

Effect of Sequence Order of Combined Training (Resistance and Endurance) on Strength, Aerobic Capacity, and Body Composition in Older Women

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Background: The aging process is a complex medical condition that leads to many unfavorable and inevitable changes in body composition, muscle strength, aerobic capacity, health status, and eventually functional capacity of individuals.

Objectives: The purpose of this study was to investigate the effect of the sequence order of combined training on maximal strength, aerobic capacity, and body composition in older women.

Patients and Methods: Forty healthy female volunteers (age = 67.35 ± 1.40 years old) were randomly divided into three experimental groups and one control group: resistance followed by endurance training (E + S, N = 9); endurance training followed by resistance training (S + E, N = 10); alternating concurrent training (ACT, N = 12); and control (C, N = 16) groups. The training program was performed 3 times per week for 8 weeks. All the participants were evaluated before and after the training period.

Results: The intra-session sequence order did not influence the adaptive response of the waist-to-hip ratio (P = 0.55), body fat percentage (BF%) (P = 0.08), and upper-limb maximal strength (P = 0.07) throughout the study. However, there were significant differences between the groups for VO₂ max (P = 0.029), lower-limb maximal strength (P = 0.000), body mass (P = 0.017), waist circumference (P = 0.006), and body mass index (P = 0.023).

Conclusions: Independent of the training sequence, an 8-week concurrent training program caused positive changes in the body composition and physical fitness of our aged female subjects. However, there was no benefit derived from sequence order training.

Keywords: Body Composition; Elderly; Physical Endurance

1. Background

The aging process is a complex medical condition that brings about many unfavorable and inevitable changes in body composition, muscle strength, aerobic capacity, health status, and eventually functional capacity of individuals. Muscle atrophy, decreased endurance capacity, and muscle weakness in the elderly will all result in reduced physical activity and ultimately the incidence of diseases such as cardiovascular disease (1). This decline occurs at a steeper slope in postmenopausal women than in men (2).

It is never too late in life to become active physically. Regular physical activity and/or exercise training can minimize the declines that occur during the aging process and may improve physical ability (3). It has been posited that the administration of both strength and endurance training can bolster functional capacity and body composition in the elderly (4). A simultaneous endurance and resistance training program combined in a regular exercise routine is called combined training (concurrent training) (5). Research has shown that combined training is both safe and effective for postmenopausal women (6). The exercise order of concurrent training, in which endurance and strength training are carried out,

shows which one (resistance or aerobic training) should precede the other (7).

It has been hypothesized that performing endurance training immediately before or after resistance training may diminish strength gains because of the residual muscle fatigue resulting from the preceding training and the inability of the muscle to adapt optimally to two different stimuli with different energy pathways during the same session (8, 9). Cutts et al. (10) reported that performing aerobic exercise prior to resistance training versus the reverse sequence had a greater impact on total energy consumption in their female subjects. Carithers et al. (11) showed that when resistance training was preceded by acute endurance training, the anabolic response was not suppressed by prior endurance training. In a study performed by Goto et al. (12), the growth hormone response was impaired when aerobic exercise preceded strength training.

Recently, Lundberg et al. (13) demonstrated that performing aerobic training before resistance training provided a greater hypertrophic response than resistance training alone. Elsewhere, Lundberg et al. (14) reported that performing concurrent aerobic plus re-

sistance produced greater increase in muscle size than resistance training in their study population. In another study, Cadore et al. (15) illustrated that exercise order had no influence on the peak oxygen uptake, while it exerted an impact on muscle quality as evaluated by the quotient between maximal dynamic strength (1-RM test) of the knee extensors and the quadriceps femoris muscle thickness in their elderly male subjects. Fleck et al. (16) remarked that 14 weeks of concurrent training, in which resistance training was always performed first in all the training sessions, led to significant strength gains (1 RM) in their middle-aged female subjects. The investigators also illustrated that VO_2 max improved until weeks 7 and 14. In another study, Ho et al. (17) demonstrated that in a 12-week concurrent training program with aerobic + resistance order for 5 days/week, the body weight and body mass index (BMI) in the concurrent training group were significantly lower than those in the control and resistance groups. The authors also observed a significant increase in VO_2 max in the concurrent training group.

