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Intervention Study on the Exercise Order of Combined Aerobic & Resistance Training in the Elderly

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Abstract: When combined aerobic and resistance training into the same session is performed, the exercise order may lead to different effects with respect to factors such as muscle strength, hormone responses, energy metabolism, and vascular function. The purpose of this study was to examine the effects of exercise order of combined aerobic and resistance training into the same session on body composition, muscle strength and arterial stiffness in the elderly. Thirty-one elderly subjects (70.5 ± 3.5 years) were randomly assigned to 3 groups; AR: aerobic before resistance training, RA: resistance before aerobic training and CON: no training. Subjects trained 2 times per week for 10 weeks. Resistance training consisted of 3 sets of 8-12 repetitions for 5 different exercises, 70%-80% of one repetition maximum (1RM). Aerobic exercise consisted of cycling at 60% of heart rate reserve (HRR). Significant interaction effects were observed in body fat percentage ($P < 0.01$) and 1RM ($P < 0.01$). However, no significant differences were observed between AR and RA. In contrast, pulse wave velocity (PWV) significantly reduced in the RA (8.8 ± 2.1 m/s to 7.6 ± 1.9 m/s, $P < 0.05$), while PWV increased in the AR (7.9 ± 2.8 m/s to 10.0 ± 2.6 m/s, $P < 0.01$), and there was significant difference between AR and RA ($P < 0.05$). In conclusion, no effects of the exercise order were observed in body composition and muscle strength. However, aerobic exercise after resistance training reduced arterial stiffness and difference of exercise order was observed.

Key words: Combined training, exercise order, arterial stiffness, muscle strength, the elderly.

1. Introduction

Aging is associated with declines in physical capabilities [1, 2]. In particular, decreases in muscle mass, muscle strength, and bone density cause difficulties in daily physical activities [3-5], leading to the decline of quality of life [6]. Also, arteries lose their compliance with advancing age, independent of atherosclerosis, hypertension and other disease states [7]. This age-related reduction in central arterial compliance is associated with an increased risk for coronary heart disease [8], hypertension [9], left ventricular hypertrophy, diastolic dysfunction [10, 11] and all-cause mortality [12].

Exercise is believed to be the most effective of all interventions proposed to improve physical healthy and quality of life for the elderly populations [13]. There are two major types of exercise, aerobic and resistance exercise training. Aerobic exercise minimizes cardiovascular disease risk factors and improves arterial compliance [14-16]. Resistance training increases muscle strength and mass, and also helps to maintain bone mineral density, which decreases with age [17, 18]. Therefore, a well-designed combination of these two training modes could minimize the negative effects of aging more extensively than either alone [19].

Several studies reported that combined aerobic and resistance training effectively reduce body mass and body fat mass, as well as increase muscle strength in middle-age and older people [20-23]. Sillanpää et al. [22] showed that combined training reduced percent body fat mass and increased lean body mass in healthy middle-age and older women. Karavirta et al. [23] reported that combined training increased muscle strength in 40-67-year-old men. Regarding vascular

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function, Figueroa et al. [24] reported that a 12-week moderate-intensity combined training improved arterial stiffness, hemodynamics in postmenopausal women. Katie et al. [25] showed that combined training reduced systolic blood pressure and improved vascular properties. However, these studies have not concerned with the exercise order in which aerobic and resistance exercises should be performed.

Recently, some researchers focused on alternating the order of aerobic and resistance exercises. Goto et al. [26] reported that the growth hormone secretion after a single bout of resistance exercise was attenuated by prior aerobic exercise. Okamoto et al. [27] assessed the effects of exercise order of aerobic and resistance training performed by 33 healthy young men and women for 8 weeks. They suggested that performing aerobic exercise after resistance training improved arterial stiffness. Moreover, Cadore et al. [28] demonstrated that performing resistance training beforehand resulted in greater increases in muscle strength based on a study involving elderly male subjects who participated in progressively-intensifying combined training. These studies have suggested that the order of combined aerobic and resistance exercise may lead to differences in their effects with respect to factors such as hormone secretion, muscle strength, and vascular function. Few studies have been conducted on the effects of the order of combined aerobic and resistance training on arterial stiffness in the elderly.

Therefore, the purpose of this study was to examine the effects of exercise order of combined aerobic and resistance training into the same session on body composition, muscle strength and arterial stiffness in healthy elderly individuals.

