Reduced Arterial Stiffness and Ankle Blood Pressure Following Stretching Exercise in Postmenopausal Women

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Abstract

An association between muscle flexibility and arterial elasticity has previously reported. Therefore, this study aimed to investigate the effects of 6-week stretching training on arterial stiffness in postmenopausal women. Forty postmenopausal women (mean age 55.00 ± 3.70 years) were randomly allocated to control group (n = 20) or stretching group (n = 20). Six weeks of stretching exercise was done in major muscle groups (neck, trunk, upper and lower extremities) for 30 minutes a day, 5 days a week. Arterial stiffness was assessed by brachial-ankle pulse wave velocity (baPWV). In addition, ankle blood pressure was measured pre and post-training. After 6 weeks, baPWV significantly improved in the stretching group ($P < 0.05$). Moreover, ankle systolic blood pressure significantly decreased in the training group compared with control participants ($P < 0.05$). A positive and significant correlation between ankle systolic blood pressure and baPWV was found ($r = 0.454$, $P = 0.003$). This study shows that stretching training was effective to reduce arterial stiffness and ankle blood pressure in postmenopausal women. Overall findings provided the therapeutic efficacy of stretching exercise improve arterial elasticity and blood pressure in postmenopausal women.

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Introduction

It is well established that estrogen hormone plays an important role in protecting the cardiovascular system. Indeed, the loss of estrogen was associated with impairment of arterial function as measured by pulse wave velocity (PWV).[1] Previous studies have documented that women undergoing menopause exhibited elevated PWV independent of age and other conventional atherosclerotic risk factors.[2] A marked increase in arterial stiffness may account for a rise in systolic and pulse pressure, which may result in an increased risk for cardiovascular events.[3] Increased arterial stiffness has also been related to poor functional outcomes, including decreases in cardio-respiratory fitness, physical activity, and quality of life.[4,5] Apart from arterial stiffness, a growing body of evidence suggests that ankle blood pressure could be an indicator of subclinical atherosclerosis, left ventricular hypertrophy, as well as a predictor of dementia.[6,7] Moreover, ankle blood pressure has been associated with elevated risk for cardiovascular events in older adults.[8] Thus, it may be useful for researchers to evaluate the changes in ankle blood pressure in women undergoing menopause.

Evidence suggests implementing regular aerobic exercise leads to decrease in arterial stiffness and reduced cardiovascular morbidity.[9,10] Recently, researchers have shown that stretching exercises, commonly used to increase range of motion, were correlated with arterial stiffness, as demonstrated by the association of poor muscular flexibility with high levels of arterial stiffness.[11] Cross-sectional studies have confirmed that middle-aged martial artists had greater muscular flexibility and less arterial stiffness than the healthy sedentary controls.[12] Furthermore, researchers have shown that regular stretching is beneficial for attenuating arterial stiffness in middle-age men[13] and obese postmenopausal women.[14] These results suggest that regular stretching seems to improve arterial functions.

However, no studies have reported the effect of stretching program on arterial stiffness and ankle blood pressure among postmenopausal women. Therefore, the aim of our study was to examine the effect of stretching program on vascular elasticity and ankle blood pressure in postmenopausal women. We hypothesize that stretching exercise would decrease arterial stiffness and ankle blood pressure in women undergoing menopause.

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Materials and Methods

Subjects

Women, aged 45-59 years, who had not menstruated for at least 12 consecutive months were recruited at Phra Yuen District, Khon Kaen province, from May to July 2017. We randomly assigned participants to stretching group (n = 20) or control group (n = 20). We excluded participants if they had a medical history of hypertension or diabetes mellitus, had fractured their upper or lower extremity or spine in the past six months, or had received hormone supplements in the past 12 months. We also excluded participants if they were obese, current smokers, taking part in regular physical activity, or taking medications for hypertension, diabetes mellitus or dyslipidemia. All participants took part voluntarily and we obtained informed consent from them prior to the onset of the intervention. The study protocol was approved by The Ethical Committee of Research in Human, Khon Kaen University (HE602034).

Experimental protocol and measurement

Initially, we screened the participants. We conducted all tests at the same time of day to avoid potential diurnal variations, and they were done in a quiet, temperature-controlled room. We measured pulse wave velocity and ankle blood pressure at baseline and at week six. To minimize the influence of external factors on cardiovascular variables, we asked participants to abstain from alcohol, caffeine and vigorous exercise for 24 h before each testing session. Furthermore, to avoid any immediate effect after a single training, the post 6th week measurement was conducted 48 hours after the last exercise training.

