International Journal of EXERCISE SCIENCE

Original Research

Starting the Resistance-Training Session with Lower-Body Exercises Provides Lower Session Perceived Exertion without Altering the Training Volume in Older Women

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ABSTRACT

International Journal of Exercise Science 12(4): 1187-1197, 2019. The aim of this study was to compare the acute effects of four resistance-training (RT) exercise orders on rate of perceived exertion (RPE) and RT variables with exercise load properly adjusted according to its position within the sequence in older women. That is, the load was adjusted so that it was possible that the sets were performed within the repetition-zone established. Fifteen trained older women (67.4 ± 5.3 years) participated in a crossover-design, combining single-joint (SJ) and multi-joint (MJ) exercises for upper- (UB) and lower-body (LB) in the following exercise orders: SEQA = UBMJ-UBSJ-LBMJ-LBMJ; SEQB = UBSJ-UBMJ-LBSJ-LBMJ; SEQC = LBMJ-LBSJ-UBMJ-UBSJ; SEQD = LBSJ-LBMJ-UBSJ-UBMJ. Each session was comprised of eight exercises with 3 sets of 8-12 repetitions. RPE was analyzed by a sequence (4) x sets (3) two-way ANOVA. Repetitions, time under tension, load, volume-load, and the average RPE of the session were analyzed by one-way ANOVA comparing the four sequences. No significant difference was identified between conditions for total repetitions, time under tension, training load, and volume-load. Lower average RPE of the session was obtained when LB exercises were performed earlier (SEQA: 7.2 ± 1.2, SEQB: 7.1 ± 1.0, SEQC: 6.7 ± 0.9, SEQD: 6.3 ± 1.1). We conclude that when lower body exercises are performed first in a training session, a lower RPE is noted throughout all the session.

KEYWORDS: Weight training, exercise order, pre-exhaustion, effort, elderly, non-local muscular fatigue

INTRODUCTION

Resistance training (RT) has been recommended as a beneficial exercise modality due to its well-known effect for enhancing muscular strength and promoting muscle growth, having a positive influence to attenuate the deleterious effects of aging on neuromuscular function (28). Most benefits associated with RT in older adults, however, may be dependent on the correct manipulation of variables that make up the exercise prescription, comprising variables related to intensity, volume, or structure, such as exercise order (EO) (1). With respect to EO, the literature suggests that it is an important variable to be considered when prescribing an RT program and that each RT session should initiate with multi-joint (MJ) exercises, followed by single-joint (SJ) exercises, and larger followed by smaller muscle groups (1, 24).

Recent studies have shown that EO influences chronic and acute outcomes, regardless of MJ or SJ and involving large or small muscles, suggesting that priority should be given to certain exercises or muscles by performing them at the beginning of the sessions (4, 19, 21, 25). Regarding the acute responses, previous investigations have shown that when exercise loads are held constant among EO, the number of repetitions performed are affected, thus influencing volume-load, rate of perceived exertion (RPE), and neuromuscular activity (19, 24, 25). It may occur due to local (i.e., agonists, antagonists, or synergist muscles) and non-local muscular fatigue (NLMF) (i.e., crossover fatigue of a non-exercised muscle group) brought about by neurological, biochemical, biomechanical, or psychological factors (9).

Several works investigating the effects of EO traditionally perform a session for load adjustment by percentage of one-repetition maximum (RM) (22) or by repetition-zone (5, 24) and use this same load for the different experimental sessions. For instance, Sforzo and Touey (24) selected a relative load of 8RM for bench press in trained men and observed that an average of 8 repetitions were performed in this exercise in the experimental session that it was performed first; however, only approximately 2 repetitions were performed in another session when the bench press exercise was performed last. In older women, it was also observed that 10 repetitions were performed when the bench press was done first with a load of 10RM, whereas when done last, only 7 repetitions were completed with that load (5). In a practical setting, a lower load would be selected for the bench press when it was performed later in the session so that it was possible for the subjects to maintain the performance of 10 repetitions. That is, the lack of adjustment of the load of each exercise based on the repetition-zone according to its position within the sequence leads to the performance of a very different amount of training volume (5, 19, 20, 24, 25) and is at odds with the practical application (4).