2. Study Methods

2.1 Subjects

Fig. 1 shows a flow chart of the study design. This study enrolled 31 elderly individuals (10 males, 21 females, aged 70.5 ± 3.5 years, mean ± SD) living in the vicinity of Doshisha University. The subjects who fulfilled the inclusion criteria were randomly assigned to 3 groups who performed aerobic exercise before resistance training (AR, $n = 10$; 3 males, 7 females),

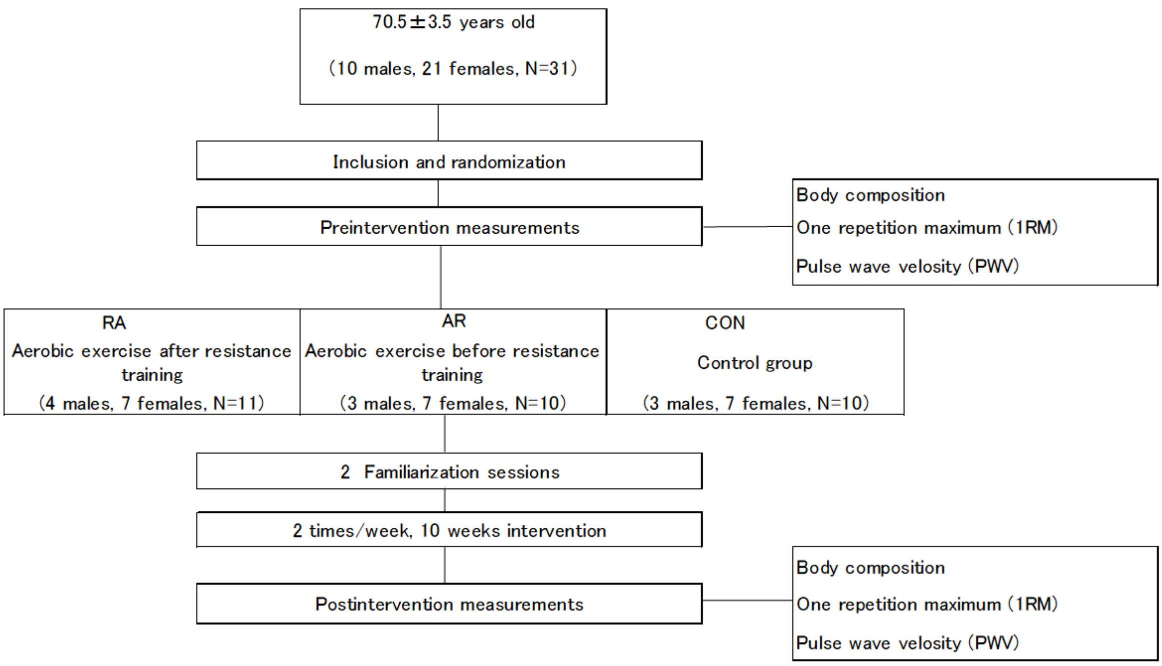

Fig. 1 Flow of subjects through the study.

performed resistance training before aerobic exercise (RA, n = 11; 4 males, 7 females), or nonintervention control conditions (CON, n = 10; 3 males, 7 females). All subjects were carefully informed about the possible risks and benefits of the study and signed the informed consent document prior to participation. All subjects were instructed not to change their eating habits. This study was approved by the Ethics Committee of Doshisha University; the Committee was responsible for the evaluation of research using human subjects (approval date/number: April 17, 2014/Nº. 1380).

2.2 Exclusion Criteria

Subjects with unstable cardiovascular condition, musculoskeletal disease, diabetes, or any other medical contraindication to perform the requested aerobic and resistance training were excluded.

2.3 Training Methods

Training activities consisted of a combination of cycling and weight machine training, and were performed twice a week over a period of 10 weeks. The subjects in the AR group performed resistance training for 20 minutes following the aerobic exercise, while the subjects in the RA group performed the resistance training prior to the aerobic exercise. Training activities were performed under the supervision of experienced instructors. The subjects in the CON group were instructed not to alter their habitual physical activities during the study intervention period. Before the training intervention, the subjects in the AR and RA groups participated in two familiarization sessions to be used the exercise machines and training methods. The subjects performed warm-up and cool-down exercises before and after the main training activities.

2.3.1 Aerobic Exercise

Aerobic exercise was performed by a cycle ergometer (manufacturer: Life Fitness). The subjects pedaled at a speed of approximately 50-55 rpm at an intensity of 60% of their heart rate reserve (HRR) and controlled by heart rate monitoring. During the exercise, subjects verbally confirmed their condition to ensure that their rating of perceived exertion (RPE) was maintained at a moderate level of “somewhat hard” (12-14). Aerobic exercise was performed for 20 minutes either before or after resistance training.

