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ORIGINAL RESEARCH

Stretching is Superior to Brisk Walking for Reducing Blood Pressure in People With High–Normal Blood Pressure or Stage I Hypertension

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Background: Aerobic exercise is recommended for reducing blood pressure; however, recent studies indicate that stretching may also be effective. The authors compared 8 weeks of stretching versus walking exercise in men and women with high–normal blood pressure or stage 1 hypertension (ie, 130/85–159/99 mm Hg). **Methods:** Forty men and women (61.6 y) were randomized to a stretching or brisk walking exercise program (30 min/d, 5 d/wk for 8 wk). Blood pressure was assessed during sitting and supine positions and for 24 hours using a portable monitor before and after the training programs. **Results:** The stretching program elicited greater reductions than the walking program ($P < .05$) for sitting systolic (146 [9] to 140 [12] vs 139 [9] to 142 [12] mm Hg), supine diastolic (85 [7] to 78 [8] vs 81 [7] to 82 [7] mm Hg), and nighttime diastolic (67 [8] to 65 [10] vs 68 [8] to 73 [12] mm Hg) blood pressures. The stretching program elicited greater reductions than the walking program ($P < .05$) for mean arterial pressure assessed in sitting (108 [7] to 103 [6] vs 105 [6] vs 105 [8] mm Hg), supine (102 [9] to 96 [9] vs 99 [6] to 99 [7] mm Hg), and at night (86 [9] to 83 [10] vs 88 [9] to 93 [12] mm Hg). **Conclusions:** An 8-week stretching program was superior to brisk walking for reducing blood pressure in individuals with high–normal blood pressure or stage 1 hypertension.

Keywords: flexibility, aerobic, systolic, diastolic

Hypertension is a leading risk factor for cardiovascular disease, chronic kidney disease, and death[1] and the leading risk factor worldwide for death and disability.[2] Hypertension is thought to be an underlying cause for 1 in 6 deaths in North Americans and along with tobacco smoking, is estimated to be responsible for the highest number of preventable deaths.[3] Even individuals with high–normal blood pressure (ie, 130–139/85–89 mm Hg) have hazard ratios for coronary heart disease and stroke between 1.5 and 2.0 versus those with blood pressure <120/80 mm Hg.[4]

There is clear empirical evidence that increasing physical activity can reduce blood pressure in people with either normal (<140/90 mm Hg) or high blood pressure.[5] The American College of Sports Medicine position statement recommends that one should perform 30 minutes of continuous or accumulated mainly aerobic physical activity per day at a moderate intensity most days of the week to reduce blood pressure[6]; this recommendation is supported by systematic reviews.[5] Although aerobic exercise is the most recommended mode of exercise for reducing blood pressure, a number of recent studies indicate that stretching can reduce arterial stiffness, improve blood flow, and increase activation of the parasympathetic nervous system, resulting in reduced blood pressure.[7–9] When muscles are stretched, blood vessels are also stretched,[10] and this may lead to structural changes in blood vessels or release of vasodilating metabolites.[8,11,12] Such changes may result in the reduction of arterial stiffness, resistance to blood flow, and blood pressure.

If stretching exercise can, indeed, reduce blood pressure, it would allow an additional option for people who need to reduce blood pressure, or it could be added to aerobic exercise routines to provide greater reduction in blood pressure. Our purpose was to compare walking and stretching exercise programs in people with moderately elevated blood pressure. A recent meta-analysis of stretching programs[13] indicates similar reduction in systolic blood pressure (ie, −3.9 mm Hg) but potentially higher reduction in diastolic blood pressure (ie, −2.7 mm Hg) compared with recent meta-analyses of walking programs (reduction in systolic blood pressure of −3.1 to −4.1 mm Hg and reduction in diastolic blood pressure of −1.5 to −1.8 mm Hg).[14–16] The only study to compare a stretching to a walking program (in sedentary pregnant women) found that stretching was superior for reducing blood pressure (systolic blood pressure of −4 mm Hg and diastolic blood pressure of −1 mm Hg) compared with walking (systolic blood pressure of +5 mm Hg and diastolic blood pressure of +4 mm Hg).[17] We, therefore, hypothesized that stretching exercise would be more beneficial than walking exercise for reducing blood pressure.