Stretching program

The stretching exercises were supervised by a physical therapist. The program involved stretching the major muscle groups, including the neck and trunk muscle (flexor, extensor, and rotator muscles), upper extremities (pectoralis major, triceps, and latissimus dorsi muscles), and lower extremities (quadriceps, hamstring, adductors, and gastrocnemius muscles) in sitting, lying, and standing posture (Figure 1).[15,16] Participants maintained all positions until the end of each stretching period or to the point of minimal discomfort. Each stretching period was 20 seconds long with a 40 second rest interval between each repetition. Participants undertook three repetitions for each muscle and avoided holding their breath during stretching. Each stretching session was 30 minutes long and participants undertook one session five days a week for six weeks. The first week of stretching exercises was supervised by a physical therapist and participants performed them at home for the remaining five weeks. We requested that participants did not change their physical activity or dietary intake throughout the study. In addition, we instructed participants to record their day-to-day exercise and nutritional status.

Figure 1 Stretching exercise patterns: A, Stretching neck muscles; B, stretching back, trunk and leg muscles; and C, Stretching arm muscles

Outcome measurements

Arterial stiffness

After 10 minutes of rest in supine position, we measured participants' baPWV using a data acquisition system (Arterial Compliance Monitor, Barts and The London's School of Medicine and Dentistry, UK) and Doppler probes (Dopplex MDII, Huntleigh Healthcare, Cardiff, UK).[17] We recorded brachial and ankle arterial pressure waveform by placing the doppler probe over the left brachial and dorsalis pedis arteries. We calculated the brachial to ankle distance by following height-based formulas:

Distance (ba) = 1.3 × (c + d) – b;
Length (b) = 0.220 × height (cm) – 2.07;
Length (c) = 0.564 × height (cm) – 18.4;
Length (d) = 0.249 × height (cm) + 30.7;

where b is the path length from suprasternal notch to brachial site, c is the path length from suprasternal notch to femoral site, and d is the path length from

Table 1 Anthropometric and baseline characteristics.

Variable	Control n = 20	Stretching n = 20
Age (years)	54.65 ± 3.70	55.35 ± 2.84
Weight (kg)	58.95 ± 8.09	59.11 ± 8.90
Height (cm)	155.60 ± 5.13	153.83 ± 5.17
Body mass index (kg/m^2)	24.31 ± 2.86	25.22 ± 3.06
Brachial BP (mmHg)		
systolic	124.00 ± 13.83	124.57 ± 12.15
diastolic	74.89 ± 8.90	73.07 ± 9.32
Heart rate (beats/min)	75.10 ± 9.95	77 ± 8.08

Data were mean ± SD. BP, blood pressure.

femoral to ankle sites.[18]

The intra-class correlation coefficient for baPWV measurement was 0.90.

Ankle blood pressure

After a 10-minute rest, ankle blood pressure was measured, using an automatic sphygmomanometer (LD-528; Scian, China), for 3 times with 2 minute rest intervals in supine position; the lower end of the cuff was placed about 2 cm above the superior aspect of the medial malleolus and the cuff was wrapped in a cylindrical fashion perpendicularly to the axis of the leg. The mean values of ankle blood pressure were utilized for further analysis. Blood pressure was assessed according to the American Heart Association recommendations.[19]

Statistical analysis

We used the Shapiro-Wilk test to evaluate the normality of the data. We analyzed between-groups differences using an independent *t* test. To analyze all data within the group, we used a paired *t* test. We set statistical significance at an alpha level of < 0.05. We conducted all of the analyses using the SPSS software package for Windows version 11.0.

Results

Participant characteristics

Baseline characteristics of the participants are given in Table 1. The mean age of participants in this study was 55.00 ± 3.70 years (range, 45-59 years). At baseline, no significant difference was found between groups in terms of age, weight, height, body mass index, brachial blood pressure and heart rate.

Training effect

At baseline, there was no significant difference in arterial stiffness, as assessed by baPWV, between the control and stretching groups (Figure 2). After six weeks of training, mean baPWV significantly decreased by about 12% in the stretching group when compared with the baseline value. Moreover, after 6 weeks of training, there was a significant difference in the reduction of baPWV between the stretching group and the control group (P = 0.001) (Figure 2). Over the course of the training, baPWV did not change significantly in the control group.

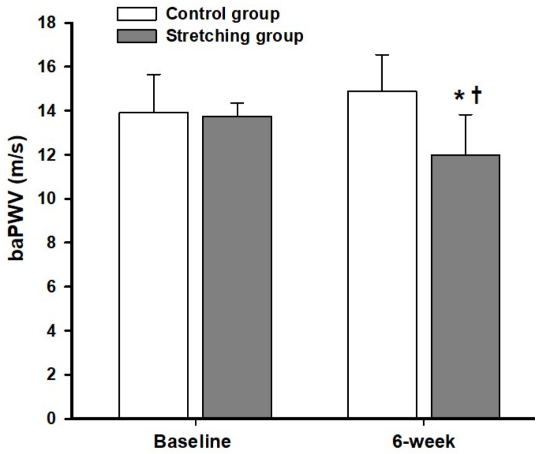

Figure 2 Mean baPWV at baseline and after a 6-week period in control and stretching group. *Significantly different from baseline (P = 0.001); †significantly different from control at 6-week (P = 0.001).