2.3.2 Resistance Training

Resistance training consisted of 5 different exercises (leg curl, leg press, chest press, seated row, and shoulder press) using weight machines (manufacturer: Life Fitness). The individual loads of resistance training were determined based on the strength tests performed at baseline and in the middle of the training period. Exercises were performed at 70%-80% of 1RM, 3 sets of 8-12 repetitions each (with 1-minute rests between sets). When the subjects could perform more than 12 repetitions with the target weight, the training road was progressively increased. The subjects were instructed to refrain from holding their breath, avoid straining, apply consistent movement speed, and perform the study exercises carefully.

2.4 Measurements

2.4.1 Body Composition

Body composition included height, weight, body fat percentage, and waist circumference. The subjects’ height was measured with a precision of 0.1 cm. The subjects’ weight and body fat percentage were measured using an electronic body fat scale (TBF-305, manufacturer: Tanita). The subjects’ body mass index (BMI) was obtained by dividing the weight (kg) by the square of the height (m). Waist circumference was defined as the abdominal circumference at the navel, and was measured using a rigid tape with a precision of 0.1 cm. Lean body mass was obtained through the formula [weight (kg) – (weight (kg) × body fat percentage (%))].

2.4.2 1RM strength

Muscle strength was measured using the one repetition maximum (1RM). Subjects performed five types of exercises (leg curl, leg press, chest press, seated row, and shoulder press). The test protocol recommended Kraemer and Fry [29] was adopted as follows: (1) a warm-up involved 5-10 repetitions at 40-60% of the estimated 1RM, (2) 1 min to rest with light stretching followed with 3-5 repetitions at 60%-80% of the estimated 1RM, (3) three to five attempts to reach the 1RM with 5 min rest interval between each new lift. The maximum weight that successfully lifted was recorded.

2.4.3 Pulse wave velocity (PWV)

PWV is an independent predictor of cardiovascular events in patient with established cardiovascular disease as well as in healthy adults [30]. Carotid-femoral pulse wave velocity (cfPWV) was measured using an automatic oscillometric device (VaSera: Fukuda Denshi Co., Ltd.). As PWV is affected by blood pressure and heart rate, the subjects were instructed to lie in a supine position on a bed and maintain a resting state for at least 10 minutes, after which a blood pressure cuff around right arm and a cardiac sonography microphone on the left parasternal border of the fourth internal space were affixed. Next, electrocardiogram electrodes were placed on both femoral and carotid artery. The subjects were appropriately informed about all measurement methods prior to participating in this study.

A pulse wave is the speed at which the electrical wave resulting from blood flow in and out of the heart is propagated to the arterial periphery. PWV is calculated based on the difference in pulse wave rise time between the two measurement sites, and on the distance between the measurement sites, which is believed to reflect arterial stiffness [31]. Thus, cfPWV is calculated by dividing the artery segment length (L) by the time difference between pulse wave rise in the carotid artery and in the femoral artery (Tcf) (cfPWV = L/Tcf).

2.5 Statistical Analysis

The data obtained in this study are given as mean values ± SD. Comparison of differences in baseline measurement values between the study groups was conducted using a one-way analysis of variance (ANOVA). In addition, pre- and post-intervention group comparisons were analyzed using a two-way ANOVA with repeated measurements of 2 factors (group × time). When significant interactions were observed, these interactions were subjected to post-testing using the Tukey method. Pre- and post-intervention comparisons of intragroup differences were conducted using a paired t-test. Statistical analyses were conducted using SPSS Statistics v. 22.0, with a significance level of $P < 0.05$.

3. Results

At baseline, there were no differences between the groups on body composition, 1RM strength and carotid-femoral pulse wave velocity. No training-related injuries occurred to any of the subjects in the AR or RA groups, and the training period was completed with no subject dropouts.

3.1 Body Composition

The results of the body composition taken for the 3 study groups before and after 10 weeks intervention are summarized in Table 1. A significant group by time interaction effect was observed in body fat percentage ($P < 0.01$). There was no significant interaction effect in height, weight, BMI, lean body mass, or waist circumference. After 10 weeks training, body fat percentage and waist circumference significantly decreased in the RA group. In the AR group, a significant decrease of waist circumference was seen. No significant changes were observed in the CON group.

