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ORIGINAL ARTICLE

Home-based resistance training improves arterial stiffness in healthy premenopausal women

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Abstract The present study investigates the effect of home-based resistance training on arterial stiffness in healthy premenopausal women. Twelve healthy non-smoking and normotensive women who were not actively involved in regular physical exercise (aged 42–55 years) performed home-based resistance training twice weekly for 10 weeks using body weight and light dumbbells. Each training session required approximately 40 min to complete. Arterial stiffness was measured using brachial-ankle pulse wave velocity (baPWV). We also determined serum total cholesterol, HDL cholesterol, glucose, triglyceride, insulin, and adiponectin and calculated the homeostasis model assessment of insulin resistance (HOMA-IR), an index of insulin resistance. After home-based resistance training, baPWV, total cholesterol, LDL cholesterol, insulin, and the HOMA-IR decreased, whereas adiponectin increased ($P < 0.05$) and levels of HDL cholesterol, glucose, triglyceride, blood pressure, and heart rate remained unaffected. These results suggest that home-based resistance training benefits vascular function in healthy premenopausal women.

Keywords Home-based resistance training · Arterial stiffness

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Introduction

Atherosclerosis is an essential process in the development of major cardiovascular and cerebrovascular events (Yamasaki et al. 2005). Atherosclerosis is one of the most important factors for the development of hypertension and leads to target organ damage and cardiovascular events (Thuillez and Richard 2005). Progression of atherosclerosis increases arterial stiffness and pulse wave velocity (PWV) in large arteries (Zureik et al. 2003).

Regular physical activity provides substantial health benefits by reducing the risk of cardiovascular diseases in men (Blair et al. 1995) and regular endurance training and vigorous physical activity might also reduce the age-related increase in arterial stiffness among men (Tanaka et al. 2000; Lazarevic et al. 2006). On the other hand, moderate-intensity resistance training does not alter arterial stiffness in normotensive postmenopausal (Casey et al. 2007) or middle-aged (Yoshizawa et al. 2009) women. In contrast, circuit training using low-intensity resistance exercise reduces arterial stiffness in healthy young women (Miura and Aoki 2005), and such training in groups has similar effects in normotensive elderly women (Miura et al. 2008). However, these studies assessed the effectiveness of exercise training on arterial stiffness using training programs at exercise facilities (Tanaka et al. 2000; Lazarevic et al. 2006; Miura and Aoki 2005; Casey et al. 2007; Miura et al. 2008; Yoshizawa et al. 2009). Home-based start strategies are needed to lower the barriers to the regular participation of women in resistance training. Such training using body weight and/or light dumbbells could be an option, but its effect on arterial stiffness in healthy premenopausal women is unknown. Because arterial stiffness increases among women as they approach menopause, increases in premenopausal arterial stiffness should be minimized.

The present study investigates whether home-based resistance training reduces arterial stiffness in healthy premenopausal women. We hypothesized that home-based resistance training reduces arterial stiffness in healthy premenopausal women.

Methods

Subjects

Twelve healthy non-smoking premenopausal women who did not perform regular physical exercise beyond routine daily activities (aged 42–55 years) participated in this study. We interviewed each of the women to confirm that all of them had menstrual cycles that regularly occurred every 25–35 days. All of the participants were normotensive (<140/90 mmHg), with no signs, symptoms, or history of any overt chronic diseases before training. The women were matched for age, menstrual cycles, brachial blood pressure, and metabolic risk factors. Experiments were carried out under the approval of the Ethical Committee of the Kinki Welfare University and all subjects provided written informed consent.

Home-based resistance training

Healthy premenopausal women participated in unsupervised low-intensity home-based resistance training twice a week (Tuesday and Friday) for 10 weeks using body weight and light dumbbells (500–1,000 g). Hand-held weights such as plastic bottles of water were substituted when dumbbells were unavailable. The women performed two sets of 12–15 repetitions with 5 sec of eccentric (lowering) and 5 sec of concentric (lifting) muscle actions at each exercise station. After finishing the repetitions, they walked 10 m to the next station. Each training session required approximately 40 min to complete. The weight of the dumbbells varied according to each exercise and was based on the ability of participants to complete 12–15 repetitions without sacrificing correct form. The six home-based exercises included squats, standing leg curls, shoulder press, bent row, bicep curls and abdominal twists. During the first week of the training, the participants were visited at home to ensure that the environment was appropriate for the study and safe.

Measurements

Measurements were obtained from the participants before (baseline) and at the completion of training 8 weeks later, between 2 and 5 p.m.

Body composition

Body composition was determined using the bioelectric impedance method (HBF-362, Omron Co. Ltd., Kyoto, Japan).