It is important to note that, in acute studies, this ideal adjustment has not been performed (5, 8, 24), but in chronic studies, it has been (2, 3, 26, 27), which may be one of the causes of the lack of relationship between the acute and chronic findings regarding EO manipulation (4). Therefore, it is unknown what are the effects of EO manipulation with proper load adjustment on the overall acute outcomes of the RT session (e.g., repetitions, volume-load, and RPE), and it may be different from previous findings (4, 25). Unknowing how the EO with this load adjustment based on repetition-zone influences the training performance hampers greater extrapolation of acute study findings for potential effects in practice since performance and training volume are related to the RT-induced adaptations. Once investigations with this proposal have been obtained, these may be a tool in bridging the gap between acute and chronic findings and in providing a more applied-to-practice view of the topic.

Moreover, most of the data available in the literature regarding EO involve untrained young adults and compare acute responses in upper body exercises only (25). Only a few investigations have been conducted with older women on acute outcomes (5, 8), and the analyses involved only two inverse orders with upper body exercises. Considering the accentuated loss of muscle mass and muscular strength in older women, especially in the lower limbs (28), a training protocol with only upper body exercise has a limited practical application for this population. The addition of exercises for lower limbs in a training session may produce a different pattern of response due to NLMF even in upper body exercises, especially when analyzing variables related to performance, fatigue, and effort (9). Since NLMF is muscle group-specific (9), comparing variations of upper and lower body exercises may provide different acute responses for the same exercise depending on its position within a session. Also, findings besides those in other populations on previous studies (24, 25) may be of greater importance to exercise prescription for older women, since responses related to RT are dependent on the training status, gender, and age (1, 7, 9).

Therefore, the purpose of this study was to compare four different EO (with adjustments in load according to each exercise sequence) on the number of repetitions, load, volume-load, and RPE in older women. Our hypothesis was that EO would result in lower volume-load and higher RPE in exercises positioned later in each sequence compared when they were positioned earlier.

METHODS

Participants

Forty-five older women were invited to participate in this study. They had previously carried out a 24-week RT program that consisted of eight whole-body exercises for 3 sets of 10-15 repetitions, performed 3 times a week. All participants had completed health history and physical activity questionnaires and were included in the study if: were 60 years old or more, were free from orthopedic dysfunction that precluded or hindered the execution of the movements to be performed, and did not consume any medication (27). Fifteen older women agreed to participate and complete all sessions of the current study (67.4 ± 5.3 years, 62.8 ± 9.2 kg, 155.4 ± 5.3 cm, 25.7 ± 3.5 kg/m^2). The mean previous experience of the participants with RT was 2.1 ± 0.7 years, with a mean frequency of three sessions per week, and all of them were members of a structured RT program (the Active Aging Longitudinal Study) for at least one and a half year. Participants were instructed to refrain from physical exercise during the current study period. Written informed consent was obtained from all participants after providing a detailed description of the study procedure. This investigation was conducted according to the Declaration of Helsinki and was approved by the University Ethics Committee. All procedures were conducted in accordance with the ethical standards of the Helsinki Declaration and complied with the ethical issues of the International Journal of Exercise Science (15).

Protocol
The study was conducted over a period of four weeks requiring participants to visit the laboratory on eight occasions (sessions 1-8), separated by an interval of 48-72 h, to perform four load familiarization sessions and four experimental sessions. A randomized, counterbalanced, crossover design was used to conduct this experiment. Prior to the experimental sessions, four sessions were performed to adjust the training load according to each sequence. The four exercise sequences were as follows: SEQA = upper body multi-joint (UBMJ), followed by upper body single-joint (UBSJ), lower body multi-joint (LBMJ), and lower body single-joint (LBSJ) exercises; SEQB = UBSJ-UBMJ-LBSJ-LBMJ; SEQC = LBMJ-LBSJ-UBMJ-UBSJ; SEQD = LBSJ-LBMJ-UBSJ-UBMJ. Figure 1 shows the experimental design of the study. All sessions were conducted during the morning hours. Before both the load adjustment and experimental sessions, participants were provided a standardized breakfast 60 min prior to the sessions, consisting of two bread slices, light cream cheese, and a cup of orange juice. This meal contained approximately 257.0 kcal, 44.4 g of carbohydrate, 8.3 g of protein, 5.1 g of fat, 2.6 g of dietary fiber, and 322 mg of sodium, according to brands packaging.

