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Arterial stiffness and blood flow adaptations following eight weeks of resistance exercise training in young and older women

Lindy M. Rossow [a,*], Christopher A. Fahs [a], Robert S. Thiebaud [b], Jeremy P. Loenneke [b], Daeyeol Kim [b], James G. Mouser [b], Erin A. Shore [b], Travis W. Beck [b], Debra A. Bemben [b], Michael G. Bemben [b]

[a] Fitchburg State University, 155 North St, Fitchburg, MA 01420, USA
[b] The University of Oklahoma, 1401 Asp Ave #14, Norman, OK 73019, USA

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ABSTRACT

Resistance training is recommended for all adults of both sexes. The arterial stiffness and limb blood flow responses to resistance training in young and older women have not been well-studied. The purpose of this study was to examine arterial stiffness and blood flow adaptations to high-intensity resistance exercise training in young and older women. Young (aged 18–25) and older (aged 50–64) women performed full-body high-intensity resistance exercise three times per week for eight weeks. The following measurements were performed twice prior to training and once following training: carotid to femoral and femoral to tibialis posterior pulse wave velocity (PWV), blood pressure, heart rate, resting forearm blood flow and forearm reactive hyperemia. Data was analyzed by ANOVAs with alpha set at 0.05. Correlations were also examined between changes in arterial stiffness and baseline arterial stiffness values. Older subjects had higher carotid–femoral PWV than younger subjects. No significant effects were found for femoral-tibialis posterior PWV or for resting forearm blood flow. Changes in carotid–femoral and femoral-tibialis posterior PWV correlated significantly with their respective baseline values. Older subjects increased peak forearm blood flow while young subjects showed no change. Total hyperemia increased significantly in both groups. In conclusion, in both young and older women, eight weeks of high-intensity resistance training appeared to improve microvascular forearm function while not changing carotid–femoral or femoral-tibialis posterior arterial stiffness. However, a large degree of individual variation was found and arterial stiffness adaptations appeared positively related to the initial stiffness values.

1. Introduction

Resistance training is recommended for both men and women, young and old as a method of increasing strength, improving risk factors for both cardiovascular and metabolic diseases, and improving quality of life both psychologically and physiologically (Wojtek et al., 2009). As arterial stiffness is an independent predictor of cardiovascular disease (Chirinos, 2012), examining arterial stiffness changes following resistance exercise training is of great importance. Few studies have examined the arterial stiffness response to resistance exercise training in women (Casey et al., 2007a, 2007b; Collier et al., 2011; Cortez-Cooper et al., 2005; Ho et al., 2012; Okamoto et al., 2009b, 2009c; Williams et al., 2013; Yoshizawa et al., 2009) and no study to date has directly compared the arterial stiffness response to resistance training between younger and older women. The arterial stiffness response to resistance exercise training has been found to vary with some studies in women showing no change (Casey et al., 2007a, 2007b; Collier et al., 2011; Yoshizawa et al., 2009), some showing an increase (Cortez-Cooper et al., 2005; Okamoto et al., 2006), and some showing a decrease (Ho et al., 2012; Okamoto et al., 2009b; Williams et al., 2013) in arterial stiffness following resistance exercise training. (In men, arterial stiffness following resistance training has been found to increase (Kawano et al., 2006; Miyachi et al., 2004; Okamoto et al., 2009c) or show no change (Cortez-Cooper et al., 2008; Heffernan et al., 2009)).

It has been suggested that high-intensity resistance exercise specifically may be detrimental for the arterial health of women due to an increase in augmentation index found in one study of young women following high-intensity resistance exercise training (Cortez-Cooper et al., 2005). In the aforementioned study, carotid–femoral pulse wave velocity (PWV), the currently accepted most representative measure of central arterial stiffness (O'Rourke et al., 2002), increased in both the resistance training and the non-exercising control group. Thus, a factor other than the training may have increased stiffness in both groups. In another study showing an increase in stiffness following training, young women were found to have a brachial-ankle PWV

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[*] Corresponding author at: 155 North Street #109, Fitchburg, MA 01420, USA. Tel./fax: +1 978 665 3158.
E-mail addresses: lrossow@fitchburgstate.edu (L.M. Rossow), cfahs1@fitchburgstate.edu (C.A. Fahs), robert.S.Thiebaud-1@ou.edu (R.S. Thiebaud), jploennke@ou.edu (J.P. Loenneke), dykim@ou.edu (D. Kim), gmouser@ou.edu (J.G. Mouser), erin.a.shore@ou.edu (E.A. Shore), tbeck@ou.edu (T.W. Beck), dbemben@ou.edu (D.A. Bemben), mgbemben@ou.edu (M.G. Bemben).

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increase following concentric exercise (but not eccentric exercise) only training (Okamoto et al., 2006). Studies reporting a decrease (Ho et al., 2012; Okamoto et al., 2009b; Williams et al., 2013) or no change (Casey et al., 2007b; Collier et al., 2011; Yoshizawa et al., 2009) in arterial stiffness in women following resistance exercise training reported protocols of varying intensities; thus it is unclear how intensity, or any training variable for that matter, affects women's arterial stiffness adaptations following resistance exercise training. It has been suggested, that high-intensity resistance training in young individuals with low baseline levels of stiffness increases stiffness while moderate-intensity training in older individuals has no effect on stiffness (Miyachi, 2013).

