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The Effect of Exercise Order in Circuit Training on Muscular Strength and Functional Fitness in Older Women

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ABSTRACT

International Journal of Exercise Science 12(4): 657-665, 2019. The purpose of this study was to analyze the effect of different orders of exercises in circuit training on strength and functional fitness in older women over a 12-week period. After 10 repetition maximum (10-RM) and functional fitness baseline testing, thirty older women were randomly assigned into two groups. The exercise order for Group 1 was leg press, wide-grip lat pulldown, knee extension, pec deck fly, plantar flexion and triceps extension; Group 2 performed the same exercises, but in the opposite order: triceps extension, plantar flexion, pec deck fly, knee extension, wide-grip lat pulldown and leg press. Both groups performed the circuit three times with a load that permitted 8 to 10 repetitions per exercise set. Both groups exhibited gains in 10-RM strength and functional fitness test performance ($p \leq 0.05$). In Comparing groups, the G1 presented greater strength gains for the wide-grip lat pulldown, while G2 showed higher values for the plantar flexion and triceps extension exercises ($p \leq 0.05$). Both circuit exercise orders were effective and could be applied to promote strength and functional fitness gains. However, based on the results for the wide-grip lat pulldown, plantar flexion and triceps extension, it seems that exercise order should be considered when specific muscle weaknesses are a priority, so that these muscles are trained first within a circuit.

KEY WORDS: Resistance, training, strength, recovery, performance

INTRODUCTION

The American College of Sports Medicine (ACSM) (3) position stand on progression models in resistance training recommends rotation of upper and lower body exercises with minimum rest between them using the circuit training method. This method might be particularly useful to train the entire body in a single session and promote localized muscular endurance and strength gains in older adults.

The ACSM position stand on progression models in resistance training (3) also recommends that large muscle group exercises or basic exercises should generally be performed first in a training session for strength development. However, in the review by Simão et al. (18), citing three studies involving untrained young men (6, 20, 21), greater increases in maximal strength were evident when exercises were performed at the beginning of a session, regardless of whether the exercises were for large or small muscle groups, suggesting that most important exercises should be performed first.

The ACSM (2) also published a position stand about *Exercise and Physical Activity for Older Adults* that recommends progressive resistance training be performed at least two days per week; incorporating moderate to vigorous intensity or weight bearing calisthenics (8-10 exercises involving the major muscle groups of 8-12 repetitions each) that train major muscle groups. However, it remains unclear whether there is an optimal exercise order for circuit training to promote strength gains in older adults.

In terms of chronic adaptations, the order of exercises during a session can influence the efficiency and effectiveness of a resistance training program (18). Previous studies suggest that circuit training promotes neuromuscular, cardiorespiratory and body composition improvements in older adults (16, 17). However, no previous studies have examined the effects of different exercise orders in circuit training on muscle strength and functionality in older adults. Comparison between different exercise orders in circuit training would provide practical insight for prescriptive purposes in older adults. Therefore, the purpose of this study was to analyze the effect of different orders of exercises in circuit training on strength and functional fitness in older women over a 12-week period.

METHODS

Participants

The sample size was determined from a study pilot previously performed in our laboratory, based on a significance of 5% and a test power of 80%. Thirty elderly women were randomly divided into two groups: one performing large muscle mass exercises first (G1 n= 15; 71.1 ± 6.0 yrs., 64.7 ± 10.0 kg, 153.8 ± 5.8 cm, 27.5 ± 4.5 kg.m^{-2}) and the other performing the exact opposite exercise order, with small muscle mass exercises performed first (G2 n=15; 73.4 ± 8.2yrs, 63.9 ± 13.9 kg, 152.5 ± 5.2 cm, 27.5 ± 5.6 kg.m^{-2}). Inclusion criteria were the following for all subjects: a) not having experience in resistance training; b) not performing any structured exercise for the duration of the study other than the prescribed resistance training; c) did not have any functional limitations or medical conditions that would be contraindicated by the research protocol. All subjects read and signed an informed consent document after being informed of the testing and training procedures to be performed during the study. The experimental procedures were approved by the Ethics Committee of the University. The study was conducted in compliance with the ethical principles of the Declaration of Helsinki and the International Conference on Harmonization Good Clinical Practices Guidelines.