Methods

The protocol was registered at clinicaltrials.gov (NCT03947996). The study was approved by the University of Saskatchewan Research Ethics Board, and all participants provided informed consent prior to participation.

Forty men and women were recruited from the general population by newspaper advertisement and posters on community boards. For study inclusion, participants were required to have high–normal blood pressure (130/85–139/89 mm Hg) or stage I hypertension (140/90–159/99 mm Hg) according to Hypertension Canada Guidelines[18] with the capability of walking unaided up to 30 minutes. Participants were excluded from the study if they were currently residing in a long-term care home; had unstable diabetes or diabetic condition taking insulin; had a cancer diagnosis in the past 2 years; had significant liver or other gastrointestinal disorders or inflammatory

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bowel disease; had significant kidney disorder; had history of unstable or severe cardiac disease; had heart attack or stroke in the past 2 years that severely affected physical mobility; had other unstable medical diseases or conditions, such as pulmonary disorder, epilepsy, or genitourinary disorder; were using hormone replacement therapy (with the exception of thyroid medication and/or estrogen creams); were using blood pressure medication and/or diuretics; or were participating in any other clinical trial within 1 month prior to randomization.

After baseline assessments, participants were randomly assigned in a 1:1 ratio using block sizes of 4 to a walking or stretching exercise program for 8 weeks. Randomization was done by an online random number generator and allocation list generated by a research assistant who was not involved in any other aspect of the study. The allocation list was concealed from the individual in charge of enrolling participants. With each newly enrolled participant, the enrolling research assistant contacted the research assistant in charge of allocation generation for the assigned exercise group. Although participants could not be blinded to group assignment, they were blinded to the hypothesis of the study. The individual involved in statistical analysis of the data was blinded to group assignment by coding of the groups.

At baseline (ie, before the exercise intervention) and at least 48 hours after the final exercise session, the following measurements were made: height, weight, waist circumference, sitting and supine blood pressure, 24-hour ambulatory blood pressure, food frequency questionnaires, Physical Activity Score for the Elderly (PASE) questionnaires, and a 6-minute walk test. Blood pressure was measured using a sphygmomanometer in sitting and supine positions. Waist circumference was measured at the level right above the iliac crest. During a 6-minute walking test, participants were asked to walk back and forth as fast as they could on a 30-m long track for 6 minutes. The total distance each participant walked was recorded.

Blood Pressure Measurements

Blood pressure was measured manually in sitting and supine positions with a mercury sphygmomanometer (model number 37217-2124; Abco Dealers Inc, Nashville, TN) after participants rested for 10 minutes. The cuff was placed over the bare arm about 2 cm above the elbow. Blood pressure was recorded to the nearest 2 mm Hg. The Oscar 2™system (SunTech Medical®; McArthur Medical Sales Inc, Rockton ON, Canada) was used to monitor blood pressure for 24-hour assessments. The device was set to measure blood pressure periodically, every 20 minutes during awake time and every 45 minutes during sleeping time. Maximum pressure was set to 180 mm Hg. Participants were instructed to wear the cuff for 24 hours. Whenever the device started to measure blood pressure, participants were asked to stay still and relax from what they were doing. Nighttime blood pressure was calculated as the average blood pressure from 12 AM to 6 AM. Daytime blood pressure was calculated as the average blood pressure from 9 AM to 10 PM. Validity of the ambulatory device is excellent: when compared with manually assessed blood pressure, the mean difference between the manually assessed blood pressure and the automated cuff was 0 (7) mm Hg for systolic and −1 (6) mm Hg for diastolic blood pressure.[19] Posttraining blood pressure measurements were taken at least 48 hours after the final training session to avoid the acute effects of exercise on blood pressure. We chose to assess blood pressure by different means (ie, sitting, supine, and ambulatory) for several reasons: sitting blood pressure is the most common mode to assess blood pressure; however, supine blood pressure may be more precise for detecting hypertension.[20] Ambulatory measures of blood pressure are recommended after hypertension is detected by office measurements (ie, either sitting or supine) to confirm whether hypertension is real or simply "white-coat" hypertension (ie, hypertension caused by anxiety in a doctor's office).[18]