In a 12-week low-frequency concurrent exercise program, Chtara et al. (18) investigated the influence of manipulating the order of resistance and endurance training on the pattern of the adaptation of physiological functions and revealed that for all the effect of endurance + resistance and resistance + endurance training on maximal muscular strength, strength endurance, and explosive strength, there were no differences between the groups with different sequence orders. Gravelle et al. (19) illustrated that performing endurance training prior to strength training when compared with the inverse order led to greater gains in endurance capacity in their young male subjects. However, greater VO_2 max increases were shown in the performing strength prior to endurance training. Recently, Cadore et al. (20) showed that resistance training, followed by endurance training, resulted in greater lower-body strength as well as greater changes in the neuromuscular economy (rectus femoris) in their elderly subjects.

Finally, the compatibility of concurrent training is not independent of the sequence order in which it is carried out. For some time, we have been interested in finding out how much endurance and resistance training and in what order would prove most beneficial for acquiring health-related physical fitness in elderly people. To the best of our knowledge, there are no systemic published scientific studies examining the effects of the sequence order of concurrent exercise on maximal strength (1-RM), aerobic capacity, and body composition in older women.

3. Patients and Methods

3.1. Subjects

Forty-eight aged healthy women (age = 65-75 years old) were recruited by referring to the retirement center. The

participants were required to be sedentary. Sedentary was defined as having exercised fewer than 20 minutes a week over the previous 6 months. The exclusion criteria included the presence of known significant neurological disorders (such as multiple sclerosis, cerebrovascular diseases, and gait disorders), definite cognitive impairment, psychiatric disease, heart failure, orthopedic or rheumatologic disorders, unstable cardiovascular system, metabolic diseases, taking any medication, chronic diseases, limited functional mobility, and orthopedic limitation hampering participation in an exercise program or interfering with laboratory test results.

The participants were familiarized with the study procedures and were informed about the possible risks and benefits involved in this study both verbally and in writing. All the subjects signed an informed consent for the protection of human subjects and were given reassurances as regards the strict confidentiality of their data. The subjects thereafter filled a medical history questionnaire. After baseline assessments, the participants were assigned to control (N = 16), resistance after aerobic training (E + S, N = 9), resistance prior to aerobic training (S + E, N = 10), and interval resistance-endurance (ACT, N = 12) groups randomly. Eight participants withdrew from the experimental groups on grounds of health problems.

3.2. Anthropometric Measures

The body fat percentage was calculated from the value of 3-site skin fold test (triceps, thigh, and suprailiac), measured with a Lafayette Skinfold Caliper II (21):

$$(1) \text{BF}\% = \frac{495}{(1.089733 - [0.0009245 \times s] + [0.0000025 \times s^2] - [0.0000979 \times \text{age}])} - 450$$

s = sum of 3 skin fold (mm), a = age (years)

The BMI was calculated for each subject using the formula:

$$\text{BMI} = \frac{\text{weight}(\text{kg})}{\text{height}^2(\text{m})}$$

Waist circumference was measured by using a flexible 2-meter standard tape measure at the maximal narrowing of the waist from the anterior view. The hip circumference was measured at the point of the maximal gluteal protuberance from the lateral view. The waist/hip ratio was calculated through dividing the waist circumference by the hip circumference. A modified Bruce protocol treadmill test, beginning with a lower workload, was employed to measure the aerobic capacity of the subjects. The modified protocol test is also a multi-stage test. The initial speed of the treadmill is set at 2.74 km/h and the inclination at 0%. The second and third stages have the same speed, but the gradient is increased by 5%. In the second stage, the inclination is increased to 5% but the speed of the treadmill remains at 2.74 km/h. In the third

stage, the speed of the treadmill is set at 1.7 mph and inclination at 10% (22). The 1-RM leg press test (23) was used to measure the lower-limb strength capabilities, and upper-limb strength was measured using the 1-RM bench press test (24).

3.3. Exercise Training Protocols

After the preliminary tests, exercise intervention constituted 8 weeks of combined (resistance + endurance) training (25). The experimental groups underwent training 3 times per week. Each session consisted of 10 minutes of general warm-up, 50 minutes of exercise training, and 10 minutes of cool-down. All the participants performed a familiarization session so as to become au fait with the training procedures, intensity, and equipment. The training program for the strength-endurance (S + E) and endurance-strength (E + S) groups was similar with a different order. Sixteen minutes of endurance training was performed at 45% Vo_2max on an ergometer for the first 2 weeks and continued for 30 minutes until the end of the 8th week. Two minutes after the endurance training, the resistance training was performed as follows: bench press; leg press; bent over lateral pull down; bilateral biceps curl; and bilateral triceps push down. The resistance training was performed at 40% of 1-RM for the first week and increased to 75% of 1-RM until the end of the 8th week. The ACT protocol was commenced with 5 minutes of warm-up on the ergometer, followed by one-third of the time duration of the endurance exercise in E + S alternated with one-third of the volume of resistance training in the E+S training group (26, 27).

