

Research article

Large and small arterial elasticity in healthy active and sedentary premenopausal women

Anette S. Fjeldstad  and Debra Bemben

Department of Health and exercise Science, University of Oklahoma, Norman, Oklahoma, USA

Abstract

The purpose of this study was to compare large and small arterial elasticity in apparently healthy sedentary and recreationally active adult women, and to examine if age affects large and small arterial elasticity. This cross-sectional study consisted of 43 premenopausal women without overt cardiovascular disease (age = 43.4 ± 4.7 yrs; mean \pm SD). The subjects were grouped into a sedentary group or a leisurely active group (30 min, 3d wk of low intensity) in addition to the following age groups: 35-40 years, $n = 13$; 41-45 years, $n = 14$; 46-54 years, $n = 16$. Subjects rested supine while pulse contour analysis was measured from the radial artery using an HDI/Pulsewave CR-2000 instrument (Hypertension Diagnostic, Inc.) to examine arterial elasticity in the large and small arteries. Activity level and menopausal status was based on self-report. There were no differences in large (14.5 ± 1.0 ml/mmHg \times 10; 14.9 ± 0.9 ml/mmHg \times 10; mean \pm SD) and small (5.5 ± 0.5 ml/mmHg \times 100; 6.4 ± 0.4 ml/mmHg \times 100) arterial elasticity between the sedentary group and the recreationally active group, respectively. Large (12.8 ± 0.9 ml/mmHg \times 10) arterial elasticity was lower in the oldest group ($p = 0.008$) compared to the youngest group (17.6 ± 5.9 ml/mmHg \times 10). After adjusting for body mass index, large arterial elasticity ($p = 0.022$) remained lower in the oldest group. There was a trend for small arterial elasticity to be lower in the older group compared to the young group ($p = 0.063$). There was no difference in large and small arterial elasticity between healthy sedentary and recreationally active premenopausal women. This suggests that more strenuous physical activity may be necessary to gain beneficial effects on the vasculature. Large arterial elasticity is decreasing with advancing age independent of body mass index.

Key words: Arterial elasticity, premenopausal, body mass index, sedentary.

Introduction

Arterial compliance is defined as the ability of an artery to expand and recoil with cardiac pulsation and relaxation (Arnett et al., 1994). A decrease in arterial compliance or an increase in arterial stiffness is common with advancing age in both men and women, (Mitchell et al., 2004) and may lead to atherosclerosis regardless of the presence of coexisting diseases (Millasseau et al., 2002). The increased prevalence of obesity in the United States has reached epidemic proportions, and is still increasing among all age-groups (Flegal et al., 2002, Ogden et al., 2002). Obesity may negatively affect the cardiovascular function through associations with hypertension (Wilson et al., 2002), dyslipidemia (Wilson et al., 2002), and inflammation (Duprez et al., 2005).

One study found that in young and older adults, body fat measures were among the strongest predictors of large arterial stiffness (Wildman et al., 2003). The inflammatory response to the body's increased amount of fat, may have a negative effect on endothelial physiology, which may lead to the formation of atherosclerotic plaque (Avogaro and de Kreutzenberg, 2005). Inflammation has been associated with large arterial stiffness in an asymptomatic population (Duprez et al., 2005).

Epidemiological studies have found that physically active men and women have lower prevalence of cardiovascular disease compared to sedentary peers (Blair et al., 1989). In addition, it has been reported that age-related increases in central arterial stiffness are absent or attenuated in endurance-trained adults, (Arnett et al., 1994; Tanaka et al., 2000) and endurance training restores levels in previously sedentary healthy middle-aged and older men (Tanaka et al., 2000). Central arterial stiffness increases with advancing age in sedentary healthy females, and is significantly lower in highly physically active women, compared to their sedentary counterparts (Tanaka et al., 1998).

Arterial elasticity can be assessed noninvasively using Pulse Contour Analysis (PCA) (Prisant et al., 2002), which is a computerized radial artery pulse wave analysis with the CR-2000 (Hypertension Diagnostics, Eagan, Minnesota, USA). The arterial pulse wave analysis of the radial artery is based on a modified Windkessel model that allows an evaluation of the elasticity of the large conduit arteries (C1) and the small microcirculatory arteries (C2) (Cohn et al., 1995; Finkelstein and Cohn, 1992).