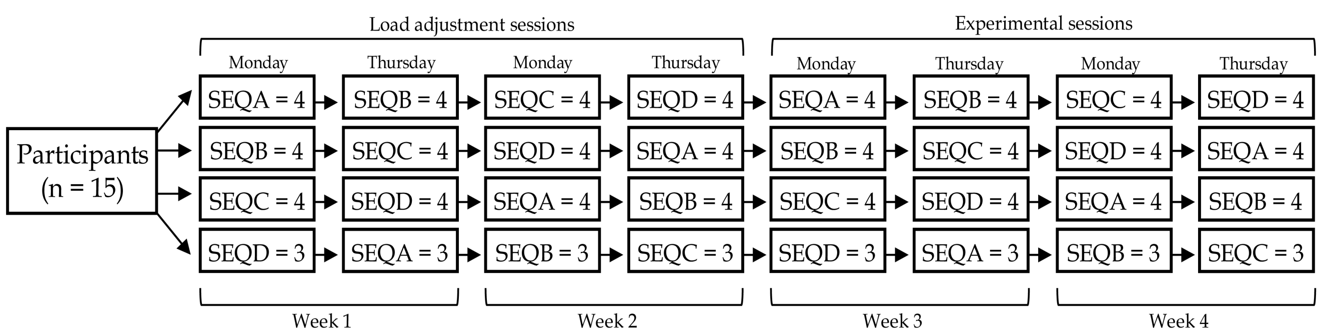

Figure 1. Experimental design. SEQA = multi to single-joint, starting with the upper body; SEQB = single to multi-joint, starting with the upper body; SEQC = multi to single-joint, starting with the lower body; SEQD = single to multi-joint, starting with the lower body.

The load adjustment sessions followed the protocol previously described (18). During sessions 1-4, participants performed three sets of each exercise, of which the first two sets were performed with eight repetitions, and the third set was performed until volitional fatigue or an inability to maintain the movement with correct execution. The number of repetitions performed in the last set in each exercise was recorded to establish the training load to be used in the experimental sessions as follows: for lower body exercises, 1 kg was increased for each repetition that exceeded eight, while for upper body exercises, 0.5 kg was increased for every two repetitions exceeding eight. The initial load selected for the sessions 1-4 was that of the last session of the 24-week training program that the participants had just completed (i.e., intensity of load for 10-15RM). The loads were adjusted for 8-12RM. The recovery interval was of 2 min between sets and 3 min between exercises.

For the experimental sessions (sessions 5-8), the EO were the same as the load adjustment-sessions, and the exercises the comprised each EO are shown in Table 1. SEQA = multi to single-joint, starting with the upper body; SEQB = single to multi-joint, starting with the upper body; SEQC = multi to single-joint, starting with the lower body; SEQD = single to multi-joint, starting with the lower body. Participants performed 3 sets of 8-12 repetitions in each exercise for all sequences. The repetitions performed in each set and load lifted in each exercise were recorded. During all sets, the time under tension (TUT) was measured by a digital chronometer. The timer was initiated when the load started to move and stopped when the exercise was completed. The TUT was only measured as a complementary measure of repetition volume to ensure/verify that participants experienced similar overload duration in the distinct EO. Participants were instructed to perform all repetitions with their habitual range of motion and execution velocity and to not rest between repetitions (intra-set rest) since it could influence performance. The rest interval was of 2 min between sets and 3 min between exercises. Session duration was approximately 45 min. The load (kg) used in all exercises was recorded individually in training logs. The volume-load (VL) was calculated by the exercise load multiplied by the number of repetitions, that is: volume-load = [load (kg) x sets (no.) x repetitions (no.)]. The total VL of each experimental session was determined by summing the VL across all exercises (6). It is important to note that it was used the same load in the 3 sets and thus was considered once for each exercise.

The RPE was collected after each set according to the OMNI scale (12). All participants were previously familiarized with the scale during the first four sessions and instructed how they should choose the RPE values in the scale. Participants were instructed to rate their exertion/effort from 0 to 10, with 0 being "extremely easy", 5 being "moderate effort" and 10 being "extremely hard" (18). The RPE of the session was calculated by a simple mean of all the RPE recorded set-by-set.