3.2 1RM strength

The results of the 1RM strength taken with respect to the 5 exercises for the 3 study groups before and after 10 weeks intervention are displayed in Table 2. Significant group by time interaction effects were observed in all exercises ($P < 0.01$). In the AR and RA groups, all 1RM strength significantly increased after training ($P < 0.01$; AR and RA, respectively). There

Table 1 Changes in physical characteristics of subjects before and after 10-week intervention.

		RA (*n* = 11)	AR (*n* = 10)	CON (*n* = 10)	interaction (group × time)
Age (yrs)		70.8 ± 3.3	70.2 ± 3.6	71.6 ± 3.7	
Height (cm)	Pre	155.8 ± 7.4	156.7 ± 9.0	157.6 ± 6.9	*P* = 0.726
	Post	155.9 ± 7.3	156.7 ± 9.2	157.7 ± 6.9	
Body weight (kg)	Pre	54.7 ± 8.0	57.8 ± 8.0	57.3 ± 9.5	*P* = 0.295
	Post	54.0 ± 7.9	57.5 ± 7.8	57.1 ± 9.5	
BMI (kg/m^2)	Pre	22.4 ± 2.2	23.5 ± 2.2	23.0 ± 2.8	*P* = 0.641
	Post	22.2 ± 2.3	23.4 ± 2.0	22.8 ± 2.8	
Lean body mass (kg)	Pre	39.3 ± 6.8	40.8 ± 7.6	40.2 ± 6.6	*P* = 0.126
	Post	39.7 ± 6.7	41.0 ± 7.6	40.2 ± 6.7	
Body fat (%)	Pre	28.2 ± 5.5	29.1 ± 6.8	29.5 ± 5.1	*P* = 0.004
	Post	26.6 ± 5.6**	29.0 ± 6.0	29.5 ± 5.0	
Waist circumference (cm)	Pre	80.9 ± 6.9	83.6 ± 7.9	84.4 ± 8.6	*P* = 0.216
	Post	77.7 ± 5.9**	81.4 ± 6.3*	83.1 ± 8.9	

Data at pre and post are presented as mean ± standard deviation.

$^{*}P < 0.05$ vs. Pre; $^{**}P < 0.01$ vs. Pre.

RA: resistance training before aerobic exercise, AR: aerobic exercise before resistance training, CON: control, BMI: body mass index.

Table 2 Changes in physical fitness before and after 10-week intervention.

		RA (*n* = 11)	AR (*n* = 10)	CON (*n* = 10)	interaction (group × time)
Grip strength (kg) (Right)	Pre	27.3 ± 6.3	25.2 ± 9.0	25.2 ± 4.4	*P* = 0.541
	Post	28.7 ± 6.0	27.0 ± 6.8	26.0 ± 5.0	
Grip strength (kg) (Left)	Pre	26.3 ± 7.0	24.2 ± 9.6	23.1 ± 5.4	*P* = 0.313
	Post	26.9 ± 5.9	26.0 ± 8.6	24.2 ± 5.1	
10 m walk (sec)	Pre	3.7 ± 0.6	3.9 ± 0.7	3.9 ± 0.6	*P* = 0.221
	Post	3.6 ± 0.5	3.7 ± 0.6	4.1 ± 0.8	
Timed up and go (sec)	Pre	4.8 ± 0.5	5.0 ± 0.4	5.2 ± 0.7	*P* = 0.640
	Post	4.6 ± 0.4	4.9 ± 0.5	5.2 ± 0.8	
One-leg balance with eyes open (sec)	Pre	112.0 ±60.8	91.2 ± 58.3	86.8 ± 63.4	*P* = 0.777
	Post	125.4 ±49.0	109.7 ±57.0	91.0 ± 64.7	
Functional reach (cm)	Pre	31.2 ± 5.3	30.9 ± 6.4	31.6 ± 6.9	*P* = 0.219
	Post	35.1 ± 5.6*	35.0 ± 3.8*	32.7 ± 7.1	
Sit and reach (cm)	Pre	32.3 ± 4.5	30.3 ± 10.2	38.1 ± 11.2	*P* = 0.324
	Post	35.0 ± 6.1	34.8 ± 12.1	39.7 ± 12.5	

Data at pre and post are presented as mean ± standard deviation.

$^{*}P < 0.05$ vs. Pre; $^{**}P < 0.01$ vs. Pre.