The most widespread noninvasive technique to assess endothelial function is flow-mediated dilation (FMD). However, the measurement procedures are time-consuming, the equipment is very expensive, and it requires an experienced examiner (Gokce et al., 2002). Other techniques available to assess arterial elasticity is magnetic resonance imaging, ultrasound measurement, and indirect measures such as pulse pressure (Havlik et al., 2003).

Most of the examinations studying the effect of exercise on arterial elasticity have been completed on men, and often only investigated large or central arterial elasticity. To our knowledge, this is the first study to examine both the large and small arterial elasticity in recreationally active and sedentary premenopausal women.

The purposes of this investigation were: (1) to compare large and small arterial elasticity in apparently healthy sedentary and recreationally active adult women,

and (2) to examine if age affects large and small arterial elasticity in premenopausal women.

We hypothesized that recreationally active women would have greater arterial elasticity than sedentary controls. Further, we hypothesized that arterial elasticity would decrease with advancing age.

Methods

Subjects

Recruitment: This cross-sectional study consisted of 43 premenopausal women without overt cardiovascular disease (age = 43.4 ± 4.7 yrs; mean \pm SD). The subjects were recruited by fliers from the University of Oklahoma and the surrounding areas.

Inclusion and exclusion criteria: Subjects were excluded from this study if their age was < 35 years or > 55 years, had a history of cardiovascular disease (CVD) or peripheral arterial disease (PAD), taking hormone replacement therapy (HRT), antihypertensive drugs, or were postmenopausal. All the subjects gave their written informed consent prior to participation, and all procedures were approved by the Institutional Review Board at the University of Oklahoma.

Measurements

Demographic information: Age, cardiovascular disease risk factors, activity level and menopausal status were obtained during a medical history interview to begin the evaluation. Height was recorded from a stadiometer (SECA Corporation; Columbia, MD) and body weight was recorded from a scale (SECA Corporation; Columbia, MD), after the subjects removed their shoes. Body mass index (BMI) was calculated according to the formula of body mass (kg) / height (m^2). Blood pressure and heart rate was measured concurrently with the large and small arterial elasticity indices. Physical activity level was based on self-report. Recreationally active was classified as engaging in low-to-moderate intensity physical activity no more than three times per week for approximately 20-30 minutes. Sedentary was classified as engaging in no physical activity.

Pulse Contour Analysis (PCA): PCA measurements were obtained in the morning following an overnight fast of at least eight hours, and prior to engaging in any strenuous physical activity. Following approximately 5-10 minutes of supine rest, large artery (C1) and small artery (C2) elasticity indices were obtained by an (HDI/Pulswave™ CR-2000 Cardiovascular Profiling System, Hypertension Diagnostic, Inc., Eagan, Minnesota, USA). An appropriate-sized blood pressure cuff was wrapped around the upper left arm, and a rigid plastic wrist stabilizer was placed on the right wrist to minimize movement of the radial artery during the measurement. With the right forearm resting in a supine position, an Arterial Pulsewave™ Sensor was placed on the skin directly over the radial artery at the point of the strongest pulse. The sensor was adjusted to the highest relative signal strength, and the C1 and C2 measures were obtained during 30 seconds of blood pressure waveform collection. This device can

measure the decay in diastolic pressure in the large arteries, and the decay in the reflective waves of the small arteries. In addition to C1 and C2, other cardiovascular parameters were recorded during the waveform collection, such as blood pressure, pulse rate, systemic vascular resistance, and total vascular impedance. All measurements were averaged over three continuous 30-second trials. This noninvasive approach is repeatable and reliable both during long-term and short-term observations. (Prisant et al., 2002).

Statistical analysis

Descriptive statistics were computed for all measurements. The subjects were grouped into a sedentary group (no physical activity) or a leisurely active group (20-30 min, 3d wk of low-to-moderate intensity) in addition to the following age groups: 35-40 years, $n = 13$; 41-45 years, $n = 14$; 46-54 years, $n = 16$.

