

Effect of Exercise on Blood Pressure in Older Persons

A Randomized Controlled Trial

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Background: Because of age-related differences in the cause of hypertension, it is uncertain whether current exercise guidelines for reducing blood pressure (BP) are applicable to older persons. Few exercise studies in older persons have evaluated BP changes in relation to changes in body composition or fitness.

Methods: This was a 6-month randomized controlled trial of combined aerobic and resistance training; controls followed usual care physical activity and diet advice. Participants (aged 55-75 years) had untreated systolic BP (SBP) of 130 to 159 mm Hg or diastolic BP (DBP) of 85 to 99 mm Hg.

Results: Fifty-one exercisers and 53 controls completed the trial. Exercisers significantly improved aerobic and strength fitness, increased lean mass, and reduced general and abdominal obesity. Mean decreases in SBP and DBP, respectively, were 5.3 and 3.7 mm Hg among exercisers and 4.5 and 1.5 mm Hg among con-

trols ($P < .001$ for all). There were no significant group differences in mean SBP change from baseline (-0.8 mm Hg; $P = .67$). The mean DBP reduction was greater among exercisers (-2.2 mm Hg; $P = .02$). Aortic stiffness, indexed by aortofemoral pulse-wave velocity, was unchanged in both groups. Body composition improvements explained 8% of the SBP reduction ($P = .006$) and 17% of the DBP reduction ($P < .001$).

Conclusions: A 6-month program of aerobic and resistance training lowered DBP but not SBP in older adults with mild hypertension more than in controls. The concomitant lack of improvement in aortic stiffness in exercisers suggests that older persons may be resistant to exercise-induced reductions in SBP. Body composition improvements were associated with BP reductions and may be a pathway by which exercise training improves cardiovascular health in older men and women.

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EXERCISE IS RECOMMENDED for reducing blood pressure (BP); however, the existing studies in older persons are generally small and have inconsistent results.¹ In younger persons, hypertension often results from a higher cardiac output state,² whereas in older persons, hypertension more often results from increased peripheral vascular resistance² and large artery stiffening.³ Because of age-related differences in the cause of hypertension, it is not certain whether current exercise guidelines for hypertension¹ fully apply to older persons.

Loss of muscle mass and increased total fat, particularly abdominal fat, are also key features of aging⁴ that correlate with many cardiovascular abnormalities, including hypertension.⁵ Exercise training improves body composition in older persons^{6,7}; however, few studies in older persons have addressed whether changes in BP are mediated by changes in body com-

position or fitness. The Senior Hypertension and Physical Exercise (SHAPE) study was a randomized controlled trial to determine whether older men and women can achieve a clinically significant reduction in BP from a 6-month supervised program of combined aerobic and resistance training.

METHODS

PARTICIPANTS

Participants were aged 55 to 75 years and had untreated milder forms of hypertension. Recruitment was primarily through newspaper advertising. Exclusions consisted of cardiovascular diseases or other serious illnesses, electrocardiographic abnormalities indicative of myocardial infarction or heart block, smoking, diabetes mellitus, and regular moderate-intensity exercise of greater than 3 to 6 metabolic equivalents for 90 minutes per week.⁸ The use of hormone therapy by women was al-

lowed. Written informed consent was obtained from all participants. The study was approved by the institutional review board at the Johns Hopkins School of Medicine (Baltimore, Md) and was conducted between July 1, 1999, and November 30, 2003.

BLOOD PRESSURE ELIGIBILITY

We followed the general procedures of the Treatment of Mild Hypertension Study.⁹ Participants who were not using antihypertensive medications entered BP screening without delay. With their physicians' approval, participants who were using a single antihypertensive medication entered BP screening 2 weeks after discontinuing use of the medication. Participants were seen weekly and were required to have a systolic BP (SBP) of 130 to 159 mm Hg or a diastolic BP (DBP) of 85 to 99 mm Hg during 2 consecutive visits and an average BP in this range across 4 visits. These levels correspond to prehypertension or stage 1 hypertension according to the guidelines of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.¹⁰ Maximal exercise testing was performed on 158 participants who had eligible BP levels. Exclusions based on exercise testing were ST-segment depression greater than 1 mm, complex arrhythmias, or ischemic symptoms. Ultimately, 115 participants were randomized to the study groups (**Figure**).