3.4. Statistical Analyses

All the values are represented as mean \pm standard deviation (SD). The normality of distribution was assessed with the Kolmogorov-Smirnov test. The data were analyzed using the dependent T test to compare the pre-test and post-test in each group. A one-way analysis of variance (ANOVA) test was utilized to compare the amount of changes in the experimental and control training groups after 8 weeks. When a significant P value was achieved, the Fisher Least Significant Difference (LSD) test was used to find the differences between the various groups.

4. Results

The results were based on the observations of 16 people in the control (age = 68.11 ± 4.25 years), 9 people in the E + S (age = 67.11 ± 3.48 years), 10 people in the S + E (age = 68.10 ± 5.56 years), and 12 people in the ACT (age = 69.58 ± 5.29 years) groups, who completed the study. The results after 8 weeks of combined training are presented in Table 1.

The data showed that all the experimental groups

experienced a significant decrease in the body mass following the exercise training intervention (E + S [P = 0.005], S + E [P = 0.003], and ACT [P = 0.000]), while the control group did not (P = 0.51). There was a significant between-group difference in terms of the body mass (P = 0.017). With respect to the results of the analysis of one-way variance and the LSD test, a significant difference was observed in the body mass between the four groups after applying exercise interventions; there were significant differences between the control and S + E groups (P = 0.02) and between the control and ACT groups (P = 0.03) after exercise.

Decreases in the BMI occurred in all groups (E + S [P = 0.005], S + E [P = 0.003], and ACT [P = 0.000]). The body fat percentage decreased in all the training groups (E + S [P = 0.000], S + E [P = 0.000], and ACT [P = 0.000]). There were significant between-group differences between the E + S and S + E groups and between the ACT and control groups in the body fat percentage (P = 0.023). The changes in the control group significantly differed from those in the S+E group (P = 0.02) during the first 8 weeks.

The waist circumference decreased from pre- to post-measurements in the E + S (P = 0.000), S + E (P = 0.008), and ACT (P = 0.003) groups. The change in the control group was not significant (P = 0.22). The body fat percentage decreased in all the intervention groups: (E + S [P = 0.000], S + E [P = 0.000], and ACT [P = 0.000]). There were no between-group differences regarding the body fat percentage (P = 0.08).

In the within-group analysis, the E + S (P = 0.17), S + E (P = 0.80), and ACT (P = 0.32) groups experienced no change in the waist-to-hip ratio during the 8-week concurrent training period.

All the training protocols conferred an increase in Vo_2max significantly in all the training groups (E + S [P = 0.003], S + E [P = 0.003], and ACT [P = 0.024]). The results of the one-way ANOVA and LSD post-hoc tests showed that Vo_2max was significantly different after the training programs (P = 0.029). After 8 weeks of concurrent training programs, Vo_2max was also significantly higher in the S + E group than in the control group (P = 0.01).

Apart from the S + E group (P = 0.06), the other groups experienced an increase in the upper-limb 1-RM significantly (E + S [P = 0.005] and ACT [P = 0.025]). No significant between-group differences were noted concerning the upper-limb strength (P = 0.07).

The lower-body strength increased in all the training groups. Dynamic leg press increased in the E + S (P = 0.002), S + E (P = 0.000), and ACT (P = 0.014) groups during the 8-week training period. A between-group difference was seen in the lower-body strength (P = 0.000), where the S + E group exhibited a significantly more increased force production than the control (P = 0.000) and ACT (P = 0.01) groups. After an 8-week concurrent training program, the lower-body strength was also significantly higher in the E + S group than in the control group (P = 0.006).