Protocol
The 10-RM tests (19) were performed on two nonconsecutive days for four exercises: leg press (LP), wide-grip latissimus pulldown (WP), plantar flexion (PF) and triceps extension (TE). Two weeks of familiarization took place prior to the 10-RM tests (four sessions). The 10-RM tests were performed following the anthropometric measurements and functional fitness tests (14) on the first day. After 48 hours, the 10-RM tests were repeated to determine test-retest reliability. The heaviest load achieved on either of the test days was considered the pre-training 10-RM. No exercise was allowed in the 48 hours between 10-RM tests. The 10-RM was determined in fewer than five attempts with a rest interval of five minutes between attempts and 10 minutes before the start of the test for the next exercise. Following the twelve weeks of training, the 10-RM tests and functional fitness tests were repeated.

After the 10-RM tests, the remaining exercises were added (knee extension – KE, pec deck fly – PD). The complete exercise protocol included 6 exercises. The exercise order for G1 was LP, WP, KE, PD, PF, and TE. The G2 performed the same exercises in the opposite order: TE, PF, PD, KE, WP, LP. All exercises for both groups were performed for three sets in a circuit format. Each set was performed between a range of 8 – 10 repetitions with 70% of 10-RM. Adjustment of training loads was done through the Omni-Res perception scale whenever volunteers completed three sets of 10 repetitions comfortably (8, 11). In addition, an experienced strength and conditioning professional supervised all training sessions. Frequency of the training program was two sessions per week with at least 48 hours of rest between sessions, and two minutes between sets and exercises. Twenty-four sessions were performed during the twelve weeks training period. The resistance for a given exercise was increased whenever an individual could perform more than the prescribed number of repetitions (8 – 10 repetitions) of a particular exercise. Prior to each training session, subjects performed a specific warm up, consisting of 20 repetitions with approximately 50% of the load used in the first exercise of the training session. During the exercise sessions, subjects were verbally encouraged to perform all sets with a complete range of motion, but there was no attempt to control the repetition velocity. Adherence to the program was 100% for all groups.

Body composition measurement: Four skinfold measures (biceps, triceps, subscapular, and suprailiac) were made using a CESCORF® skinfold caliper. The Durnin and Wormerley (7) equation was used to estimate body fat percentages.

Functional tests: Functional tests applied were based on Rikli and Jones´s protocol (14). Tests used were: 1) 30s Chair Stand - Number of full stands in 30s with arms folded across chest, 2) Arm Curl - Number of bicep curls in 30s holding hand weight (women 5 lb), 3) Chair Sit and Reach - From sitting position at front of chair with leg extended and hands reaching toward toes, number of centimeters (+ or −) from extended fingers to tip of toe, 4) Back Scratch - With one hand reaching over shoulder and one up middle of back, number of inches between extended middle fingers (+ or −), 5) 8-Foot Up-and-Go - Number of seconds required to get up from seated position, walk 8 feet, turn, and return to seated position on chair and 6) 6-Minute Walk - Number of meters walked in 6 min around 50-meter course.

Statistical analysis
The total work performed by G1 and G2 was calculated by multiplying the number of sessions by the number of sets and load (session x sets x load). Intra-class correlation coefficients (ICC) were used to determine 10-RM test-retest reliability. The statistical analysis was initially done by the Shapiro-Wilk normality test. All variables presented normal distribution. A 2X2 repeated-measures analysis of variance (ANOVA) was used to analyze group X trail interactions in 10-RM, body composition and functional fitness tests, post-hoc Bonferroni. T-test were used to analyze for differences in total work performed. An alpha level of $p \leq 0.05$ was considered statistically significant for all comparisons. Probability values of $p \leq 0.05$ were regarded as statistically significant. All data were analyzed by IBM SPSS version 20.0.