BASELINE AND 6-MONTH FOLLOW-UP MEASURES

Blood Pressure

Blood pressure at screening, baseline, and 6 months was measured using an automated device (Dinamap MPS Select; Johnson & Johnson, New Brunswick, NJ) by nurses at the Johns Hopkins Bayview General Clinical Research Center, Baltimore, Md. These visits were scheduled for the same time of day for each participant and at least a day after an exercise workout. After 5 minutes of sitting rest, BP was measured 3 times, with 1 minute between readings. If the BPs differed by more than 5 mm Hg, additional readings were obtained. The mean of 3 consecutive readings within 5 mm Hg of each other was used as the examination value. The mean BP of all screening visits and an additional visit after the participant qualified for the study but before randomization was used as the baseline BP. Final BP was the mean of BP measurements taken twice during the last month of the intervention period and once during the final testing period.

Aerobic and Strength Fitness

Peak oxygen uptake was determined on a treadmill using a SensorMedics Vmax 229 Metabolic System (SensorMedics Inc, Yorba Linda, Calif). The initial walking speed was 4.8 km/h at a grade of 0%, and the grade increased by 2.5% every 3 minutes. Participants were encouraged to reach 18 or higher on the Borg Rating of Perceived Exertion Scale,¹¹ and they stopped at volitional fatigue.

Muscle strength was assessed by 1-repetition maximum on each of 7 exercises on a multistation machine (Hoist 6000; Hoist Fitness, San Diego, Calif). One-repetition maximum is the highest weight lifted following methods described elsewhere.¹² The upper body exercises were the bench press, shoulder press, seated mid-rowing, and latissimus dorsi pull down. The lower body exercises were the leg extension, leg curl, and leg press. Total strength is the sum of the weights of these 7 exercises.

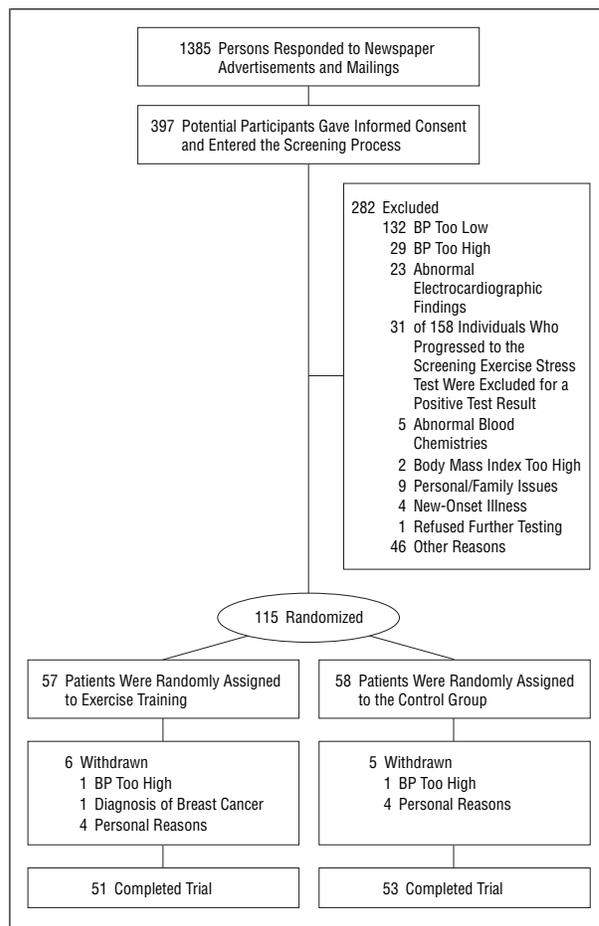


Figure. Progress of the participants through the Senior Hypertension and Physical Exercise (SHAPE) study. BP indicates blood pressure.

Body Composition

Body weight and height were measured while wearing minimal clothing. Waist circumference was measured at the narrowest part of the torso. Body mass index was calculated as weight in kilograms divided by the square of height in meters. Total fat mass, lean mass, and percentage of body fat were determined using dual-energy x-ray absorptiometry (GE Lunar Prodigy; General Electric Medical Systems, Milwaukee, Wis). Abdominal total, visceral, and subcutaneous fat were measured from images obtained using a magnetic resonance imaging system (Siemens Vision 1.5T; Siemens Medical Systems, Iselin, NJ). Using the National Institutes of Health image application (<http://rsb.info.nih.gov/nih-image/>), an experienced reader traced and averaged the areas of interest from 3×512^2 of 1-cm-thick axial plane inversion-recovery images at 1 slice below, at, and above the umbilicus. The procedures used for analyzing abdominal fat are described elsewhere.^{12,13} The estimated coefficients of variation are 1.6% for subcutaneous fat and 6.5% for abdominal visceral fat.