Food Frequency Questionnaire

A food frequency questionnaire (Block 98.2 FFQ; Block Dietary Data Systems, Berkeley, CA) was given at baseline and after the intervention to determine the dietary pattern of each participant before and during the interventions. Each time, participants were asked to recall the dietary history for the last 2 months. A picture guide was given to estimate the serving portion. The questionnaire packages were sent to NutritionQuest (Block Dietary Data Systems) for analysis. All participants were counseled to follow the "DASH Eating Plan" (a diet that limits salt, sweets, sugary beverages, and red meat intake and emphasizes vegetables, fruits, low fat dairy, whole grains, fish, poultry, beans, and nuts).

PASE-Activity Scale

The Physical Activity Scale for the Elderly (PASE) was used to determine the activity level[21] before and during the last week of the interventions. The PASE is reliable and correlates with fitness measures such as strength, balance, and maximal oxygen consumption,[21,22] and energy expenditure as assessed by doubly labeled water.[23] Participants were asked to recall the last 7 days of physical activities, excluding those done during the exercise intervention. The reason for excluding physical activities done during the intervention was to see if the exercise intervention caused participants to compensate by reducing their other typical physical activities.

Exercise Protocol

The stretching program consisted of 21 stretching exercises of the lateral neck, inferior and posterior shoulder, shoulder protraction and extension, chest, gastrocnemius, soleus, latissimus dorsi, quadratus lumborum, quadriceps, hamstrings (2 different stretches), upper back, lower back, spinal rotators, hip flexors, hip extensors, hip adductors, hip abductors, and the gluteus. Each stretch was done twice and held for a 30-second duration with 15 seconds of rest between stretches. The exercise consisted of a 30-minute walking per session and was done on either outdoor walking trails or on a treadmill inside during inclement weather. The intensity was 50% to 65% of predicted maximal heart rate (220 – age). When doing outdoor walking, participants were instructed to count the number of beats in 15 seconds using their radial or carotid pulse. They were instructed to multiply their beats in 15 seconds by 4 to get beats per minute. Participants were instructed to count their pulse approximately 10 minutes into their exercise and toward the end of their exercise session. They were instructed to increase the walking speed if their pulse was lower than target heart rate. When walking inside on a treadmill, a heart rate monitor (Polar, Toronto ON, Canada) was used to assess heart rate and adjust treadmill speed accordingly to reach the target heart rate. For each exercise group, sessions were supervised 3 days per week. Participants were instructed to do exercise on their own another 2 days per week. A log book was given to monitor exercise compliance.

Statistical Analyses

Differences between groups over time for each outcome were determined by an exercise group (stretching vs walking) × sex (male vs female) × time (baseline vs 8 wk) analysis of variance with repeated measures on the "time" factor. As there were no group × sex × time interactions (indicating that males and females responded equally over time to the interventions), sexes were combined in analyses, and data were analyzed by exercise group × time analysis of variances to improve statistical power. If the group × time interaction was significant, a Bonferroni post hoc test was used to determine if there were differences between groups at specific time points or if there were differences within group from pretraining to posttraining. Differences between groups for post-intervention blood pressure measurements (ie, at 8th wk), along with absolute and relative (ie, in percentage) change scores, were also analyzed by an analysis of covariance with baseline blood pressure as a covariate. Significance was accepted at $\alpha \leq .05$. All results are presented as means (SD).

Results

Baseline characteristics of all participants randomized to walking or stretching exercise groups are presented in Table 1. Figure 1 shows the participant flow through the study. Four participants from the walking group (3 females and 1 male) and one participant from the stretching group (1 female) dropped out of the study due to lack of time to participate in the exercise programs and were lost to follow-up. Participants in the walking group completed 99% of assigned sessions compared with 98% for participants in the stretching group.