RESULTS

There were no significant differences between groups in anthropometric parameters, 10-RM loads, or functional fitness test performance prior to training. The 10-RM test-retest reliability showed high ICC at baseline for G1 (LP, r=0.99; WP, r=0.99; PF, r=0.99; TE, r=0.98), G2 (LP, r=0.98; WP, r=0.96; PF, r=0.96; TE, r=0.98) and after 12 weeks of training G1 (LP, r=0.99; WP, r=0.99; PF, r=0.99; TE, r=0.97), G2 (LP, r=0.98; WP, r=0.96; PF, r=0.96; TE, r=0.98).There was no difference in total work between G1 and G2 (8184 ±1423.1 vs. 8222.4 ± 1309.1; t_{28} = -0,077; p = 0.94), respectively.

Table 1 shows the anthropometric characteristics at baseline and at 12 weeks of training. There was a significant trial effect for %body fat (mean reduction = 1.6%; 95% CI = 1.0 to 2.1 %), lean body mass (mean improvement = 1.0 kg; 95% CI = 0.6 to 1.4 kg) and body fat (mean reduction = 1.0 kg; 95% CI = -0.6 to -1.4 kg). Both groups exhibited significant improvements in lean body mass and reductions in body fat.

Table 1. Anthropometric characteristics (n=15 in each group)

Variable	**Trial**	G1 Mean ± SD	G2 Mean ± SD	Group effect	Trial effect	Group vs. Trial effect
Age (years)		71.1 ± 6.0	73.4 ± 8.2	-	-	-
Height (cm)	Pre	153.8 ± 5.8	152.5 ± 5.2	-	-	-
	Post	153.9 ± 5.9	152.6 ± 5.2			
Weight (kg)	Pre	64.7 ± 10.0	63.9 ± 13.9	F = .02	F = .02	F = 0.78
	Post	64.5 ± 8.9	64.1 ± 13.4	p = .90	p = .90	p = 0.38
IMC (kg.m^2)	Pre	27.5 ± 4.5	27.5 ± 5.6	F = .001	F = .69	F = 0.79
	Post	27.3 ± 4.2	27.5 ± 5.4	p = .98	p = .41	p = 0.38
% Body Fat	Pre	41.9 ± 4.2	42.5 ± 4.8	F = .239	F = 33.561	F = .350
	Post	40.1 ± 4.7	41.1 ± 5.2	p = .63	p < .001*	p = .56
Lean body mass (kg)	Pre	37.3 ± 4.0	36.2 ± 5.1	F = .465	F = 28.082	F = .015
	Post	38.3 ± 3.6	37.1 ± 5.0	p = .50	p < .001*	p = .91
Fat mass (kg)	Pre	27.4 ± 6.3	27.8 ± 9.0	F = .036	F = 27.636	F = .827
	Post	26.2 ± 6.1	26.9 ± 8.8	p = .85	p < .001*	p = .37

(CI 95%: 95%confidence interval for mean; SD - standard deviation)

Figure 1 shows the 10-RM test results in kg. There was a significant trial effect for Leg Press ($F = 262.163$; $p < .001$). Both groups showed an average improvement of 13.9kg (95% CI = 12.1 to 15.6). There was a significant group X trial interaction effect for Lat Pull Down ($F = 6.736$; $p = 0.01$). G1 vs. G2 have an average improvement of 10.4 ± 2.7 kg vs. 7.7 ± 3.1 kg, respectively. There was a significant group X trial interaction effect for Plantar Flexion ($F = 4.979$; $p = 0.03$). G2 vs. G1 have an average improvement of 6.5 ± 2.6 kg vs. 4.7 ± 1.7 kg, respectively. There was a significant group X trial interaction effect for Triceps Extension ($F = 14.824$; $p = 0.001$). G2 vs. G1 have an average improvement of 13.2 ± 5.1 kg vs. 7.7 ± 2.2 kg, respectively.