Arterial Stiffness

Aortic stiffness was measured by aortofemoral pulse-wave velocity using methods described elsewhere.¹⁴ Briefly, pulse-wave velocity is the distance or transit time (in centimeters per second) of the pulse wave from the base of the neck for the common carotid to the right femoral artery. The pulse waves at these sites were obtained simultaneously using Doppler probes. The distance traveled by the pulse wave was measured over the partici-

pant's torso. The carotid to the aortic distance was subtracted from the sum of the aortic to umbilicus to femoral site to adjust for the opposite blood flow in that arterial branch. The reproducibility of this method in our laboratory yields Pearson and intraclass correlation coefficients of 0.90 and 0.88, respectively.

Diet and Physical Activity

The Stanford Seven Day Physical Activity Recall Survey¹⁵ was used to assess total daily energy expenditure. Dietary data were obtained from 3-day food records and were analyzed using a software program (Nutritionist V; First DataBank, San Bruno, Calif). The dietary analysis focused on total daily energy intake and salt intake.

Exercise Intervention

Following American College of Sports Medicine guidelines,¹ participants attended 3 supervised sessions per week. The prescribed number of sessions was 78 (3 days a week for 26 weeks). If a participant had attended fewer than 62 sessions at 6 months (80% compliance), an extra month was allowed to get as close to 62 sessions as possible.

Each session began with a stretching warm-up, followed by resistance training and then aerobic training. Resistance training consisted of 2 sets of 10 to 15 repetitions per exercise at 50% of 1-repetition maximum on the same weight machine used for testing. The exercises were the latissimus dorsi pull down, leg extension, leg curl, bench press, leg press, shoulder press, and seated mid-rowing. When the participant completed 15 repetitions of an exercise with little difficulty, the weight was increased. Aerobic exercise lasted 45 minutes, and participants were allowed to choose a treadmill, stationary cycle, or stair stepper for their workout. Participants wore heart rate (HR) monitors (Polar Inc, Lake Success, NY) that were programmed for a target HR range of 60% to 90% of maximum HR. As fitness improved, the exercise workload was increased to maintain target HR levels.

Control Group Diet and Physical Activity and BP Monitoring

Because activity and diet are usual care recommendations for hypertension,¹⁰ participants were given the National Institute on Aging guidelines for exercise (<http://www.niapublications.org/exercisebook>) and the American Heart Association Step 1 diet (<http://www.americanheart.org>) before randomization. No additional dietary advice was provided, and participants were asked to maintain their normal caloric intake during the study. During recruitment, participants were told that they could join the supervised program for up to 6 months after the intervention period ended, and all were given the same monthly stipend. Participants in both groups reported to the research center twice monthly for BP safety checks. If SBP was greater than 159 mm Hg or DBP was greater than 99 mm Hg, patients were assessed weekly; patients were withdrawn if the BP was higher than the acceptable range for 4 consecutive weeks.

STATISTICAL ANALYSIS

Data analysis was performed using a software program (JMP 5.1; SAS Institute Inc, Cary, NC). Assuming standard deviations for SBP and DBP of 8 and 6 mm Hg, respectively, it was determined that 96 participants would yield 80% power to detect group and sex differences in SBP and DBP of 4.5 and 3.5 mm Hg, respectively. Independent *t* tests were used to examine between-group differences at baseline. For each variable, the change from

baseline to 6 months was calculated. Analyses were performed on change scores using the mixed model procedure, with group and sex as categorical variables and baseline measures as covariates. Analysis of variance with repeated measures was used to evaluate changes within groups. Pearson correlation coefficients were calculated for BP changes vs changes in other variables. Variables that correlated significantly with BP changes were entered into stepwise regression models.

RESULTS

There were 8 dropouts (4 per group for personal reasons) and 3 withdrawals (1 per group for elevated BP and 1 exerciser for an unrelated illness). Complete data are available for 104 participants: 51 exercisers (25 men and 26 women) and 53 controls (26 men and 27 women). Their overall mean \pm SD age was 63.6 \pm 5.7 years; 87% were non-Hispanic white, 11% were African American, 1% were Asian American, and 1% were Hispanic. Among participants who completed the study, there were no significant group differences in baseline characteristics (**Table 1**). Participants who did not complete the study (data not shown) had baseline characteristics similar to those who completed the study.