RA: resistance training before aerobic exercise, AR: aerobic exercise before resistance training, CON: control.

was no significant difference between the two training groups. No significant changes were observed in the CON group.

3.3 Carotid-femoral Pulse Wave Velocity (cfPWV)

The results of cfPWV taken for the 3 study groups before and after 10 weeks intervention are displayed in Fig. 2. There was a significant group by time interaction effect in cfPWV ($P < 0.01$), and a significant difference between the RA and AR groups was observed in the results of subsequent tests ($P < 0.05$). Following the intervention, cfPWV decreased significantly in the RA group (8.8 ± 2.1 m/s to 7.6 ± 1.9 m/s, $P < 0.05$), but it increased significantly in the AR group (7.9 ± 2.8 m/s to 10.0 ± 2.6 m/s, $P < 0.01$). No significant change in cfPWV

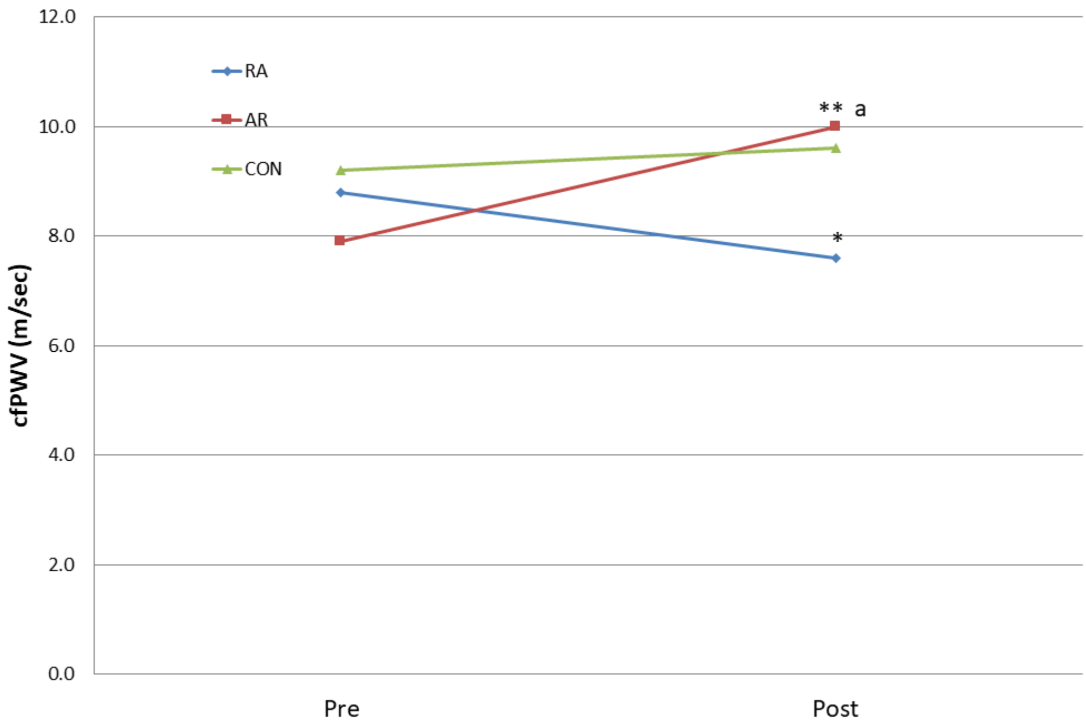

Fig. 2 Changes in cfPWV before and after 10-week intervention. RA: resistance training before aerobic exercise; AR: aerobic exercise before resistance training; CON: control, *P < 0.05 vs. Pre; **P < 0.01 vs. Pre; ^{a}P < 0.05 vs. AR.

was observed in the CON group.

4. Discussion

This study was designed to examine the effects of exercise order of combined aerobic and moderate- to high-intensity resistance training on body composition, muscle strength and arterial stiffness in healthy elderly individuals for 10 weeks. The major finding of this study was that RA was more effective than AR for improving arterial stiffness in the elderly. Furthermore, both training regimens were effective in decreasing waist circumference and improving muscle strength regardless of the exercise order. The results of the present study suggest that performing aerobic exercise after resistance training is more effective for improving arterial stiffness in the elderly.

In a previous study, Okamoto et al. [27] reported that performing aerobic exercise after resistance training improved arterial stiffness in the young men and women. Moreover, Kawano et al. [32] reported that aerobic exercise for 30 minutes after resistance training prevents carotid arterial stiffening caused by resistance training in young healthy men. These reports suggest that performing aerobic exercise after resistance training may suppress the sclerosis of major arteries caused by resistance training in young adults. The results of the present study are in line with those of previous studies, and suggest that performing aerobic exercise after resistance training improved arterial stiffness in the elderly as well.