The effects of age and physical activity on arterial elasticity indices were assessed with two-way ANCOVA (age \times physical activity). The analyses were adjusted for BMI or body surface area (BSA). The effects of age and activity level on blood pressure were assessed with a one-way ANOVA. If a significant age group difference was detected, a Bonferroni post hoc test was done to determine which groups were significantly different. All values are presented as mean \pm SD. Statistical analyses were performed with the SPSS 11.5 soft ware (Chicago, IL). Statistical significance was set at $p < 0.05$.

Table 1. Physical characteristics of subjects (n = 43). Data are means (\pm SD).

Age (yrs)	43.4 (4.7)
Height (m)	1.64 (.06)
Weight (kg)	74.5 (22.4)
BMI ($kg \cdot m^{-2}$)	27.5 (7.8)
SBP (mmHg)	122.7 (15.0)
DBP (mmHg)	72.0 (9.2)
LAEI (ml/mmHg $\times 100$)	14.7 (4.4)
SAEI (ml/mmHg $\times 100$)	6.1 (2.1)

Abbreviations: SBP = Systolic blood pressure, DBP = Diastolic blood pressure, LAEI = Large artery elasticity index, SAEI = Small artery elasticity index.

Results

Table 1 shows subject demographics. The mean age for the subjects was 43.4 years, and the BMI reached the overweight category $27.5 m \cdot kg^{-2}$, according to the World Health Organization (Organization, 1998). According to self-report, 42% of the subjects were classified as sedentary. Table 2 represents levels of physical activity and arterial elasticity indices. There were no significant differences ($p > 0.05$) in large and small artery elasticity between the sedentary group and the recreationally active group, respectively. Table 3 shows arterial elasticity indices for the three age groups. Large artery elasticity was significantly lower in the oldest group ($p = 0.008$) compared with the youngest group. After adjusting for body mass index, large artery elasticity ($p = 0.022$) remained lower in the oldest group. Further, adjusting for body surface area did not alter the results. Small artery elasticity tended to be lower in the older group compared to the

young group, but did not reach level of significance ($p = 0.063$).

Table 2. Arterial elasticity indices for sedentary and recreationally active women. Data are means (\pm SD) adjusted for body mass index.

Activity Level	LAEI (ml/mmHg x100)	SAEI (ml/mmHg x100)
Sedentary (n = 18)	14.5 (1.0)	5.5 (.5)
Rec. Act. (n = 25)	14.9 (.9)	6.4 (.4)

Abbreviations: LAEI= Large artery elasticity index, SAEI = Small artery elasticity index, Rec. Act. = Recreationally active.

Systolic blood pressure in the young (114.9 ± 10.7 mmHg; mean \pm SD), middle (119.4 ± 12.3 mmHg), and older (132.0 ± 15.9 mmHg) group were significantly different ($p = 0.004$). The difference was between the young and the old group ($p = 0.005$), and between the middle and the old group ($p = 0.045$). Diastolic blood pressure in the young (68.9 ± 7.1 mmHg), middle (69.3 ± 9.13 mmHg), and older (76.8 ± 9.2 mmHg) group were significantly different ($p = 0.025$). The difference was between the young and the old group ($p = 0.054$), whereas the difference between the middle and older group did not reach level of significance ($p = 0.065$). There were no significant differences in systolic ($p = 0.55$) or diastolic ($p = 0.61$) blood pressure between the sedentary and the recreationally active group.

Table 3. Age group comparisons for arterial elasticity indices. Data are means (\pm SD) adjusted for body mass index.

Age Groups	LAEI (ml/mmHg x100)	SAEI (ml/mmHg x100)
35-40 (n=13)	17.7 (5.9)	7.1 (2.2)
41-45 (n = 14)	14.2 (2.9)	5.9 (1.9)
46-54 (n = 16)	12.7 (2.6) *	5.3 (1.9)

* $p < 0.05$ compared with 35-40 age group.

Abbreviations: LAEI= Large artery elasticity index, SAEI = Small artery elasticity index.

Discussion

This investigation examined the effects of physical activity on large and small arterial elasticity in apparently healthy premenopausal women. Our findings suggest that there is no difference in large and small artery elasticity in premenopausal recreationally active and sedentary women. Furthermore, large artery elasticity decreases with advancing age.

These results are in agreement with Tanaka et al. (2000) who determined that central artery elasticity was lower in the middle-aged and older men, compared with the young men, but there were no differences in arterial elasticity between sedentary and recreationally active men at any age.