Table 1. Comparison of Changes in the Measured Variables before and after 8 Weeks of Exercise Interventions ^{a,b}

Groups	Mean \pm SD		P Value Within Group	P Value Between Groups
	Pre-test	Post-test		
Body mass, kg				0.017
E + S	74.66 \pm 4.68	72.77 \pm 4.67	0.005	
S + E	70.80 \pm 3.90	68.60 \pm 3.86	0.003	
ACT	66.41 \pm 2.69	64.41 \pm 2.44	0.000	
Con	76.88 \pm 3.78	76.66 \pm 4.05	0.51	
E + S	29.89 \pm 1.20	29.12 \pm 1.21	0.005	
BMI, kg/m²				0.023 ^c
S + E	29.23 \pm 1.71	28.30 \pm 1.56	0.003	
ACT	27.57 \pm 0.92	26.76 \pm 0.86	0.000	
Con	31.75 \pm 0.91	31.63 \pm 1.01	0.42	
% Body fat				0.08
E + S	30.49 \pm 1.0	26.90 \pm 1.47	0.000	
S + E	31.66 \pm 1.35	27.77 \pm 1.30	0.000	
ACT	30.65 \pm 1.05	27.88 \pm 0.95	0.000	
Con	28.50 \pm 0.92	27.50 \pm 1.0	0.08	
WC (cm)				0.006 ^d
E + S	98.33 \pm 3.08	93.44 \pm 3.03	0.000	
S + E	95.40 \pm 3.08	92.50 \pm 3.18	0.008	
ACT	93.50 \pm 2.64	90.25 \pm 3.08	0.003	
Con	97.44 \pm 4.36	97.00 \pm 4.53	0.22	
(WHR)				0.55
E + S	0.91 \pm 0.01	0.89 \pm 0.01	0.17	
S + E	0.88 \pm 0.01	0.88 \pm 0.01	0.80	
ACT	0.92 \pm 0.01	0.91 \pm 0.02	0.32	
Con	0.88 \pm 0.02	0.88 \pm 0.02	0.83	
Vo₂max, mL/kg/min				0.029 ^c
E + S	29.07 \pm 1.88	34.01 \pm 2.05	0.003	
S + E	24.60 \pm 1.35	31.81 \pm 1.05	0.003	
ACT	23.70 \pm 1.78	27.93 \pm 2.18	0.024	
Con	24.77 \pm 3.03	24.25 \pm 3.01	0.43	
Upper-body maximal dynamic strength test (1 RM)				0.07
E + S	17.11 \pm 3.46	25.66 \pm 3.05	0.005	
S + E	28.60 \pm 1.88	30.30 \pm 2.22	0.06	
ACT	18.58 \pm 2.32	25.08 \pm 3.42	0.025	
Con	18.33 \pm 3.22	18.88 \pm 3.09	0.34	
Lower-body maximal dynamic strength test (1 RM)				0.000 ^d
E + S	29.66 \pm 5.37	67.22 \pm 7.73	0.002	
S + E	26.40 \pm 3.39	68.50 \pm 7.87	0.000	
ACT	30.25 \pm 5.25	51.91 \pm 8.78	0.014	
Con	32.77 \pm 4.57	34.66 \pm 4.25	0.18	

^a Abbreviations: ACT, Alternative resistance-endurance; Con group, Subjects who did not participate in exercise training; BMI, Body mass index; E+S, Resistance after aerobic training; S+E, Resistance prior to aerobic training; WC, Waist circumference; WHR, Waist-to-hip ratio.

^b Control Group: N = 16; E+S: N = 9; S+E: N = 10; ACT: N = 12.

^c Significant difference between the two groups ($P < 0.05$).

^d Significant difference between the two groups ($P < 0.01$).

5. Discussion

There has been a paucity of research probing into the effect of the sequence order of combined training (resistance and endurance) on strength, aerobic capacity, and body composition in older women. To our knowledge, the present study is the first to examine the influence of manipulating the sequence order of concurrent training on adaptations of strength, Vo_2 max, and body composition in aged women. Few studies have investigated the effect of concurrent resistance and endurance training in elderly populations (28-31).

The findings of the current study are somewhat limited due to its small sample size. All the experimental groups showed decreases in the body mass, BMI, body fat percentage, waist circumference, and waist-to-hip ratio. It seems that through its involvement of strength and endurance, this type of training provided a greater stimulus and reduced the body fat percentage and body mass in our aged female subjects. The literature provides evidence of a relationship between energy expenditure from physical exercise training and lean body mass (32). Research shows that concurrent training is more efficient in terms of reducing the body fat percentage when compared to resistance and endurance training alone (17, 33, 34). Similar results, despite differences in subject populations, were also cited by Antunes et al. (32), who found that combined aerobic and resistance exercise training was effective for the burning of the body fat percentage in their obese adolescent subjects. Likewise, Ghahramanloo et al. (35) showed that 8 weeks of combined training improved the body fat percentage of the young men in their study. The results of the present study support the findings of some previous studies reporting a reduction in the body fat percentage and body weight (36).