Table 2 shows the changes in blood pressure from pretraining to posttraining for walking and stretching exercise groups as well as adjusted posttraining means and change scores using baseline measures as a covariate. There were significant group × time interactions for nighttime diastolic and mean arterial blood pressures, sitting systolic and mean arterial blood pressures, and supine diastolic and mean arterial blood pressures, indicating greater reductions in the stretching compared with the walking group ($P < .05$). Stretching and walking groups did not differ over time for nighttime systolic blood pressure, daytime systolic, diastolic, or mean arterial blood pressures, sitting diastolic blood pressure, and supine systolic blood pressure. Using baseline measures as a covariate, adjusted posttraining means were significantly lower for stretching versus walking groups for nighttime systolic, diastolic, and mean arterial blood pressures and supine diastolic and mean arterial blood pressures. Absolute and relative (ie, in percentage) change scores between groups were also significantly different for each of these blood pressure variables when adjusted for baseline blood pressure.

Waist circumference decreased more in the walking (108 [13] to 103 [10] cm) compared with the stretching (100 [15] to 100 [16] cm) group (group × time; $P = .029$). There was no change in body mass over time for either group (data not shown).

There were no differences over time for PASE scores (walking 164 [61] to 152 [72] vs stretching 152 [53] to 175 [79] arbitrary units; group × time $P = .16$) or 6-minute walking distance (walking 539 [70] to 566 [78] vs stretching 552 [84] to 576 [78] m) between groups. Stretching and walking groups were similar over time for dietary intakes (Table 3). The baseline difference for sodium intake between groups was not significantly different ($P = .59$). The difference between groups for sodium intake over time was also not statistically different ($P = .74$).

Discussion

The most important finding from our study was that a program of stretching exercises was beneficial for reducing blood pressure in

Table 1 Baseline Measures for Stretching and Walking Exercise Groups

Measurement	Walking (n = 20; 11 males, 9 females)	Stretching (n = 20; 5 males, 15 females)
Age, y	61.2 (15.0)	61.9 (8.4)
Height, cm	170 (12)	165 (12)
Mass, kg	90.9 (14.1)	82.7 (20.1)
Waist girth, cm	103 (10)	100 (16)
6-min walk, m	539 (70)	552 (84)
PASE (arbitrary units)	164 (56)	151 (47)
Systolic blood pressure (mm Hg; nighttime)	127 (13)	124 (12)
Diastolic blood pressure (mm Hg; nighttime)	67 (7)	66 (7)
Mean arterial pressure (mm Hg; nighttime)	86 (9)	85 (9)
Systolic blood pressure (mm Hg; daytime)	145 (7)	145 (7)
Diastolic blood pressure (mm Hg; daytime)	81 (7)	84 (8)
Mean arterial pressure (mm Hg; daytime)	103 (5)	105 (5)
Systolic blood pressure (mm Hg; sitting)	138 (8)	145 (12)
Diastolic blood pressure (mm Hg; sitting)	88 (7)	89 (6)
Mean arterial pressure (mm Hg; sitting)	105 (6)	108 (7)
Systolic blood pressure (mm Hg; supine)	134 (7)	137 (16)
Diastolic blood pressure (mm Hg; supine)	83 (7)	85 (7)
Mean arterial pressure (mm Hg; supine)	100 (6)	102 (9)

Abbreviation: PASE, Physical Activity Scale for the Elderly. Note: All values are presented as mean (SD).

