – lat pull-down						

[7]. However, there are three basic differences between the two studies: (a) Simão et al. [7] used 10RM resistance while this study used 60% of 1RM to failure, (b) Simão et al. [7] evaluated trained men and women with 6 months of resistance training experience while in this study only trained women with 2 years of experience were evaluated, (c) Simão et al. [7] evaluated the RPE with a Borg scale while this study utilized the Omni scale. Despite these methodological differences, the studies agree that performance decreases in exercises at the end of an exercise sequence. The study results presented here are confirmed by the data from Simão et al. [7], which also indicated a significant reduction in the number of repetitions in the third set when it was compared to the first set, and that more fatigue occurred, as shown by more significant decreases in repetitions per set in successive sets of the same exercise, specifically when the exercise sequence began with large-muscle group and progressed to small-muscle group exercises.

The RPE was used to evaluate the level of local fatigue immediately after the end of the fourth set of each exercise and at the end of the sequences. There were significant increases in the RPE median after the performance of four sets of BP (in SEQ A) and BC (in SEQ B) when these exercises were performed later in the sequences. On the other hand, there was no significant difference in the RPE median between the sequences, confirming the results obtained by Simão et al. [7, 8] and Bellezza et al. [2] which found no significant dif-

ferences in RPE mean [2, 7, 8] or RPE median [8] for different exercise sequences. In the present and previously mentioned studies [2, 7, 8], each exercise of the sequences were performed to concentric failure in all sets. The validation criteria of the RPE scales have been shown for sub-maximal effort (sets at various percentages of 1RM with sets not performed to concentric failure) [14]. Therefore, it is possible that significant differences in the RPE occur only when a fixed number of repetitions at a predetermined percentage of 1RM are performed, as was done when validating the OMNI-RES scale [14].

A unique aspect of this study, when compared to other acute studies [2–10], is the training intensity that was utilized. No previous study investigated the influence of exercise order with low intensities, commonly used when trying to develop local muscular endurance (60% of 1RM or less). The intensities utilized in previous acute studies [2–10] ranged between 8RM [6, 9, 10] and 10RM [2–5, 7] or 80% of 1RM [8]. Therefore, this is the first study that analyzed the influence of exercise order on training programs designed for the development of local muscular endurance.

In summary, this study demonstrates that exercise order during a resistance training session, emphasizing local muscular endurance involving upper body exercises, affects the total number of repetitions performed to failure with 60% of 1RM. For both large- and small-muscle group exercises the maximum number of repetitions performed in the last exercise of the

sequence decreases in trained women. Higher levels of RPE for the last exercises of the sequences were also observed; however, the results demonstrate that the RPE median immediately following an exercise sequence was not affected by exercise order when all sets are performed to concentric failure. Further research should investigate the influence of exercise order on local muscular endurance in lower body exercises and other exercise orders, as well as the effect of different exercise orders on the performance of women without previous experience in resistance training.

Conclusion

The present study found that exercise order can influence performance during a local muscular resistance training endurance session performed by trained women. As the exercise session progressed the total number of repetitions performed to failure decreases. This is especially true for the last exercise in a sequence, whether it is a large- or small-muscle group exercise. The implications of this study are relevant in the future design of resistance training sessions with the goal of improving local muscular endurance or in resistance training phases that require moderate intensities. It is suggested that in training programs aimed at improving local muscular endurance, exercises or movements most important to the objective of the training session should be performed at the beginning of the session. This is true regardless whether the exercise is a large- or small-muscle group exercise.

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