Statistical Analysis

Shapiro-Wilk and Levene's tests were used to determine normality and homogeneity, respectively. Non-normal variables were analyzed with $\log_{10}$ adjustment. RPE was analyzed by a sequence x sets (4 x 3) two-way ANOVA. Average RPE of the session and all other variables were analyzed by one-way ANOVA comparing the four sequences. Fisher's post-hoc was applied to multiple comparisons when necessary. The data were expressed as means, standard deviations, and 95% confidence intervals (CI). For all statistical analyses, significance was set at $p < 0.05$. The data were analyzed using SPSS Statistics, v. 24.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The load lifted and volume-load in each exercise according to each sequence are presented in Table 1. There was no significant difference in both variables between the four sequences. The number of total repetitions in each EO was similar (SEQA = 276 ± 13; SEQB = 276 ± 11; SEQC = 278 ± 14; SEQD = 277 ± 11; $p = 0.982$; Figure 2a), as well as the total TUT (SEQA = 438.6 ± 35.4 s; SEQB = 451.7 ± 19.2 s; SEQC = 460.5 ± 28.7 s; SEQD = 441.4 ± 34.3 s; $p = 0.212$; Figure 2b) and total VL (SEQA = 9,956.4 ± 1,303.2 kg; SEQB = 10,047.5 ± 1,405.2 kg; SEQC = 10,054.4 ± 1,620.4 kg; SEQD = 10,077.8 ± 1,236.9 kg; $p = 0.996$; Figure 2c).

The RPE scores are presented in Table 2. No significant interaction effect of sets x sequence was noted for any exercise, which means effort did not differ throughout the sets when comparing different sequences. A main effect of sets was observed in almost all exercises, in which an increase in RPE was observed throughout the sets, with exception to CP (p = 0.09) and BC (p = 0.10). Moreover, the RPE presented different responses in each exercise depending on its position in the sequence.

Table 1. Lifted load and volume-load per exercise for all exercise orders in older women (n = 15).

	Load (kg)				Volume-load (kg)				*p*-value	
	SEQA	SEQB	SEQC	SEQD	SEQA	SEQB	SEQC	SEQD	Load	VL
CP	31 ± 9	31 ± 8	32 ± 8	31 ± 8	1066 ± 294	1086 ± 318	1122 ± 316	1105 ± 266	0.92	0.97
SR	29 ± 4	28 ± 4	29 ± 4	29 ± 4	987 ± 173	1001 ± 187	1020 ± 157	991 ± 142	0.97	0.95
TP	25 ± 5	26 ± 6	26 ± 6	26 ± 5	802 ± 263	865 ± 196	872 ± 201	886 ± 189	0.71	0.74
BC	19 ± 2	19 ± 2	19 ± 2	19 ± 2	654 ± 115	645 ± 123	634 ± 117	633 ± 100	0.98	0.95
LP	90 ± 7	87 ± 10	90 ± 7	89 ± 7	3109 ± 401	3093 ± 457	3051 ± 425	3136 ± 346	0.93	0.96
KE	29 ± 5	29 ± 6	28 ± 6	29 ± 7	990 ± 199	986 ± 217	977 ± 241	958 ± 181	0.99	0.98
LC	13 ± 3	14 ± 4	13 ± 3	14 ± 4	445 ± 131	476 ± 156	470 ± 106	474 ± 122	0.69	0.92
SC	53 ± 7	53 ± 7	53 ± 7	54 ± 6	1900 ± 246	1900 ± 246	1903 ± 242	1894 ± 234	0.94	0.99

Note: Data are expressed as mean ± standard deviation. CP = chest press; SR = seated row; TP = triceps pushdown; BC = biceps preacher curl; LP = horizontal leg press; KE = knee extension; LC = leg curl; SC = seated calf raise; VL = volume-load (load x repetitions x sets); SEQA = CP-SR-TP-BC-LP-KE-LC-SC; SEQB = BC-TP-SR-CP-SC-LC-KE-LP; SEQC = LP-KE-LC-SC-CP-SR-TP-BC; SEQD = SC-LC-KE-LP-BC-TP-SR-CP.

The RPE scores are presented in Table 2. No significant interaction effect of sets x sequence was noted for any exercise, which means effort did not differ throughout the sets when comparing different sequences. A main effect of sets was observed in almost all exercises, in which an increase in RPE was observed throughout the sets, with exception to CP (p = 0.09) and BC (p = 0.10). Moreover, the RPE presented different responses in each exercise depending on its position in the sequence.

Comparisons between all sequences are also presented in Table 2. For upper body exercises, RPE was higher when they were performed before the lower body exercises in the training session (SEQA and SEQB), as noted by significance ($p < 0.05$) in SR and TP. On the other hand, for lower body exercises, greater RPE values were found in all exercises when they were performed after the upper body exercises in session (SEQA and SEQB). In addition, there was observed a main effect of sequence on average RPE of the session (p = 0.01). Only the SEQD was significantly different from the others sequences: SEQA = 7.2 ± 1.2 (95%CI = lower/upper bound: 6.6/7.7), SEQB = 7.1 ± 1.0 (6.5/7.7), SEQC = 6.7 ± 0.9 (6.3/7.3), SEQD = 6.3 ± 1.1 (5.7/6.8). Spaghetti plots of the raw data are presented in Figure 2d.