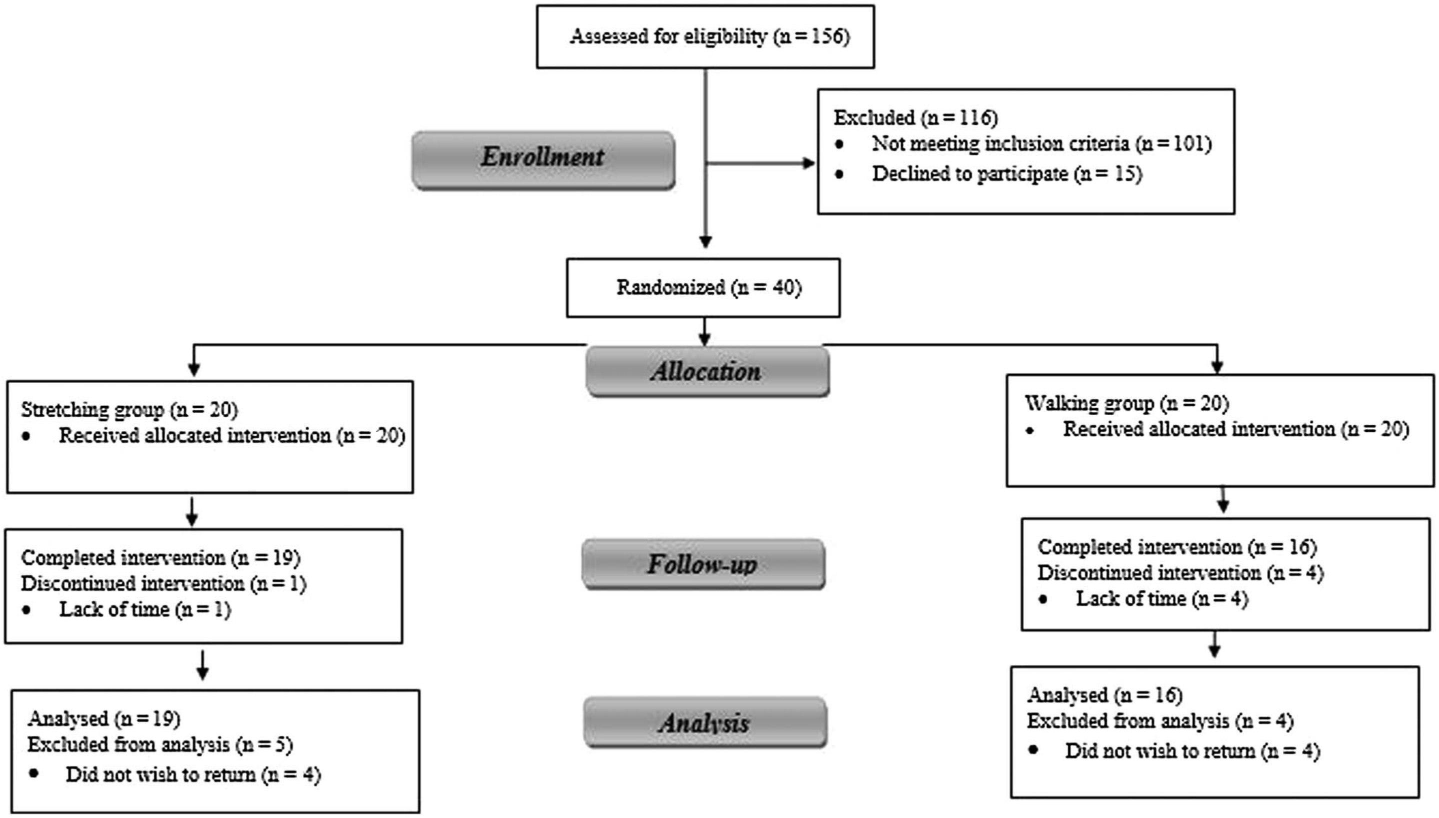

Figure 1 — CONSORT flow diagram.

people with high–normal or stage 1 hypertension. Specifically, in comparison with walking, the stretching program decreased systolic and mean arterial pressures while sitting, diastolic and mean arterial pressures while supine, and nighttime diastolic and mean arterial blood pressures. When baseline values were used as a covariate, adjusted posttraining means were lower in the stretching versus walking group for nighttime systolic, diastolic, and mean arterial blood pressures and supine diastolic and mean arterial blood pressures. The walking program was more effective than the stretching program for reducing waist circumference as expected from a program that most likely involved greater caloric expenditure. There were no changes between groups for physical activity outside of the intervention according to PASE scores, indicating that participants did not compensate for the exercise programs by decreasing their typical physical activity levels. Our study is the first to show that a stretching program is more effective than a walking program for reducing blood pressure in people with moderately elevated blood pressure. It might be ideal, therefore, to include a stretching program along with aerobic training such as walking, as walking is effective for reducing other cardiovascular disease risk factors such as blood glucose concentrations.[15]