Ankle systolic blood pressure of the stretching group was significantly reduced following six weeks of stretching training (Table 2) when compared to control participants. Ankle systolic blood pressure and mean ankle arterial pressure did not differ significantly in either group after the intervention (P > 0.05).

Discussion

Our study demonstrated that after a six-week program of stretching training, postmenopausal women had a significant reduction in ankle blood pressure and arterial stiffness. These findings are similar to previous studies, which reported an improvement in arterial elasticity after stretching exercises in middle-aged and older adults[15] as well as in obese postmenopausal women.[14] Additionally, researchers have shown that only single of stretching exercise reduced arterial stiffness.[20] Recently, Nishiwaki et al.

Table 2 Ankle blood pressure of control and stretching groups.

Ankle BP (mmHg)	Baseline		6-week	
	Control	Stretching	Control	Stretching
Systolic	139.00 ± 19.11	136.58 ± 15.79	140.69 ± 12.85	123.55 ± 11.58*†
Diastolic	71.21 ± 8.94	69.25 ± 8.41	70.76 ± 11.32	69.97 ± 9.78
Mean	93.61 ± 11.51	91.09 ± 9.66	93.90 ± 14.15	88.01 ± 9.82

Data were mean ± SD. *Significantly different from baseline (P = 0.001); †significantly different from control at 6-week (P = 0.001). BP, blood pressure.

(2015) have reported that arterial stiffness significantly declined in middle-aged men after they began a regular stretching program.[13] Our present findings found that a similar improvement could be obtained in postmenopausal women when they undertook a program of stretching exercise, and this was indicated by a decrease of 12% in baPWV. These results suggest that regular stretching may be a beneficial adjunct therapy to reduce arterial stiffness in postmenopausal women.

The current study not only demonstrated the effect of stretching on arterial function but also its ability to reduce ankle blood pressure. The reduction of blood pressure in obese postmenopausal women as a result of participating in a stretching program has already been reported.[14] There is evidence that stretching exercise might have anti-hypertensive effect through improved endothelial function[21] and decreased sympathetic tone[22] which reduces vascular resistance and vascular tone in peripheral arteries, and consequently may contribute to blood pressure reduction.[23] In contrast, there was no significant change in brachial blood pressure following a stretching intervention in middle-aged men, which might be due to the fact that baseline blood pressures of the participants were within the normal range.[12] Interestingly, the blood pressure of all participants in our study was within the normal range, but, in contrast to the study involving middle-aged men, ankle systolic blood pressure decreased after the stretching program. Therefore, this might imply that a program of stretching training can effectively lower ankle blood pressure.

The mechanisms responsible for the reduction in baPWV due to stretching exercise are not fully understood within the research community. However, a decrease in arterial stiffness may occur because stretching causes increased nitric oxide production, which could improve vascular endothelial function.[21] Stretching stimulates calcium to enter vascular endothelial cells through stretch-activated calcium channels, and this leads to an increase in nitric oxide production from the vascular endothelium.[24] The improvement in vascular endothelial function after stretching training might be associated with reactive hyperemia caused by decreased blood vessel diameter concomitant with temporary blood flow restriction during stretching stimuli.[25] Therefore, after a stretch is released, wall shear stress may be increased, thus improving expression and activation of nitric oxide.[26,27] Moreover, the generation of reactive oxygen species in vascular endothelium may be attenuated via acceleration in the expression of antioxidants in vascular endothelial cells that occurs following stretching exercise.[28] Stretching exercise might therefore inhibit the destruction of vascular endothelial wall caused by oxidative stress, which leads to a decrease in arterial stiffness. In addition, enhanced vagal activity produced by stretching training is also another possible mechanism involved in the alleviation of arterial stiffness.[29]

A previous study have indicated that people who have elevated ankle blood pressure had a 2.7-fold multivariate-adjusted risk of cardiovascular death and a 2.1-fold risk of death from any cause compared to people with normal brachial and ankle blood pressure.[6] On the other hand, a four-week stretching program was associated with a reduction in baPWV, with no significant change in blood pressure in middle-aged men.[13] Nevertheless, it is not only blood pressure but also other factors that are involved in reducing arterial stiffness after stretching exercises. Further study is required to examine the effect of stretching on the reduction of arterial stiffness. A limitation of the present study is that participants were healthy menopausal women, therefore our findings cannot be generalized to the general population of menopausal women and those who have different health status. In addition, we did not conduct a long-term follow-up to examine any possible sustained effects of stretching on vascular function.

In conclusion, the findings of this study demonstrated that stretching was effective as an alternative form of exercise to improve arterial function and blood pressure among postmenopausal women.

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Conflict of Interest

None to declare.

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