Very little work has examined limb microvascular blood flow responses to resistance exercise in women only and both of these studies have shown an improvement in limb microvascular blood flow following training in elderly (Egana et al., 2010) and middle-aged (Kingsley and Figueroa, 2012) women. Another study comparing men's and women's microvascular limb blood flow adaptations to resistance exercise also showed an improvement in women's microvascular limb (forearm) blood flow (Collier et al., 2011) with training. In men, limb microvascular blood flow has generally been found to improve (Fahs et al., 2012; Heffernan et al., 2009) although it has also been shown to decrease (Bond et al., 1996). In a study in which sex was not specified, no change in forearm microvascular function was found (Arce Esquivel and Welsch, 2007) following resistance exercise training. Femoral artery blood flow has been shown to decrease with age in both men and women (Dinenno et al., 1999, 2001; Moreau et al., 2003), however, this reduction has been found to be absent in men who are resistance trained (Miyachi et al., 2005). Age-related differences in women's blood flow responses to resistance training remain to be elucidated.

The purpose of this study was to examine arterial stiffness and blood flow responses to high-intensity resistance training in young and older women. It was hypothesized that high-intensity resistance training would not change either central or peripheral arterial stiffness and would improve forearm blood flow.

2. Materials and methods

2.1. Subjects

Forty-four subjects consented to participate. Six subjects decided to not participate prior to any testing or training. Nine subjects decided not to participate following pre-testing or following some exercise training. The major reason for choosing not to participate following consent and/or testing and training was the time commitment. Twenty-nine subjects (young = 16; older = 13) completed both testing and training. These included one African American, three Asian American, two Native American, and twenty-three Caucasian subjects. Young subjects were aged 19–25 (22 ± 2) years and older subjects were aged 51–62 (57 ± 3) years, postmenopausal, and not taking exogenous hormones. "Postmenopausal" was defined as greater than 12 months without experiencing menses and was assessed by questionnaires administered to the subjects. (Although a physician was not asked to specifically confirm postmenopausal status, study information was given to the physicians of all older subjects and the physicians were required to provide clearance for the subject to participate.) All subjects were not resistance trained (defined as >6 months without performing regular resistance exercise) and were not highly endurance trained but may have performed regular low or moderate-intensity endurance exercise (<5 h per week) which was allowed to be continued during the study. Subjects had no known orthopedic or metabolic disorders which could have prevented them from participation in the exercise program. All subjects were normotensive either naturally (n = 25) or under control with medication (n = 4 older subjects). As the number of older subjects in this study was limited, medication use was not controlled for in the analyses. (Other medications, not thought to affect the outcomes of the study, were also consumed by some subjects.) Physician clearance was required for older subjects to participate and no physician indicated cardiovascular disease as a concern with the subject's participation. This study was approved by the Institutional Review Board of the University of Oklahoma and all subjects provided written, informed consent.

2.2. Experimental design

Subjects first visited the laboratory for a familiarization visit. Each subject then came to the laboratory for two testing visits approximately three weeks apart (Pre1 and Pre2) which served as a control period. The week following Pre2, eight weeks of three weekly visits to the laboratory for resistance training commenced. Within one week (2–7 days) following the final training session, subjects returned to the laboratory for a final testing session (Post).

2.3. Familiarization visit

During this visit, subjects were familiarized with the six exercise machines (Cybex) on which they would be training (leg press, leg extension, leg curl, chest press, shoulder press, and lat pull-down), and were informed of the one-repetition maximum (1-RM) protocol.

2.4. Testing visits

During these visits, subjects had a variety of measurements performed on them: weight, brachial blood pressure (BP), carotid–femoral and femoral-tibialis posterior PWV, resting forearm blood flow, and forearm reactive hyperemia. Height was also assessed on the first visit only. Prior to testing visits, no medication known to affect blood pressure (other than the aforementioned chronic BP control medication used by four older subjects) was allowed. Subjects were asked to fast for at least 2 h prior to testing and to not consume any caffeine or to exercise on the day of testing prior to the visit.

2.5. Blood pressure (BP)

Following approximately 10 min of supine quiet rest, blood pressure (BP) was assessed using an automatic BP measuring device (Omron Healthcare Inc., Vernon Hills, IL). Two BP measurements were taken and approximately 1 min was allowed between measurements. If systolic BP measurements were within 5 mm Hg of each other, the average of the measurements was used for analysis. If the first two systolic BP measurements were not within 5 mm Hg, further rest was allowed and, following several minutes, the BP measurement was repeated until a stable value was obtained; these two measurements within 5 mm Hg of each other were then used averaged and used for analyses.

2.6. Pulse wave velocity (PWV)

Following BP assessment, PWV, an indicator of arterial stiffness, was assessed using applanation tonometry (SphymoCor, AtCor Medical, Sydney, Australia). Both central (carotid–femoral) and regional (femoral-tibialis posterior) PWV were assessed. A high-fidelity strain-gauge transducer (Miller Instruments, Houston, TX, USA) was placed over the right common carotid and the femoral artery, sequentially, to obtain pulse pressure waveforms. Over-body distances from the right common carotid artery to the suprasternal notch and from the suprasternal notch to the femoral artery were measured using a standard tape measure. The carotid to suprasternal notch distance was then subtracted from the suprasternal notch to femoral distance to give an estimate of aortic to femoral artery distance. The over-body distance from the femoral to the tibialis posterior artery was also measured and pulse waves were obtained at these sites as well. Three lead electrocardiographic monitoring (ECG) was used as a timing marker. Pulse wave velocity was derived from these measured distances and the time delay between the ECG