Our data showed non-significant between-experimental group differences (order effect) in the body mass, BMI, waist circumference, and waist-to-hip ratio following 8 weeks of combined training. Chiming in with our findings, Ghahramanloo et al. (35) reported no differences in terms of impact on oxygen consumption when performing concurrent training in different sequences. Similarly, Cadore et al. (15) showed that the sequence order of combined strength and endurance training had no influence on the body fat percentage of the aged men in their study.

Our results support the findings of a study by Kuusmaa et al. (27), who demonstrated that, independent of the order of training, 24 weeks of concurrent training led to a significant decrease in the total body mass and body fat percentage of their study population. Furthermore, irrespective of the sequence order, no differences were found in body composition improvements between the groups. It seems that longer training courses may have caused the greater differences between the groups with different sequence orders in our study.

In our study, concurrent training, independent of sequence order, enhanced aerobic capacity in the experi-

mental groups by comparison with the control group. Concordant with our findings, some investigators have stated that combining endurance and strength training in the same training session can improve aerobic capacity more effectively than either one alone (17, 37-39). Concurrent combined training can improve Vo_2 max through an increase in the activities of oxidation enzymes, muscle size (40), and quantity and volume of mitochondria (41).

Few studies have shown the influence of the sequence order of endurance and resistance training on Vo_2 max. Our study is inconsistent with some previous research reporting that exercise sequence might be an important variable in the adaptations to a concurrent training program. Chtara et al. (18) illustrated that aerobic capacity improvement was greater in their young male subjects when strength training was performed before endurance. In another study, Chtara et al. (38) showed that circuit resistance training immediately after endurance training (E + S) produced greater improvement in the endurance capacity and aerobic capacity than the reverse order (S + E). It should, however, be noted that there were no significant differences between the groups in training-induced adaptations to aerobic capacity in the present study.

It seems that combining resistance and endurance training did not interfere with the development of aerobic capacity in our aged female subjects. Similar results have been found in more recent studies. Schumann et al. (42) illustrated that there was no between-group difference between their study groups with different sequence training in aerobic capacity. Our findings are consistent with those in a study by Cadore et al. (20), who found no differences in VO_2 max between S + E and E + S in their elderly male subjects following 12 weeks of concurrent training.

In the present study, an 8-week concurrent training program improved lower-body dynamic 1-RM in our E + S and S + E groups, there being no statistically significant differences between the groups. Likewise, other researchers have found that the sequence order of concurrent training does not have an effect on the lower-body strength gains (18, 19, 43). Our findings are consistent with those of Cadore et al. (15), who illustrated strength gains independent of the order of concurrent training. The authors found that greater gains occurred when resistance training was performed prior to endurance training. It seems that different intensity, volume, gender, and age can explain different adaptations. Similar to the present study, other researchers have also verified the lower-body strength gains following concurrent training (18, 19, 43). There were no interferences between concurrent resistance and endurance exercise in Vo_2 max, upper-body, and lower-body maximal dynamic strength. Recently, the results of a meta-analysis suggested that whereas there was no interference effect in muscular hypertrophy and strength, power was more sen-

sitive to the interference effect than either strength or hypertrophy (9). Furthermore, in a recent study, Schumann et al. (44) showed that there were significant gains in 1-RM strength following 24 weeks of concurrent training independent of the loading order. Similar results for the effect of order training on chronic adaptation have been found in the youth (45) and elderly women (33). On the other hand, some studies have shown interference effect in concurrent training. Chtara et al. (38) reported that after 12 weeks of concurrent training with different loading protocols, the improvements were significantly higher for the E+S group than for the S + E group concerning the 4-km test and $\text{Vo}_{2\text{max}}$.

It can, thus, be concluded that, independent of the order of training, an 8-week concurrent training program resulted in positive changes in the body composition and physical fitness of our aged female subjects. This study, however, did not reveal whether the order of training can affect strength, $\text{Vo}_{2\text{max}}$, and body composition in elderly women. Our study was limited due to its small sample size. More research is needed to strengthen the results of this study with a larger population.

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