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Effect of exercise order of combined aerobic and resistance training on arterial stiffness in older men☆

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ABSTRACT

Arterial stiffness increases with advancing age, and is as an emerging biomarker in the assessment of vascular health. Some studies suggest that high-intensity resistance training increases arterial stiffness, but low- to moderate-intensity resistance training does not effect on arterial stiffening. Current evidence suggests that performing aerobic exercise after resistance training improved arterial stiffness in the young men and women. However, few studies have been conducted on the effects of the order of combined training on arterial stiffness in the elderly. 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 older men. Forty-five older men (aged 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 waist circumference ($P < 0.01$), grip strength ($P < 0.01$), 10-m walk speed ($P < 0.05$) and 1RM strength ($P < 0.01$). However, no significant differences were observed between AR and RA. In contrast, pulse wave velocity (PWV) significantly reduced in the RA (9.0 ± 1.6 m/s to 8.0 ± 1.6 m/s, $P < 0.05$), whereas, it did not change in the AR, and there was a significant group difference ($P < 0.05$). In conclusion, no effects of the exercise order were observed in body composition, physical fitness and muscle strength. However, aerobic exercise after high-intensity resistance training reduced arterial stiffness and difference of exercise order was observed. We suggest that the exercise order may favorably affect arterial stiffness when combined aerobic exercise and high-intensity resistance training is performed into the same session.

1. Introduction

Aging is associated with declines in physical capabilities (Fiatarone and Evans, 1993; Flegg and Lakatta, 1988). In particular, decreases in muscle mass, muscle strength, and bone density cause difficulties in daily physical activities (Wolfson et al., 1995; Walsh et al., 2006; Schrager et al., 2007), leading to the decline of quality of life (Theou et al., 2010). Also, arterial stiffness increases with advancing age (Vaiktevicius et al., 1993), and is an emerging biomarker in the assessment of vascular health (Laurent et al., 2012). This age-related reduction in central arterial compliance is associated with an increased risk for coronary heart disease (Alan et al., 2003), hypertension (Liao et al., 1999), left ventricular hypertrophy, diastolic dysfunction (Saba et al., 1993; Nichols et al., 1985)and all-cause mortality (Vlachopoulos et al., 2012). Exercise in older adults is one of the key components of a healthy lifestyle (Miszko et al., 2003). There are two major types of exercise, aerobic and resistance exercise training. Regular aerobic exercise training improves aerobic capacity (Coggan et al., 1992) and has favorable effects on cardiovascular risk factors and improves arterial compliance (Tanaka et al., 2000; Sugawara et al., 2009; Tanahashi et al., 2014). Resistance training improves muscle mass, strength and power, even when resistance training begins at an older age (Kryger and Andersen, 2007), and also helps to maintain bone mineral density, which decreases with age (Louise and Deepa, 2010; Montero-Fernandez and Serra-Rexach, 2013). Moreover, resistance training has been reported to enhance insulin sensitivity (Holton et al., 2004), and daily energy expenditure (Hunter et al., 2000). Thus, based on the specific effects of aerobic and resistance training, a combination of these two

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training modes could potentially minimize the negative effects of aging more extensively than either alone (Ferketich et al., 1998).

However, some studies suggest that high-intensity resistance training is associated with increased blood pressure during exercise (Pratley et al., 1994; MacDougall et al., 1985), reduced major artery compliance and increased arterial stiffness (Miyachi et al., 2004; Cortez-Cooper et al., 2005; Okamoto et al., 2006). Current evidence suggests that low- to moderate-intensity resistance training does not effect on arterial stiffening (Cortez-Cooper et al., 2008; Yoshizawa et al., 2009; Okamoto et al., 2011). Interestingly, resistance training results in decreased blood pressure as a training adaptation despite increases in blood pressure during exercise (Cornelissen et al., 2011). 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. On the other hand, regular aerobic exercise is known to be efficacious for preventing and reversing arterial stiffening in healthy adults (Tanaka et al., 2000; Sugawara et al., 2009). In a previous review, Higashi and Yoshizumi (2004) reported that beneficial effects of aerobic exercise, such as increased shear stress, reduced vasoconstrictors, and lowered blood pressure, may independently or interdependently contribute to improvement in endothelial function. Recently, several studies have reported that combined aerobic and resistance training effects on vascular function. Figueroa et al. (2011) reported that a 12-week moderate-intensity combined training improved arterial stiffness, hemodynamics in postmenopausal women. Katie et al. (2013) showed that combined training reduced systolic blood pressure and improved vascular properties. 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. However, most 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. Okamoto et al. (2007) reported that performing aerobic exercise after resistance training improved arterial stiffness in the young men and women. Kawano et al. (2006) reported that aerobic exercise for 30 min 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. Few studies have been conducted on the effects of the order of combined aerobic and resistance training on arterial stiffness in the elderly. We suppose the exercise order of combined training might affect arterial stiffness. To optimize the combined training prescription for older adults, the most effective combination of intensity, volume, as well as exercise order must be discussed. 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, physical fitness, muscle strength and arterial stiffness in healthy older men.

2. Methods

2.1. Participants

Community-dwelling men aged 60 and older were locally recruited through advertisements and oral communications for inclusion in a 10-week combined aerobic and resistance training program. Exclusion criteria were current participation in structured aerobic exercise and/or participation in resistance exercise in the last 6 months prior to the study, unstable cardiovascular disease, musculoskeletal disease, diabetes, or any other medical contraindication to perform the requested aerobic and resistance training. All men had not been restricted exercise by their physicians. Fig. 1 shows a flow of participants through the study. Forty-five older men (aged 70.5 ± 3.5 years, mean ± SD) were briefed on the details of the study before participation and were encouraged to ask questions prior to and throughout the duration of the study. A consciousness investigation on health and exercise had been previously conducted for the participants of this research. A cross-over design being adopted in this research as well as the fact that all participants would be able to receive training, even if at varying times, was explained as the intended goal of this research. After being fully informed of study procedures and screening for possible exclusion criteria, participants provided informed consent. All participants were randomly assigned to three groups that performed aerobic exercise before resistance training (AR, n = 16), performed resistance training before aerobic exercise (RA, n = 16), or no training during intervention (CON, n = 13). The control group was defined for this study as performing exercise after intervention. This study was approved by the Ethics Committee of Doshisha University; the Committee was responsible for the evaluation of research using human subjects.

2.2. Training design

Before the training intervention, women were familiarized with all equipment used for testing and training. Training activities consisted of a combination of cycling and weight machine training, and were performed twice a week over a period of 10 weeks. Participants in the AR group performed resistance training for 20 min following the aerobic exercise, while participants in the RA group performed the resistance training prior to the aerobic exercise. Participants performed warm-up and cool-down exercises before and after the main training activities. Training activities were performed under the supervision of experienced instructors. All participants were instructed not to alter their habitual physical activities and diet during the study intervention period.

2.2.1. Aerobic exercise

Aerobic exercise was performed by a cycle ergometer (manufacturer: Life Fitness). Participants pedaled at a speed of approximately 50–55 rpm at an intensity of 60% of their heart rate reserve (HRR). During the exercise, participants 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 min either before or after resistance training.

2.2.2. 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 participants could perform > 12 repetitions with the target weight, the training road was progressively increased. The participants were instructed to refrain from holding their breath, avoid straining, apply consistent movement speed, and perform the study exercises carefully.

2.3. Outcome measures

2.3.1. Anthropometrics and body composition

Height was measured with a precision of 0.1 cm. Weight and body fat percentage were measured using an electronic body fat scale (TBF-305, manufacturer: Tanita). 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 (%)].