DISCUSSION

The main finding of this study was that different EO affected the exercises-RPE and the average RPE of the session, without altering load lifted, training volume, and volume-load. We had hypothesized that EO would result in decreased volume-load (load x repetitions) in exercises positioned later in each sequence, which was not confirmed. Adjusting the load of each exercise according to its position within the sequence (which may represent a more practical context of

RT) might lead to similar training volume-load between sequences, opposing to when it was not adjusted (5, 19, 25). A previous study with young adults also found similar volume-load scores between different EO when this adjustment was performed (20). The lack of difference between sequences in training variables, although not expected, also may be assigned to load adjusted according to the predetermined repetition-zone; whereas, for the TUT, it may be a function of the very high relation to the number of repetitions performed, since the participants were instructed to maintain habitual range of motion and execution velocity. The similarity on analyzed training variables makes the results on RPE dependent on the impact of EO manipulation, as suggested by a previous critique (4). In addition, as RPE across sets between sequences presented the same pattern (i.e., no significant interaction sets x sequence effects), the comparisons are restricted to exercises.

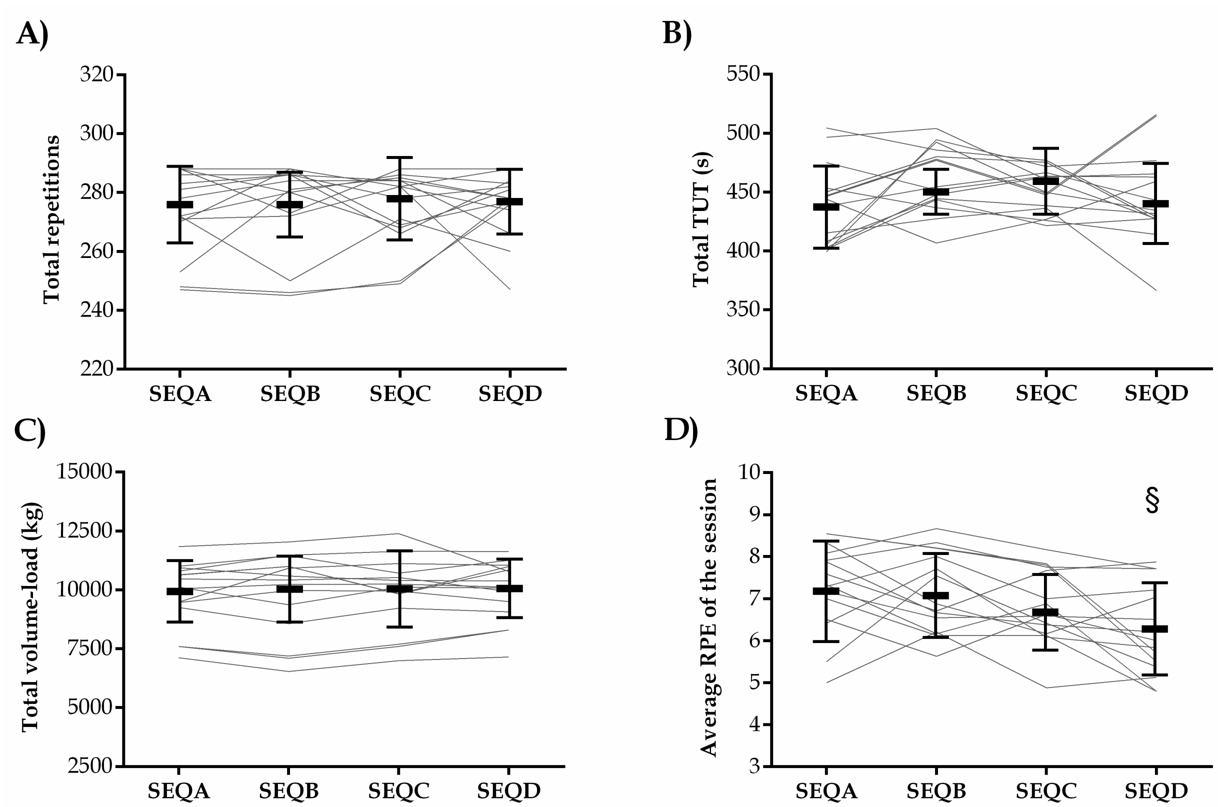

Figure 2. Total repetitions (Panel A), total time under tension (TUT, Panel B), total volume-load (Panel C) and session rating of perceived exertion (RPE, Panel D) performed in all the session. SEQA = multi to single-joint, starting with the upper body; SEQB = single to multi-joint, starting with the upper body; SEQC = multi to single-joint, starting with the lower body; SEQD = single to multi-joint, starting with the lower body. Each line represents a subject, and the markings represent mean and standard deviation values. § = $p < 0.05$ vs. all the other sequences.