Our finding of improved blood pressure with a stretching program is supported by a number of studies from the literature that have either found reduction in blood pressure, reduction in arterial stiffness, or improvement in vagal tone with stretching exercise programs. Two large cross-sectional studies have evaluated the relationship between flexibility, arterial stiffness, and blood pressure. One study of 1150 adults failed to find a relationship between flexibility and blood pressure; however, participants classified as having "poor" flexibility based on a sit-and-reach test (which assesses flexibility in the hamstrings and lower back) had significantly higher arterial stiffness than those with "good" flexibility.[24] The second study evaluated 566 adults and showed that those over 40 years with poor flexibility had a 30% higher arterial stiffness and a 5 mm Hg higher systolic blood pressure compared with those with good flexibility.[25] This latter study controlled for the effect of other aspects of physical fitness (eg, aerobic capacity) using a multiple regression model, showing that flexibility independently predicted a reduced arterial stiffness and blood pressure.

Cortez-Cooper et al[26] compared a program of flexibility training to other exercise training programs (ie, strength training and a program of combined strength and aerobic training). Training was 2 to 3 days per week over 13 weeks. Although there were minimal changes in blood pressure (ie, a 3 mm Hg reduction in systolic blood pressure in the flexibility group), the flexibility group had a 23% increase in carotid arterial compliance, whereas the other training groups had no change. This study indicates that flexibility training is superior to strength training or combined strength and aerobic training for improving arterial health. Study participants started the intervention with healthy blood pressure levels; those with hypertension at baseline were excluded, which could have minimized the change in blood pressure over the intervention, as there would have been little room for improvement. These results are similar to another study, which found significant reductions in arterial stiffness but minimal changes in blood pressure in a stretching versus control group over 4 weeks of 5 sessions per week of flexibility training.[27] Once again, all participants were normotensive at baseline, so this may have left little room for improvement.

Table 2 **Change in Blood Pressure With 8 Weeks of Walking or Stretching**

Measurement	Pretraining	Posttraining	Adjusted posttraining means[a]	Adjusted change score[a]	Adjusted % change[a]	Group × time *P* value	*P* value for adjusted means[b]	*P* value for adjusted % change
Night SBP								
Stretching	123 (12)	120 (13)	121 (13)	−4 (13)	−3 (11)	.11	.026	.019
Walking	128 (15)	133 (16)	132 (13)	6 (13)	6(10)			
Night DBP								
Stretching	67 (8)	65 (10)	66 (8)	−2 (8)	−3 (12)	.012	.012	.014
Walking	68 (8)	73 (12)	73 (8)	5 (8)	8 (12)			
Night MAP								
Stretching	86 (9)	83 (10)[†]	84 (9)	−3 (9)	−3 (10)	.026	.014	.013
Walking	88 (9)	93 (12)	92 (9)	5 (9)	6 (10)			
Day SBP								
Stretching	147 (7)	143 (11)	143 (11)	−4 (12)	−3 (8)	.33	.35	.38
Walking	146 (7)	146 (15)	146 (11)	0 (12)	0 (8)			
Day DBP								
Stretching	85 (7)	83 (8)	82 (6)	−1 (6)	−1 (7)	.49	.62	.61
Walking	82 (7)	82 (9)	84 (6)	0 (6)	0 (8)			
Day MAP								
Stretching	106 (6)	103 (8)	103 (8)	−2 (7)	−2 (7)	.38	.46	.46
Walking	104 (5)	104 (10)	104 (8)	0 (8)	0 (7)			
Sitting SBP								
Stretching	146 (9)	140 (12)	138 (11)	−4 (11)	−3 (7)	.035	.19	.16
Walking	139 (9)	142 (12)	143 (11)	1 (11)	1 (7)			
Sitting DBP								
Stretching	89 (6)	84 (6)	84 (7)	−4 (7)	−4 (7)	.11	.14	.15
Walking	87 (7)	87 (8)	88 (7)	−1 (7)	−1 (7)			
Sitting MAP								
Stretching	108 (7)	103 (6)*	102 (6)	−4 (6)	−4 (6)	.028	.09	.08
Walking	105 (6)	105 (8)	106 (6)	0 (6)	0 (6)			
Supine SBP								
Stretching	137 (16)	132 (14)	131 (11)	−4 (11)	−3 (8)	.47	.31	.52
Walking	134 (7)	133 (10)	134 (11)	−1 (11)	−1 (9)			
Supine DBP								
Stretching	85 (7)	78 (8)**	77 (7)	−6 (7)	−7 (8)	.0053	.015	.016
Walking	81 (7)	82 (7)	83 (7)	0 (7)	0 (8)			
Supine MAP								
Stretching	102 (9)	96 (9)**	95 (7)	−5 (7)	−5 (7)	.018	.043	.039
Walking	99 (6)	99 (7)	100 (7)	−1 (7)	0 (7)			