Resistance training has become an integral component in the health program that can prevent or treat age-related diseases, which is such as osteoporosis, sarcopenia, falling and functional disability [17, 18]. However, some studies suggest that high-intensity resistance training is associated with reduced major artery compliance and increased arterial stiffness [33-35]. On the other hand, current evidence suggests that low- to moderate-intensity resistance training does not effect on arterial stiffening [36-38]. Interestingly, resistance training results in decreased blood pressure as a training adaptation despite increases in blood pressure during exercise [39]. These suggest that the resistance training-related factors contributing to arterial stiffness are complex and the physiological mechanism underlying the effects of resistance training on vascular function is not yet well-understood. Therefore, further studies should focus on resistance training on vascular hemodynamic.

In contrast to resistance training, regular aerobic exercise such as walking, jogging or cycling is known to be efficacious for preventing and reversing arterial stiffening in healthy adults [13-15, 26]. Arterial stiffness increases with advancing age [7], and is as an emerging biomarker in the assessment of vascular health [40]. Large arterial stiffness is associated with an increased risk for coronary heart disease [8], hypertension [9], left ventricular hypertrophy, diastolic dysfunction [10, 11] and all-cause mortality [12]. However, although aerobic exercise effectively decreases arterial stiffness, it does not induce gains in strength and lean body mass, as well as increases in bone density compared with resistance training [4, 41]. In contrast, resistance training increases [33-35] or does not alter [36-38] arterial stiffness compared with aerobic exercise. Therefore, prescribing aerobic and resistance training in combination is proposed as an efficacious strategy to improve cardiovascular as well as musculoskeletal functions in the elderly. Previous study showed that moderate-intensity combined training improved arterial stiffness and greater muscle strength in postmenopausal women [24]. The present study, despite higher intensity combined training, results in decreased arterial stiffness by performing aerobic exercise after resistance training. We suppose that training intensity or exercise order of combine training is associated with improvement, or no deterioration, in arterial stiffness. Further studies are required to investigate combinations of aerobic exercise with modes of resistance exercise that have beneficial effects on vascular functions.

We found that combined aerobic and resistance training improved muscle strength regardless of the exercise order. Previous study reported that performing aerobic exercise after resistance training resulted in greater increases in muscle strength based on a study involving elderly male subjects who participated in progressively-intensifying combined training [28]. The present study involved 2 times a week for 10 weeks training and included both sexes, while the above-mentioned study focused on 3 times per week for 12 weeks and elderly male subjects only. As such, there it is a possible that differences in training results could arise from differences in subject sex, duration, volume and frequency of training. Some studies have indicated potential gender differences in the muscle mass responses to resistance training [42, 43]. However, few studies examine gender differences of combined training on arterial stiffness. Thus, it is desirable to conduct further research on the topic controlling for conditions.

Limitations of this study are as follows: first, this study assessed a small subject sample, and men and women were grouped together. Because of this, this study was unable to determine the presence of sex-based differences; second, differences in the intensity of resistance training may lead to different results; and third, this study did not consider the physiological mechanisms underlying vascular endothelial functions. As such, future studies should investigate the reproducibility of these results and assess comparatively the impact of the intensity of resistance training activities, and evaluate the physiological mechanisms underlying vascular endothelial functions in the context of combined training programs for groups of subjects of each sex.

5. Conclusion

Exercise training is an important strategy to maintain or improve physical health and quality of life in the elderly populations. Aerobic exercise is effective in minimizing various risk factors associated with cardiovascular diseases and reducing arterial stiffness. Resistance training can improve muscle strength and muscle mass, and prevent or treat age-related diseases, which is such as osteoporosis, sarcopenia, and functional disability. Therefore, a combination of these two training modes could minimize the negative effects of aging and maintain quality of life in the elderly more extensively than either alone. Based on our results, no effects of exercise order were observed in body composition and muscle strength. However, aerobic exercise after resistance training reduced arterial stiffness, and a significant difference of exercise order was observed. Therefore, when combined aerobic and moderate- to high-intensity resistance training is performed into the same session, performing aerobic exercise after resistance training may prevent arterial stiffness. Further studies investigating the volume, frequency and intensity of training, and subject sex are needed.

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