Our results partly corroborate other research that demonstrated manipulating EO could affect RPE in older women (8). However, previous data showed greater RPE values when SJ exercises were performed first, which is contrary to our findings. These conflicting results may be partly related to methodological issues between studies, such as the load adjustment method, training protocol, different training status of the participants, and the procedure for assessing RPE.

Table 2. Ratings of perceived exertion per exercise for all exercise orders in older women (n = 15).

	SEQA			SEQB			SEQC			SEQD		
	1st set	2nd set	3rd set	1st set	2nd set	3rd set	1st set	2nd set	3rd set	1st set	2nd set	3rd set
CP	6.8 ± 1.6	6.9 ± 1.6	7.1 ± 1.9	6.5 ± 1.5	6.7 ± 1.4	7.4 ± 1.5*#	6.3 ± 1.3	6.5 ± 1.2	6.9 ± 1.3*#	6.5 ± 1.3	6.4 ± 1.2	6.9 ± 1.3*#
SR	7.1 ± 0.9	7.2 ± 1.6	7.6 ± 1.6*	6.9 ± 1.3	7.3 ± 1.4	7.6 ± 1.6*#	5.9 ± 1.3	6.4 ± 1.4*	7.1 ± 1.4*#	6.0 ± 1.7	6.5 ± 1.2*	7.0 ± 1.2*#
TP	6.6 ± 1.7	7.6 ± 1.3*	8.0 ± 1.4*	7.1 ± 1.4	7.5 ± 1.3	7.7 ± 1.3*	7.0 ± 1.0	7.5 ± 1.0*	7.8 ± 0.8*	6.3 ± 1.4	6.5 ± 1.5	6.9 ± 1.7*
BC	7.1 ± 1.7	7.1 ± 1.7	7.7 ± 2.0*#	6.8 ± 0.9	6.8 ± 1.2	7.4 ± 1.3*#	7.0 ± 1.4	7.3 ± 1.7	7.6 ± 1.5*	6.6 ± 1.2	6.9 ± 1.3	7.1 ± 1.4*
LP	6.9 ± 0.9	7.1 ± 1.1	7.4 ± 1.2*	7.0 ± 1.1	7.4 ± 1.2	7.7 ± 1.0*#	6.5 ± 1.3	6.4 ± 1.0	6.5 ± 1.2	5.8 ± 1.9	6.1 ± 1.8	6.2 ± 1.6*
KE	7.6 ± 1.2	8.0 ± 1.2*	8.6 ± 1.5*#	7.1 ± 1.7	7.9 ± 1.6*	8.5 ± 1.6*#	7.2 ± 1.2	7.2 ± 0.9	8.1 ± 0.9*#	6.5 ± 1.9	7.1 ± 1.7*	7.3 ± 2.1*
LC	7.0 ± 1.9	7.1 ± 2.0	7.5 ± 2.2*	7.1 ± 1.6	7.3 ± 1.6	7.8 ± 1.6*#	6.9 ± 1.7	6.9 ± 1.5	7.1 ± 1.7	5.9 ± 2.1	6.4 ± 1.8*	7.1 ± 1.5*#
SC	5.5 ± 1.7	5.6 ± 1.7	5.7 ± 1.8	5.4 ± 0.9	5.6 ± 0.8	5.8 ± 0.7*	5.2 ± 1.5	5.1 ± 1.6	5.6 ± 1.3*#	4.0 ± 1.6	4.4 ± 1.6*	4.4 ± 1.7*