ADHERENCE TO THE EXERCISE PROGRAM

Exercisers completed a mean \pm SD of 69 \pm 8 of their prescribed 78 sessions (88%). Eleven participants exercised for an extra month because of missed sessions, and 1 participant did not meet 80% compliance, having attended 34 sessions (44%). The mean \pm SD HR was 135.5/min \pm 10.4/min during a mean \pm SD of 2587 \pm 55 seconds per session spent in aerobic exercise. Exercise HR was in the prescribed ranges 98% of the time.

CHANGES FROM BASELINE FOR KEY STUDY OUTCOME VARIABLES

After 6 months, exercisers reduced their SBP and DBP by a mean of 5.3 and 3.7 mm Hg, respectively ($P < .001$ for both); controls reduced their SBP and DBP by a mean of 4.5 and 1.5 mm Hg, respectively ($P < .001$ for both) (**Table 2**). The DBP reduction was greater among exercisers vs controls by -2.2 mm Hg ($P = .02$). The SBP reduction was not significantly different between groups ($P = .67$). Pulse-wave velocity, which was measured in a subset of 82 participants (40 exercisers [21 men and 19 women] and 42 controls [21 men and 21 women]), did not change significantly within or between groups. The exercisers exceeded controls in increases in peak oxygen uptake by 4.1 mL/kg per minute and total strength by 53.7 kg ($P < .001$ for both). Exercisers also lost 2.3 kg of body weight compared with a 0.5-kg loss among controls ($P < .001$), which yielded a reduction in body mass index of 0.7 more than controls ($P < .001$). Exercisers reduced their percentage of body fat by 3.5% and increased their percentage of lean body mass by 3.5% more than controls ($P < .001$ for both). The greater reduction in total abdominal fat by -46.0 cm² among exercisers ($P < .001$) was accounted for by greater reductions of 23 cm² in abdominal subcutaneous fat and 23 cm² in abdominal visceral fat area ($P < .001$ for both).

Table 1. Baseline Characteristics of 104 Randomized Participants in the Senior Hypertension and Physical Exercise (SHAPE) Study

Characteristic	Exercise Group (n = 51)	Control Group (n = 53)	P Value*
Age, mean (95% CI), y	63.0 (61.5 to 64.5)	64.1 (62.4 to 65.8)	.35
Resting hemodynamics, mean (95% CI)			
Systolic blood pressure, mm Hg	140.3 (138.2 to 142.4)	141.7 (139.7 to 143.8)	.33
Diastolic blood pressure, mm Hg	76.8 (74.8 to 78.9)	76.4 (73.9 to 78.9)	.78
Heart rate, beats/min	69.8 (67.7 to 71.9)	71.9 (69.3 to 74.4)	.22
Aerobic and strength fitness, mean (95% CI)			
Peak oxygen uptake, mL/kg per minute	24.4 (22.9 to 25.9)	24.2 (22.8 to 25.7)	.85
Upper body muscle strength, kg	173.2 (154.5 to 192.0)	175.9 (155.9 to 195.9)	.84
Lower body muscle strength, kg	155.2 (141.0 to 169.4)	151.8 (138.8 to 164.7)	.72
Total muscle strength, kg	328.4 (296.2 to 360.6)	327.7 (295.3 to 360.0)	.97
Body composition, mean (95% CI)			
Body mass index, kg/m ²	29.4 (28.3 to 30.4)	29.7 (28.3 to 31.0)	.75
Weight, kg	83.2 (79.1 to 87.3)	84.9 (79.6 to 90.2)	.61
Waist circumference, cm	94.0 (90.6 to 97.3)	95.0 (91.1 to 99.0)	.68
Abdominal total fat (MRI), cm ²	432.6 (399.5 to 465.6)	449.6 (404.2 to 495.0)	.54
Abdominal visceral fat (MRI), cm ²	146.5 (127.3 to 165.7)	142.7 (123.7 to 161.6)	.77
Abdominal subcutaneous fat (MRI), cm ²	285.1 (255.4 to 314.9)	305.7 (268.9 to 342.4)	.38
Total body fat (DXA), %	37.9 (35.4 to 40.4)	37.7 (35.0 to 40.5)	.54
Lean body mass (DXA), %	58.5 (56.1 to 61.5)	58.9 (56.2 to 61.5)	.85
Aortic stiffness, mean (95% CI)			
Pulse to wave velocity, cm/s†	900.9 (824.0 to 997.9)	940 (843 to 1037)	.53

Abbreviations: CI, confidence interval; DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance imaging.