Abbreviations: DBP, diastolic blood pressure; MAP, mean arterial pressure; SBP, systolic blood pressure.
[a]Adjusted means using pretraining means as a covariate. [b]Note that adjusted *P* value represents difference between groups for adjusted posttraining means and adjusted change scores. Values are presented as mean (SD).
*Different from pretraining value ($P < 0.05$; Bonferroni post hoc). **Different from pretraining value ($P < 0.01$; Bonferroni post hoc). [†]Posttraining value for stretching different from walking ($P < 0.05$; Bonferroni post hoc).

Recent studies of individuals with higher baseline blood pressure or with normal blood pressure but with longer duration of training showed that flexibility training is effective for improving vascular health, decreasing sympathetic nervous system activation and improving blood pressure. In postmenopausal women with high–normal blood pressure or stage I hypertension (similar to the participants in our study), 8 weeks of flexibility training (3 d/wk) was superior to a nonexercise control for reducing systolic blood pressure (by 6 mm Hg) and diastolic blood pressure (by 3 mm Hg) and reducing sympathetic vasomotor modulation (assessed by the low-frequency component of systolic blood pressure variability) by 22%.[28] Similar to our study, Yeo[17] compared a stretching program to a walking program (both prescribed at 40 min/d, 5 d/wk) for effects on blood pressure but in a very different population of sedentary pregnant women with normal blood pressure. Their study involved the longest duration of flexibility training yet evaluated (ie, 38 wk). Systolic blood pressure decreased by 4 mm Hg in the stretching group and increased 5 mm Hg in the walking group

Table 3 Dietary Intakes

Group	Kcal/d		Protein, g/d		Fat, g/d		Carbohydrate, g/d		Sodium, mg/d	
	Pretraining	Post training	Pretraining	Post training	Pretraining	Post training	Pretraining	Post training	Pretraining	Post training
Stretching	1768 (682)	1595 (517)	75 (28)	71 (24)	82 (36)	72 (29)	182 (74)	164 (57)	2337 (778)	2060 (844)
Walking	1970 (591)	1820 (552)	71 (29)	71 (22)	95 (38)	86 (40)	198 (72)	188 (66)	2545 (1059)	2374 (1145)

Note: All values are presented as mean (SD).

(identical to the difference in change scores between groups for sitting systolic blood pressure in our study; Table 2). Diastolic blood pressure decreased by 1 mm Hg in the stretching group compared with a 4 mm Hg increase in the walking group (again this difference in change scores is identical to the current study for sitting diastolic blood pressure; Table 2). Another long-duration flexibility training study (6 mo, 5 times per week) in normotensive participants showed systolic blood pressure could be reduced by 9 mm Hg and diastolic blood pressure by 8 mm Hg.[9] Nitric oxide-dependent vasodilation was improved by 3 months of training, whereas arterial stiffness was significantly reduced by 6 months of training. Six months of detraining resulted in most of the changes returning to baseline. Studies of exercise interventions that included stretching as a major component (ie, yoga, Pilates) show excellent benefit for reducing blood pressure. A systematic review of yoga interventions in prehypertensive and hypertensive individuals showed that yoga reduces systolic blood pressure by 10 mm Hg and diastolic blood pressure by 7 mm Hg.[29] A study of a 16-week Pilates intervention using ambulatory blood pressure monitoring in hypertensive women compared with healthy controls showed reductions in daytime systolic and diastolic blood pressure of 11 and 5 mm Hg and reduction in nighttime systolic and diastolic blood pressure of 7 and 3 mm Hg, respectively.[30] The ability to conclude that stretching in these programs was the driver for reducing blood pressure is limited because yoga and Pilates also involve isometric muscle contractions, and yoga involves breathing control and meditation, all of which can reduce blood pressure in addition to stretching.[31–33]