Arterial stiffness

After resting in the supine position for at least 10 min, brachial-ankle PWV (baPWV) was measured at rest using an automatic oscillometric device (formPWV/ABI, Omron-Colin Co. Ltd., Komaki, Japan) with sensory cuffs wrapped around both brachia and ankles. The participants abstained from caffeine and fasted for at least 24 h before being tested. The cuffs wrapped around both arms and ankles were connected to a plethysmographic sensor to determine volume pulse form and to an oscillometric sensor to measure blood pressure. The pulse volume waveforms were recorded using a semiconductor pressure sensor, with the sample acquisition frequency for PWV set at 1,200 Hz. Volume waveforms for the brachia and ankles were stored for a sampling time of 10 s with automatic gain analysis and quality adjustment. Sufficient waveform data were obtained in these stored samples.

The transit times (Tba) between the wave front of the brachia and that of the ankle was defined as the time interval. The distance between the sampling points of the brachial-ankle PWV was calculated according to the height of the participant. The length from the suprasternal notch to the brachium (Lb) was obtained from superficial measurements and is expressed as: Lb = 0.2195 × participant height (cm) − 2.0734.

The path length from the suprasternal notch to the ankle (La) was obtained from superficial measurements and is expressed as: La = 0.8129 × participant height (cm) + 12.328.

That is, baPWV was calculated as follows (Tomiyama et al. 2003): baPWV = (La − Lb)/Tba.

As our study cohort comprised adult women, the effects of female hormones on arterial stiffness should be considered (Tomiyama et al. 2003). Therefore, baPWV was measured at the same phase of the menstrual cycle in each participant.

Metabolic risk factors

Blood samples collected from the vein of the non-dominant arm (non-active limb) of each participant using a Vacutainer with EDTA–2Na and Trasylol were mixed with 1 ml of distilled water and centrifuged for 15 min at 4,000 rpm. Fasting serum concentrations of cholesterol, glucose, insulin, and triglyceride were determined using standard enzymatic techniques with intra- and inter-assay coefficients of variance of <5.0%. Homeostasis model assessment of insulin resistance (HOMA-IR), an index of insulin resistance, was calculated using the following equation: fasting glucose × insulin/22.5.

Serum high-molecular weight adiponectin concentrations were determined using radioimmunoassays with intra- and inter-assay coefficients of variance of 2.4–3.0 and 4.2–5.1%, respectively.

Grip strength

Grip strength was measured as the higher of two values measured using a digital dynamometer (TKK5461, Takei Scientific Instruments Co. Ltd., Niigata, Japan).

Statistical analysis

Data are presented as the mean ± SD. Data were analyzed by repeated measures one-way ANOVA followed by Bonferroni/Dunn post hoc test for multiple comparisons. Findings were considered significant at $P < 0.05$.

Results

All the subjects completed the training program for 10 weeks. None of body mass, body mass index, body fat, lean body mass, waist girth, hip girth, waist to hip ratio, and grip strength changed after home-based resistance training (Table 1). Total cholesterol, LDL cholesterol, insulin, and HOMA-IR decreased and adiponectin increased (Table 2, $P < 0.05$), after home-based resistance training, whereas baPWV was reduced (Fig. 1, $P < 0.05$). Serum HDL cholesterol, glucose, triglyceride, resting blood pressure, and heart rate did not change after training (Table 2).

Table 1 Physical characteristics of subjects

	Before training	After training	Significant difference
Height (cm)	159.2 ± 1.4	–	
Body mass (kg)	59.7 ± 2.6	60.1 ± 2.5	NS
Body mass index (kg/m^2)	23.6 ± 1.0	23.7 ± 1.0	NS
Body fat (%)	30.6 ± 1.4	30.5 ± 1.4	NS
Lean body mass (kg)	41.0 ± 1.2	41.4 ± 1.1	NS
Waist girth (cm)	71.5 ± 2.7	71.3 ± 2.5	NS
Hip girth (cm)	90.9 ± 1.8	89.8 ± 1.8	NS
W/H ratio	0.79 ± 0.01	0.79 ± 0.01	NS
Grip strength (kg)	28.5 ± 1.1	29.6 ± 1.2	NS

Mean ± SD

Table 2 Cardiovascular risk factor and cardiovascular indices

	Before training	After training	Significant difference
Total cholesterol (mg/dl)	212 ± 8	198 ± 8	$P < 0.05$
HDL cholesterol (mg/dl)	67 ± 4	67 ± 4	NS
LDL cholesterol (mg/dl)	132 ± 7	117 ± 6	$P < 0.05$
Fasting glucose (mg/dl)	92 ± 2	93 ± 2	NS
Fasting insulin (μU/dl)	5.8 ± 0.8	4.6 ± 0.7	$P < 0.05$
HOMA-IR	1.3 ± 0.2	1.0 ± 0.1	$P < 0.05$
Triglyceride (mg/dl)	65 ± 6	77 ± 9	NS
Adiponectin (Jg/ml)	6.8 ± 1.3	9.1 ± 1.5	$P < 0.05$
Systric pressure (mmHg)	118 ± 5	116 ± 4	NS
Mean pressure (mmHg)	89 ± 4	87 ± 3	NS
Diastric pressure (mmHg)	71 ± 3	72 ± 3	NS
Pulse pressure (mmHg)	47 ± 3	45 ± 3	NS
Heart rate (bpm)	67 ± 2	66 ± 2	NS