*None of the comparisons of baseline characteristics between exercise and control subjects were statistically significant.

†Performed in a subset of 82 participants (40 exercisers [21 men and 19 women] and 42 controls [21 men and 21 women]).

Table 2. Changes in Blood Pressure, Fitness, Body Composition, and Aortic Stiffness From Baseline in 104 Randomized Participants

Variable	Exercise Group (n = 51)	Control Group (n = 53)	Difference (Exercise – Control)	P Value*
Resting hemodynamics, mean (95% CI)				
Systolic blood pressure, mm Hg	-5.3 (-8.1 to -2.5)	-4.5 (-6.7 to -2.2)	-0.8 (-4.4 to 2.8)	.67
Diastolic blood pressure, mm Hg	-3.7 (-5.1 to -2.4)	-1.5 (-2.9 to -0.2)	-2.2 (-4.1 to -0.3)	.02
Heart rate, beats/min	-3.9 (-5.4 to -2.4)	-2.2 (-3.8 to 0.5)	-1.8 (-4.1 to 0.5)	.12
Aerobic and strength fitness, mean (95% CI)				
Peak oxygen uptake, mL/kg per minute	4.0 (3.2 to 4.8)	-0.1 (-0.8 to 0.5)	4.1 (3.1 to 5.2)	<.001
Upper body muscle strength, kg	28.0 (23.9 to 32.1)	0.8 (-2.7 to 4.3)	27.3 (21.8 to 32.5)	<.001
Lower body muscle strength, kg	29.3 (25.0 to 33.7)	2.8 (-1.7 to 7.4)	26.5 (20.3 to 32.7)	<.001
Total muscle strength, kg	57.3 (49.6 to 64.7)	3.6 (-2.6 to 9.9)	53.7 (44.0 to 63.3)	<.001
Body composition, mean (95% CI)				
Body mass index, kg/m ²	-0.8 (-1.1 to -0.5)	-0.2 (-0.4 to 0.1)	-0.7 (-1.1 to -0.3)	<.001
Weight, kg	-2.3 (-3.1 to -1.4)	-0.5 (-1.2 to 0.1)	-1.7 (-2.8 to -0.7)	.002
Waist circumference, cm	-2.9 (-4.1 to -1.7)	-0.8 (-1.8 to 0.1)	-2.0 (-3.6 to -0.5)	.01
Abdominal total fat (MRI), cm ²	-52.5 (-66.6 to -38.7)	-6.5 (-20.3 to 7.3)	-46.0 (-65.4 to -26.5)	<.001
Abdominal visceral fat (MRI), cm ²	-26.7 (-35.6 to -17.9)	-3.8 (-10.8 to 3.3)	-23.0 (-34.2 to -11.8)	<.001
Abdominal subcutaneous fat (MRI), cm ²	-25.8 (-35.1 to -16.5)	-2.9 (-11.7 to 6.0)	-23.0 (-35.7 to -10.3)	<.001
Total body fat (DXA), %	-3.5 (-0.4 to -2.8)	-0.2 (-0.7 to 0.3)	-3.3 (-4.1 to -2.4)	<.001
Lean body mass (DXA), %	3.5 (2.8 to 4.2)	0.2 (-0.3 to 0.7)	3.3 (2.4 to 4.1)	<.001
Aortic stiffness, mean (95% CI)				
Pulse-wave velocity, cm/s†	111.2 (-35 to 257.5)	16.9 (-96 to 130)	94.4 (-276.5 to 87.8)	.35

Abbreviations: CI, confidence interval; DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance imaging.

*Test for between-group difference on the change from baseline.

†Performed in a subset of 82 participants (40 exercisers [21 men and 19 women] and 42 controls [21 men and 21 women]).

SEX DIFFERENCES IN THE RESPONSE TO EXERCISE TRAINING

Among exercisers, men had greater increases in upper body ($P < .001$), lower body ($P = .03$), and total ($P < .001$) muscle strength than women (**Table 3**). Exercising men also had greater reductions in abdominal visceral fat ($P = .004$). No other sex differences in response to exercise were observed.