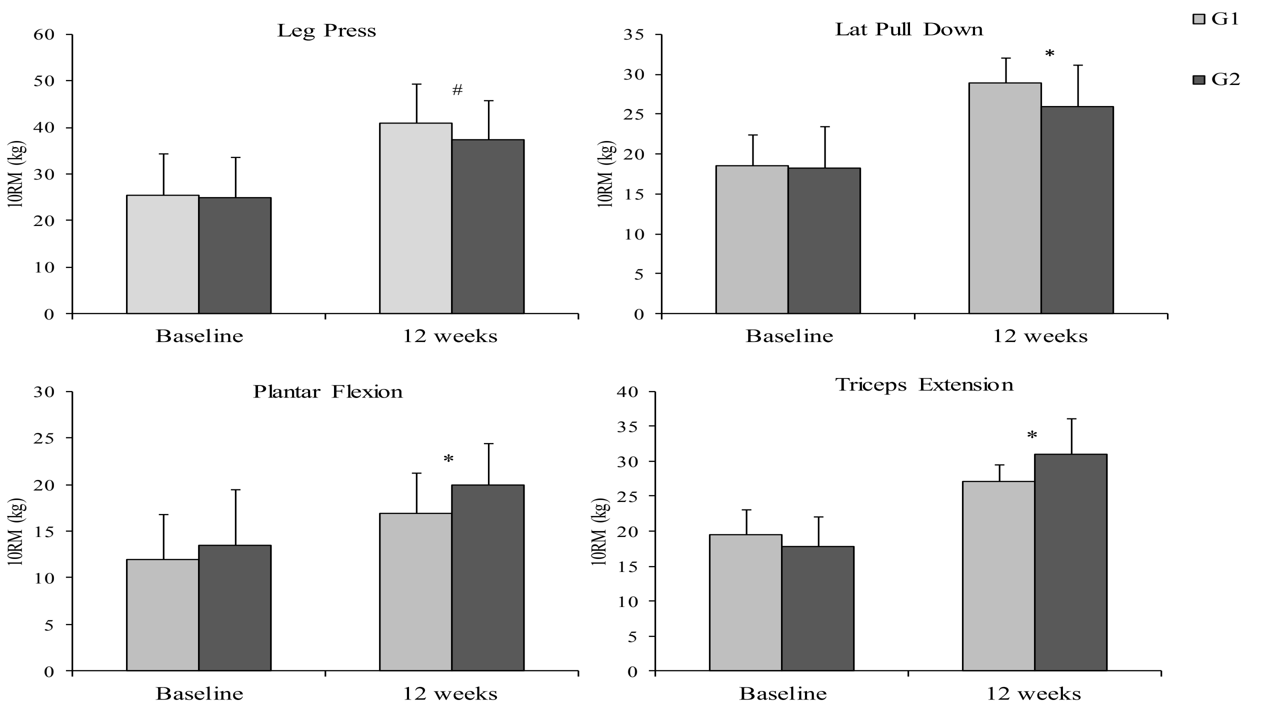

Figure 1. 10-RM (Mean and SD) of LP, WP, PF and TE exercises for G1 (n=15) and G2 (n=15) at baseline and at 12 weeks of RT. # Trial effect; *Group X trial interactions.

There was a significant trial effect for all fitness test performance. Both groups increased functional fitness test performance (see Table 2).

Table 2. Functional fitness results (n=15 in each group)

Variable	Trial	G1 Mean ± SD	G2 Mean ± SD	Group effect	Trial effect	Group vs. Trial effect
30s Chair Stand[1]	Pre	12.5 ± 2.9	13.8 ± 1.8	F = 1.223	F = 21.385	F = .190
	Post	14.9 ± 3.9	15.8 ± 2.4	p = .28	p < .001*	p = .67
Arm Curl[1]	Pre	17.7 ± 2.3	18.1 ± 3.4	F = 0.000	F = 79.122	F = 2.037
	Post	20.8 ± 2.3	20.3 ± 2.8	p = .99	p < .001*	p = .17
Chair Sit-and-Reach[2]	Pre	1.2 ± 4.4	2.6 ± 5.0	F = .364	F = 38.423	F = .100
	Post	5.8 ± 5.9	6.8 ± 5.5	p = .55	p < .001*	p = .76
Back Scratch[2]	Pre	-9.4 ± 10.7	-13.1 ± 11.9	F = .741	F = 24.617	F = .065
	Post	-3.3 ± 9.9	-6.4 ± 9.2	p = .40	p < .001*	p = .80
Foot Up-and-Go[3]	Pre	8.1 ± 1.2	7.8 ± 1.6	F = .179	F = 96.221	F = .060
	Post	5.8 ± 1.1	5.7 ± 0.7	p = .68	p < .001*	p = .81
6 Minute Walk[4]	Pre	447.4 ± 77.1	480.3 ± 37.3	F = 1.272	F = 9.587	F = 1.320
	Post	489.1 ± 49.9	499.4 ± 43.9	p = .27	p = .005*	p = .26

CI 95%: 95%confidence interval for mean; SD - standard deviation; [1]Number of repetitions; [2]Value in centimeters (cm); [3]Value in seconds (s); [4]Value in meters (m).