There are a number of physiological mechanisms by which stretching might be effective for reducing blood pressure. When muscle is stretched as in flexibility training, blood vessels are also stretched.[10] This may induce structural changes within blood vessels[11] that can affect blood vessel diameter or decrease arterial stiffness to reduce resistance to flow, which, in turn, reduces blood pressure. When rabbit carotid arteries were chronically stretched, endothelial cell and smooth muscle cell replication rate was increased, and there was remodeling of the endothelial matrix with increased elastin and collagen contents.[11] Stretching may produce ischemia within muscles, which may trigger vascular adaptations.[8] Stretching of lower hind limbs of older rats (30 min/d, 5 d/wk for 4 wk) resulted in increased production of vascular endothelial growth factor and increased capillarization, adaptations that led to decreased vascular resistance, which could potentially decrease blood pressure.[8] Another mechanism by which stretching might affect blood pressure is that stretching of blood vessels induces the release of metabolites from endothelial cells that cause vasodilation. For example, in the same study with older rats, chronic stretching increased nitric oxide synthase levels, leading to increased endothelial-dependent vasodilation and blood flow during exercise.[8] Healthy participants who performed 12 weeks of stretching of the knee extensors and plantar flexors (4 stretches performed 5 times each for 45 s, 5 sessions per week) increased flow-mediated dilation, which is dependent on nitric oxide release.[34] A final mechanism by which stretching might affect blood pressure is via its effect on the sympathetic and parasympathetic nervous systems. Following an acute bout of stretching, there is a reduced activation of the sympathetic nervous system in conjunction with an increased activation of the parasympathetic nervous system.[7] This would decrease vasoconstriction and increase vasodilation, reducing resistance to blood flow, causing a decrease in blood pressure.

A limitation of our study is the relatively small sample size; the study needs to be replicated in a larger randomized controlled trial. All of our blood pressure changes showed similar trends to be reduced by the stretching program; however, some of the changes were not statistically significant. There may have been a lack of statistical power for some of our analyses. This lack of statistical power permitted us to include only one covariate in our analyses (ie, baseline blood pressure). A larger sample size would have permitted inclusion of other covariates, such as sodium intake, age, and physical activity outside the exercise program. Another limitation is that we did not assess any physiological mechanisms by which stretching might reduce blood pressure, such as changes in arterial stiffness, vasodilation, or parasympathetic nervous system activation. There were no changes in the 6-minute walking score in participants who performed our walking program. This indicates that our walking program (eliciting target heart rate 50%–65% of predicted maximal heart rate) may not have been of sufficient intensity; however, a recent meta-analysis indicates there is only a weak dose–response relationship between the intensity of exercise training and reduction in blood pressure.[15] A greater number of participants dropped out of the walking program (ie, 4) compared with the stretching program (ie, one). This is in agreement with one other study that found greater adherence to stretching versus walking programs (although this study was in a very different population; ie, pregnant women).[17] Changes in physical activity outside of the intervention may affect results. In our study, we assessed changes in physical activity between groups using the PASE questionnaire, which has been validated against gold-standard methods for physical activity assessment.[23] Using this questionnaire, we found no significant changes in physical activity levels outside of the intervention between groups. Future studies should use more accurate assessments of physical activity, such as pedometers or accelerometers. A final limitation was that there was an imbalance of men and women across groups; however, we did not observe any significant group × sex × time interactions, indicating that men and women responded similarly to the exercise interventions. Future studies that include men and women should consider stratifying by sex prior to randomization.

In summary, our study shows for the first time that a stretching program might be more effective than a walking program for reducing blood pressure in people with moderately-elevated blood pressure. This finding is important as it offers people a greater number of exercise options for reducing blood pressure. Considering that walking is beneficial for reducing other cardiovascular risk factors (ie, waist circumference in the present study), it might be best to add a comprehensive stretching routine to aerobic exercise for overall cardiovascular benefit.

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Erratum: Ko et al. (2021)

In the original publication of this article, the clinical trial registration number was incorrectly listed in the text and acknowledgments as NCT02391779; the correct registration number is NCT03947996. The online version of this article has been corrected. The authors regret this error.