An earlier study by the same author concluded that the age-related decrease in central artery elasticity was not observed in highly physically active women compared to that of sedentary controls (Tanaka et al., 1998). This suggests that high levels of physical activity may prevent the age-related decrease in arterial elasticity in women. The technique used to measure arterial elasticity was arterial applanation tonometry. This study also concluded that central, but not peripheral artery elasticity decreases with

advancing age in sedentary healthy females. A study by Schmitz et al. (2001) also support our findings, that self-reported habitual physical activity does not increase arterial elasticity as measured by ultrasound, in middle-aged men and women. Another study by Havlik et al. (2003) contradicts these findings. Their results suggest that both a minimal and moderate amount of physical activity might be sufficient to increase arterial elasticity in older men and women. This study used aortic pulse-wave velocity to measure arterial elasticity. This suggests the possibility that a relatively small increment of physical activity may have beneficial effects on arterial elasticity in an older sedentary population.

In our investigation, small artery elasticity was not different for sedentary and recreationally active women, and the decrease in small artery elasticity with advancing age did not reach level of significance. It has been suggested that the physiological mechanism behind the decrease in arterial elasticity with increasing age are more rapid in the large elastic arteries compared to the small muscular arteries (Hayashi et al., 2005; Snijder et al., 2004). The large arteries have a cushioning function that damps fluctuations in flow, whereas the small arteries do not exhibit the same extent of pulsatile changes in diameter, and may not undergo the adaptations leading to decreased elasticity of the artery (Boutouyrie et al., 1992).

Elevated arterial blood pressure is associated with an increase in age (Seals, 2003), sedentary lifestyle (Fagard and Cornelissen, 2007), and a decrease in both large and small arterial elasticity (Prisant et al., 2001), so it is important to examine these variables. Our study did not find any significant difference in blood pressure between the sedentary group and the recreationally active group. However, both systolic and diastolic blood pressure increased with advancing age. The subjects with the highest systolic pressure also had the largest decrease in large artery elasticity. It is important to note that regardless of the difference in blood pressure among the three age-groups, all groups remained in the normotensive category. This may suggest that a small increase in systolic blood pressure that occurs with advancing age still might have a negative impact on the vasculature.

The main limitation of this examination is the cross-sectional design, which does not establish a cause and effect relationship between arterial elasticity and level of physical activity. Another limitation is that the PCA is a noninvasive measure of large and small arterial elasticity, and an invasive measure would be more precise. A third limitation is that physical activity levels were not objectively measured, and classification of physical activity and health history was based on self-report, which might be subject to recall bias and misclassification. It is possible that the narrow age-range and our small sample size limited the detection of an association of physical activity and arterial elasticity.

Conclusion

Future directions: A supervised training study conducted on women and examining the effect of exercise on arterial elasticity is needed. As of now, it is not possible based on

the results here to draw conclusions about the significance of the relationship between recreational exercise and arterial elasticity.

In conclusion, these findings show that there is no significant difference in large and small artery elasticity between healthy recreationally active and sedentary premenopausal women. Further, large artery elasticity decreased with advancing age independent of BMI.

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Key points

- There was no difference in large and small artery elasticity between healthy sedentary and recreationally active women.
- Large artery elasticity decreases with advancing age.
- Subjects with the highest systolic blood pressure had the largest decrease in large artery elasticity.

AUTHORS BIOGRAPHY

Anette S. FJELDSTAD

Employment

Graduate Research Assistant at the Cardiovascular Laboratory in the Department of Health and Exercise Science at the Univ. of Oklahoma, USA.

Degree

MS

Research interest

Cardiovascular disease, blood vessel function, inflammatory markers and exercise.

E-mail: Anette.S.Fjeldstad-1@ou.edu

Debra BEMBEN

Employment

Assoc. Prof., and Graduate Liaison. Director of the Bone Research Laboratory in the Department of Health and Exercise Science at the Univ. of Oklahoma, USA.

Degree

PhD

Research interest

Endocrine function, bone health and exercise in women.

E-mail: dbembem@ou.edu

✉ Anette S. Fjeldstad

University of Oklahoma, 1401 Asp Avenue, Norman, OK 73019, USA.