DISCUSSION

To our knowledge, this was the first study to investigate the effect of different exercise orders in a circuit format in older people. The current results revealed significant differences in strength gains on all tested exercises. Our findings also suggest that circuit training in either order (i.e. large to small muscle mass or small to large muscle mass) is equally effective to promote gains in functional fitness and body composition improvements.

Exercise order is an important variable in resistance prescription; however, literature analyzing its chronic effects in older adults is scarce. This lack of available research makes it very difficult to compare our results with previous studies (6, 20, 21, 22). Previous studies in younger adult samples showed that greater strength increases were achieved for exercises when placed at the beginning of an exercise session, independent of whether it was a large or small muscle mass exercise. The results of the present study demonstrated that all exercises increased muscle strength levels (pre versus post intervention). However, the strength gains were influenced by the order of the exercises, for example, the G1 showed greater values for the WP exercise, while the G2 showed greater values in the TE and PF exercises, respectively. These results agree with those found by other studies (6, 20, 21, 22). However, it is important to highlight that for exercise LP did not present statistically significant differences between groups after 12 weeks. A possible explanation for this fact may be due to the different muscle groups worked in the training sessions and also by the circuit protocol that alternates exercises of upper and lower limbs with minimum interval between them.

Circuit training is a time-efficient method recommended for older adults (2, 17). Moreover, previous studies demonstrated that circuit training results in neuromuscular, cardiorespiratory and body composition (fat free mass and bone mineral density) improvements in older adults (16) and even in trained young men (1). Romero-Arenas et al. (16) compared the effects of high intensity circuit training versus traditional resistance training over 12 weeks on upper and lower body strength, body composition and cardiovascular parameters during an incremental treadmill test. Both groups showed significant increases in isokinetic strength, lean mass and bone mineral density, but only the circuit training group showed a significant decrease in fat mass. These results suggest that circuit training can be effective for older adults if exercises are performed at high intensities. Our results were consistent with Romero-Arenas et al. (16), demonstrating that in both circuit training programs (irrespective of exercise order) with moderate intensity loads (eight to ten repetitions at Omni-Res RPE scale of 8 – 10), resulted in muscle strength, body composition (increase of lean mass, reduction of fat mass and percentage of fat) and functional fitness improvements for all exercises and tests performed.

Muscle strength is a key factor in the ability to perform daily living activities into old age and maintaining quality of life (4, 5, 10, 12, 13, 15). Furtado et al. (9) conducted a cross-sectional study with 700 elderly women to verify the effects of an eight-month multimodal resistance training program performed three sessions a week. Each session was conducted in 30 minutes and followed a circuit format, consisting of three sets of 15-20 repetitions using body weight and elastic bands at moderate intensity. There are some methodological differences to the present study, like the lower intensity loads; however, there were significant improvements in strength and functional fitness.

It´s important to mention that the present study had some limitations. The diet of subjects was not controlled, daily caloric intake was not registered and body composition parameters used in our study were not measured with gold standard procedures. Moreover, we studied a sample composed exclusively of elderly women; further research should address other populations. Lastly, it is clear that circuit training is effective, but it should be compared to traditional resistance training performed in straight sets.

In conclusion, circuit training increased muscle strength and functional fitness in older women. Therefore, both circuit exercise orders were effective and could be applied to promote strength and functional fitness gains. However, based on the results for the wide-grip latissimus pulldown, plantar flexion and triceps extension, it seems that exercise order should be considered when specific muscle weaknesses are a priority, so that these muscles are trained first within a circuit.

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