Mean values of each exercise

	SEQA	SEQB	SEQC	SEQD		SEQA	SEQB	SEQC	SEQD
CP	7.0 ± 1.6	6.9 ± 1.4	6.6 ± 1.2	6.7 ± 1.2	LP	7.2 ± 1.0†‡	7.4 ± 1.0†‡	6.5 ± 1.1	6.0 ± 1.7
SR	7.3 ± 1.3†‡	7.3 ± 1.4†‡	6.5 ± 1.2	6.5 ± 1.2	KE	8.1 ± 1.3‡	7.8 ± 1.5‡	7.5 ± 0.9	7.0 ± 1.8
TP	7.5 ± 1.2‡	7.5 ± 1.3‡	7.4 ± 0.9‡	6.6 ± 1.5	LC	7.2 ± 2.0‡	7.4 ± 1.5‡	7.0 ± 1.6	6.5 ± 1.7
BC	7.3 ± 1.7	7.0 ± 1.1	7.3 ± 1.4	6.9 ± 1.2	SC	5.7 ± 1.7‡	5.6 ± 0.8‡	5.3 ± 1.4‡	4.2 ± 1.6

Note: * = $p < 0.05$ vs. 1st set; # = $p < 0.05$ vs. 2nd set; † = $p < 0.05$ vs. SEQC; ‡ = $p < 0.05$ vs. SEQD. Data are expressed as mean ± standard deviation. CP = chest press; SR = seated row; TP = triceps pushdown; BC = biceps preacher curl; LP = horizontal leg press; KE = knee extension; LC = leg curl; SC = seated calf raise; SEQA = CP-SR-TP-BC-LP-KE-LC-SC; SEQB = BC-TP-SR-CP-SC-LC-KE-LP; SEQC = LP-KE-LC-SC-CP-SR-TP-BC; SEQD = SC-LC-KE-LP-BC-TP-SR-CP.

Several methodological disparities, especially the lack of measurement of set-by-set RPE (8) and the inclusion of lower body exercises, hamper further comparisons.

This study is not without some limitations. For one, the sample was comprised of a small number of subjects. We analyzed resistance-trained older women and therefore, applying these results to other populations should be made carefully due to possible differences in outcomes related to sex, age, and training status (1, 7, 9). In addition, although the RPE scale has been repeatedly related to markers such as muscle activation and lactate concentrations (11, 13, 17), no physiological measures were conducted to confirm the results regarding training overload. Moreover, although we controlled food intake of the participants before all eight sessions, subjective measures such as mood, recovery, and fatigue were not assessed, hindering our ability to determine whether these factors exerted an influence on measured variables.

Based on the findings of this study, we conclude that starting the resistance-training session with lower-body exercises provides lower average RPE in a session, without altering the training volume in older women. Additionally, when the load is adjusted properly, EO does not influence training volume-load. The results of this study contribute significantly to trainers, coaches, and exercise professionals who work with older women, aiding in a more scientific-based exercise prescription. The similarity in the acute response of all other variables allows training to be more dynamic/versatile regarding choosing exercise order.

ACKNOWLEDGEMENTS

We would like to express thanks to all the participants for their engagement in this study, the National Council of Technological and Scientific Development (CNPq/Brazil) for the scientific initiation scholarship conferred to JPN and AJM, and grants conceded to ASR and ESC.

REFERENCES

1. ACSM. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 41(3): 687–708, 2009.
2. Assumpção CO, Tibana RA, Viana LC, Willardson JM, Prestes J. Influence of exercise order on upper body maximum and submaximal strength gains in trained men. Clin Physiol Funct Imaging 33(5): 359–363, 2013.
3. Avelar A, Ribeiro AS, Nunes JP, Schoenfeld BJ, Papst RR, Trindade MCC, et al. Effects of order of resistance training exercises on muscle hypertrophy in young adult men. Appl Physiol Nutr Metab 44(4): 420–424, 2019.
4. Carpinelli R. Does the sequence of exercise in a resistance training session affect strength gains and muscular hypertrophy? A critical examination of the evidence. Med Sport 17(1): 37–50, 2013.
5. Cid Jesus J, Brown A, Cardozo D, Santos LGD dos, Dias I, Cahuê F, et al. The influence of exercise order on strength performance in post menopause women. Med Express Epub doi: 10.5935/MedicalExpress.2018.mo.005, 2018.
6. Cunha PM, Nunes JP, Tomeleri CM, Nascimento MA, Schoenfeld BJ, Antunes M, et al. Resistance training performed with single- and multiple-sets induces similar improvements in muscular strength, muscle mass, muscle quality, and IGF-1 in older women: A randomized controlled trial. J Strength Cond Res Epub doi: 10.1519/JSC.0000000000002847, 2018.

7. Deschenes MR, Kraemer WJ. Performance and physiologic adaptations to resistance training. Am J Phys Med Rehabil 81(11 Suppl): S3-16, 2002.