Mean ± SD

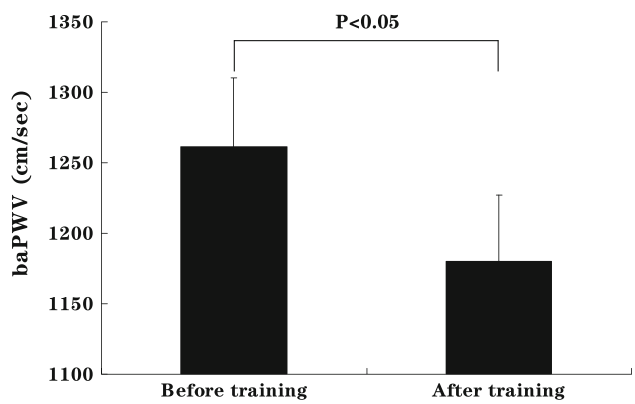

Fig. 1 Comparison of baPWV before and after training. Values are mean SD. *baPWV* brachial-ankle pulse wave velocity

Discussion

To the best of our knowledge, this is the first study to investigate the effect of home-based resistance training on arterial stiffness in healthy premenopausal women. The key novel findings were that arterial stiffness was reduced along with improved total cholesterol, LDL cholesterol, fasting insulin, HOMA-IR, and adiponectin by home-based resistance training. These findings suggest that home-based resistance training exerts a beneficial effect upon vascular function.

The effects of female hormone on arterial stiffness should be considered when a study cohort comprises women. The PWV is lower in women than in men due to the vasodilatory and NO-producing effects of estrogen (Tomiyama et al. 2003). However, although arterial compliance changes with the menstrual cycle, others have reported that PWV does not significantly change in women (Williams et al. 2001). Therefore, we measured baPWV at the same phase of the menstrual cycle in each of the women. Considering the measurements, we concluded that changes in the baPWV were caused by the training. However, because estrogen might reduce PWV and arterial compliance (Weinberger et al. 2002; Miura et al. 2003), the effects of the menstrual cycle must be considered.

Arterial stiffness depends upon elastin and collagen composition, the calcium content of elastin, and changes in vasoconstrictor tone. Increased arterial stiffness might be due to age-associated structural changes in the arterial walls. Aging is associated with a decrease in elastin and a concomitant increase in collagen and connective tissues in the arterial walls (Guyton et al. 1983) and an increase in arterial stiffness due to menopause (Kozakova et al. 2007). Mechanical distension of arteries in response to home-based resistance training might stretch collagen fibers and modify their cross-linking, which is related to reduced arterial stiffness. The present results imply that home-based resistance training might produce such effects. Nevertheless, the precise mechanisms responsible for the changes in arterial stiffness induced by this type of training remain unknown, and the present findings require confirmation.

Improvements in baPWV after home-based resistance training might be related to improved metabolic control due to significant changes in total cholesterol, LDL cholesterol, fasting insulin, HOMA-IR, and adiponectin. Insulin resistance plays an important role in the progression of arteriosclerotic disorders (Kasayama et al. 2005). The effects of hyperinsulinemia on the vascular system might include improved sodium reabsorption (ter Maaten et al. 1999), stimulation of the sympathetic nervous system (Young 1988), and the promotion of vascular smooth muscle cell growth (Begum et al. 1988), all of which might contribute to increased arterial stiffness. Moreover, adiponectin derived from adipocytes has an antiatherosclerotic effect, since adiponectin has anti-inflammatory properties and might regulate inflammatory responses at atherosclerotic lesions (Ouchi et al. 2000, 2001; Matsuda et al. 2002). Adiponectin is also an independent predictor of PWV (Mahmud and Feely 2005). Therefore, a decrease in insulin resistance and an increase in adiponectin might participate in decreasing arterial stiffness among healthy premenopausal women. Although the cause-and-effect relationship cannot be determined using the present design, we discovered that adiponectin increases among healthy premenopausal women in response to home-based resistance training in a circuit format. The effects of resistance training on insulin sensitivity and adiponectin (Fatouros et al. 2005; Klimcakova et al. 2006) have not been studied in detail and the results are controversial.

Several other important limitations of the present study should be emphasized. Our findings did not reveal any change in body composition or physical fitness. This result is consistent with the findings of Miura et al. (2008) who also reported that group training twice weekly reduces arterial stiffness, although body composition and physical fitness do not significantly change. An exercise frequency of at least three times a week is recommended to improve functional fitness in older women (Nakamura et al. 2007). Participation in our exercise program twice a week will not alter either body composition or levels of physical fitness. We did not have a control group that remained sedentary during the study period, which is a crucial limitation of interventional studies in general. In addition, we included only healthy premenopausal women whose blood pressure was not expected to change after training.

We concluded that home-based resistance training exerts a beneficial effect on overall vascular function in healthy premenopausal women and might lower the barriers toward regular participation in more conventional exercise among this segment of the population.

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