CHANGES IN HABITUAL PHYSICAL ACTIVITY AND DIET

There were no significant within- or between-group differences for changes in total daily energy or sodium dietary intake. Total daily energy expenditure increased by 2.2 kcal/kg among exercisers ($P = .02$) and by a nonsignificant 0.7 kcal/kg among controls ($P = .27$).

Table 3. Change From Baseline by Sex and Intervention Group*

Variable	Men	Women	Difference (Men – Women)
Resting hemodynamics, mean (95% CI)			
Systolic blood pressure, mm Hg			
Exercise	–3.3 (–7.0 to 0.5)	–7.2 (–11.6 to –2.9)	–4.0 (–9.6 to 1.6)
Control	–4.2 (–7.0 to –1.5)	–4.7 (–8.4 to –1.0)	–0.5 (–0.5 to 4.1)
Diastolic blood pressure, mm Hg			
Exercise	–4.5 (–6.3 to –2.6)	–3.0 (–5.1 to –0.9)	1.5 (–1.2 to 4.1)
Control	–2.4 (–4.4 to –0.4)	–0.7 (–2.6 to 1.2)	1.6 (–1.1 to 4.3)
Heart rate, beats/min			
Exercise	–4.7 (–6.5 to –2.9)	–3.2 (–5.7 to –0.7)	1.5 (–1.5 to 4.5)
Control	–2.8 (–5.2 to –0.5)	–1.5 (–4.0 to 1.0)	1.3 (–2.0 to 4.7)
Aerobic and strength fitness, mean (95% CI)			
Peak oxygen uptake, mL/kg per minute			
Exercise	4.3 (2.9 to 5.8)	3.7 (2.8 to 4.5)	–0.6 (–2.3 to 1.0)
Control	0.2 (–0.8 to 1.3)	–0.5 (–1.3 to 0.3)	–0.7 (–2.0 to 0.5)
Total muscle strength, kg			
Exercise	69.7 (58.9 to 80.6)	45.8 (37.3 to 54.4)	–23.9 (–37.4 to –10.4)†
Control	2.7 (–10.0 to 15.4)	4.5 (0.1 to 8.9)	1.9 (–11.5 to 15.1)
Upper body muscle strength, kg			
Exercise	35.5 (28.9 to 42.0)	21.1 (17.4 to 24.8)	–14.4 (–21.7 to –7.0)†
Control	1.8 (–4.7 to 8.4)	–0.2 (–3.4 to 3.1)	–2.0 (–9.2 to 5.2)
Lower body muscle strength, kg			
Exercise	34.3 (28.0 to 40.5)	24.7 (18.9 to 30.6)	–9.5 (–17.9 to –1.2)‡
Control	0.8 (–8.4 to 10.1)	4.7 (1.8 to 7.6)	3.9 (–5.8 to 13.5)
Body composition, mean (95% CI)			
Body mass index, kg/m ²			
Exercise	–0.7 (–1.1 to –0.4)	–0.9 (–1.4 to –0.4)	–1.7 (–0.8 to 4.8)
Control	–0.2 (–0.5 to 0.2)	–0.2 (–0.5 to 0.2)	0.0 (–0.5 to 4.8)
Weight, kg			
Exercise	–2.2 (–3.3 to –1.1)	–2.3 (–3.7 to –0.1)	–0.1 (–1.8 to 1.6)
Control	–0.6 (–1.7 to 0.4)	–0.5 (–1.4 to 0.4)	0.2 (–1.2 to 1.5)
Waist, cm			
Exercise	–3.0 (–5.0 to –1.1)	–2.7 (–4.3 to –1.1)	0.3 (–2.2 to 2.7)
Control	–1.4 (–2.6 to –0.1)	–0.3 (–1.7 to 1.2)	1.1 (–0.8 to 3.0)
Abdominal total fat (MRI), cm ²			
Exercise	–64.6 (–80.2 to –49.1)	–41.7 (–64.7 to –18.8)	22.9 (–4.2 to 50.0)
Control	–11.1 (–30.2 to 8.0)	–2.1 (–23.0 to 18.9)	9.0 (–18.6 to 36.7)
Abdominal visceral fat (MRI), cm ²			
Exercise	–40.6 (–54.8 to –26.3)	–14.5 (–23.9 to –5.2)	26.0 (9.4 to 42.7)§
Control	–7.4 (–18.6 to 3.9)	–0.3 (–9.4 to 8.9)	7.1 (–7.1 to 21.3)
Abdominal subcutaneous fat (MRI), cm ²			
Exercise	–24.1 (–35.0 to –13.3)	–27.3 (–42.7 to –11.9)	–3.2 (–21.6 to 15.2)
Control	–4.0 (–14.7 to 6.7)	–1.7 (–16.5 to 13.0)	2.3 (–15.6 to 20.1)
Total body fat (DXA), %			
Exercise	–3.6 (–4.5 to –2.7)	–3.4 (–4.6 to –2.3)	1.9 (–1.2 to 1.6)
Control	–0.2 (–0.1 to 0.5)	–0.3 (–0.1 to 0.5)	0.0 (–1.1 to 0.1)
Lean body mass (DXA), %			
Exercise	3.6 (2.7 to 4.4)	3.4 (2.3 to 4.5)	0.2 (–1.5 to 1.2)
Control	0.2 (–0.6 to 0.9)	0.2 (–0.6 to 1.0)	0.1 (–0.1 to 1.1)
Aortic stiffness, mean (95% CI)			
Pulse-wave velocity, cm/s			
Exercise	46.0 (–117.5 to 209.4)	183.4 (–80.4 to 447.1)	137.4 (–164.6 to 439.4)
Control	6.0 (–97.9 to 109.9)	27.8 (–184.2 to 239.7)	21.8 (–209.6 to 253.2)