8. Farinatti PT, da Silva NS, Monteiro WD. Influence of exercise order on the number of repetitions, oxygen uptake, and rate of perceived exertion during strength training in younger and older women. J Strength Cond Res 27(3): 776–785, 2013.

9. Halperin I, Chapman DW, Behm DG. Non-local muscle fatigue: Effects and possible mechanisms. Eur J Appl Physiol 115(10): 2031–2048, 2015.

10. Halperin I, Copithorne D, Behm DG. Unilateral isometric muscle fatigue decreases force production and activation of contralateral knee extensors but not elbow flexors. Appl Physiol Nutr Metab 104(6): 919–929, 2014.

11. Hiscock DJ, Dawson B, Donnelly CJ, Peeling P. Muscle activation, blood lactate, and perceived exertion responses to changing resistance training programming variables. Eur J Sport Sci 16(5): 536–544, 2015.

12. Lagally KM, Robertson RJ. Construct validity of the OMNI resistance exercise scale. J Strength Cond Res 20(2): 252–256, 2006.

13. Lagally KM, Robertson RJ, Gallagher KI, Goss FL, Jakicic JM, Lephart SM, et al. Perceived exertion, electromyography, and blood lactate during acute bouts of resistance exercise. Med Sci Sports Exerc 34(3): 552–559, 2002.

14. Miljkovic N, Kim J-Y, Miljkovic I, Frontera WR. Aging of skeletal muscle fibers. Ann Rehabil Med 39(2): 155–162, 2015.

15. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific riscovery in exercise science. Int J Exerc Sci 12(1): 1–8, 2019.

16. Nunes JP, Ribeiro AS, Schoenfeld BJ, Cyrino ES. Comment on: "Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis." Sport Med 48(2): 491–494, 2018.

17. Pierce K, Rozenek R, Stone MH. Effects of high volume weight training on lactate, heart hate and perceived exertion. J Strength Cond Res 7(4): 211–215, 1993.

18. Ribeiro AS, Avelar A, Schoenfeld BJ, Fleck SJ, Souza MF, Padilha CS, et al. Analysis of the training load during a hypertrophy-type resistance training programme in men and women. Eur J Sport Sci 15(4): 256–264, 2015.

19. Ribeiro AS, Nunes JP, Cunha PM, Aguiar AF, Schoenfeld BJ. The potential role of pre-exhaustion training in maximizing muscle hypertrophy: A review of the literature. Strength Cond J 41(1): 75–80, 2019.

20. Ribeiro AS, Romanzini M, Nascimento MA, Cheche Pina FL, Souza MF, Avelar A, et al. Influence of the execution order of weight exercises on total training volume when load is adjusted according to the sequence. Brazilian J Phys Act Heal 19(3): 351–360, 2014.

21. Ribeiro AS, Schoenfeld BJ, Nunes JP. Large and small muscles in resistance training: Is it time for a better definition? Strength Cond J 39(5): 33–35, 2017.

22. Ribeiro AS, da Silva DRP, do Nascimento MA, Avelar A, Ritti-Dias RM, Cyrino ES. Effect of the manipulation of exercise order in the tri-set training system. Brazilian J Kinanthropometry Hum Perform 15(5): 527–534, 2013.

23. Schoenfeld BJ, Grgic J, Ogborn D, Krieger JW. Strength and hypertrophy adaptations between low- versus high-load resistance training: A systematic review and meta-analysis. J Strength Cond Res 31(12): 3508–3523, 2017.

24. Sforzo GA, Touey PR. Manipulating exercise order affects muscular performance during a resistance exercise training session. J Strength Cond Res 10(1): 20–24, 1996.

25. Simão R, de Salles BF, Figueiredo T, Dias I, Willardson JM. Exercise order in resistance training. Sport Med 42(3): 251–265, 2012.

26. Simão R, Spineti J, de Salles BF, Oliveira LF, Matta T, Miranda F, et al. Influence of exercise order on maximum strength and muscle thickness in untrained men. J Sport Sci Med 9(1): 1–7, 2010.

27. Tomeleri CM, Ribeiro AS, Nunes JP, Schoenfeld BJ, Souza MF, Schiavoni D, et al. Influence of resistance-training exercise order on muscle strength, hypertrophy and anabolic hormones in older women: A randomized controlled trial. J Strength Cond Res Epub doi: 10.1519/JSC.0000000000003147, 2019.

28. Westcott WL. Resistance training is medicine: Effects of strength training on health. Curr Sports Med Rep 11(4): 209–216, 2012.