Abbreviations: CI, confidence interval; DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance imaging.

*There were 51 exercisers (25 men and 26 women) and 53 controls (26 men and 27 women).

† $P < .001$ for the difference between men and women.

‡ $P = .03$ for the difference between men and women.

§ $P = .004$ for the difference between men and women.

||Performed in a subset of 82 participants (40 exercisers [21 men and 19 women] and 42 controls [21 men and 21 women]).

CORRELATES OF CHANGE IN BP

The SBP change correlated with changes in abdominal total fat ($P = .006$) and abdominal subcutaneous fat ($P = .006$) and with abdominal visceral fat at the $P = .07$

level (**Table 4**). The DBP change correlated with changes in peak oxygen uptake ($P = .02$), total muscle strength ($P = .02$), body weight ($P = .05$), percentage of body fat ($P < .001$), percentage of lean body mass ($P = .002$), abdominal total fat ($P = .001$), abdominal subcutaneous fat

Table 4. Pearson Correlation Coefficients for Changes in Blood Pressure vs Changes in Selected Variables*

Variable	Systolic Blood Pressure	P Value	Diastolic Blood Pressure	P Value
Peak oxygen uptake	-0.04	.68	-0.24	.02
Total muscle strength	-0.03	.76	-0.23	.02
Weight	0.17	.09	0.20	.05
Body mass index, kg/m ²	0.12	.23	0.14	.15
Waist	0.12	.23	0.18	.07
Percentage of total body fat	0.17	.08	0.31	.001
Percentage of total lean mass	-0.16	.09	-0.30	.002
Abdominal total fat	0.18	.07	0.24	.02
Abdominal visceral fat	0.27	.006	0.30	.003
Abdominal subcutaneous fat	0.27	.006	0.27	.006
Pulse-wave velocity	-0.17	.14	-0.11	.35
Total daily energy expenditure	-0.13	.18	-0.20	.04
Total daily energy intake	0.16	.11	0.15	.12
Sodium intake	0.10	.37	0.10	.34

*There were 104 participants for each variable except pulse-wave velocity (n = 82).

($P = .006$), abdominal visceral fat ($P = .003$), and total daily energy expenditure ($P = .04$). Changes in pulse-wave velocity were not correlated with changes in BP. In stepwise regression analysis, the change in abdominal subcutaneous fat was the only independent correlate of the SBP reduction, accounting for 8% of the variance ($P < .01$). In stepwise regression analysis, the variance in the DBP reduction was accounted for by the change in percentage of body fat (10%; $P = .003$), percentage of lean mass (4%; $P = .004$), and body weight (3%; $P = .04$).

COMMENT

In this sample of older men and women with predominantly mild systolic hypertension, 6 months of supervised exercise training produced an excellent training response, including increased fitness and lean body mass and reduced general and abdominal obesity in both sexes. Exercisers and controls reduced their SBP statistically significantly; only DBP was reduced statistically significantly more among the exercisers.

Several considerations may contribute to the smaller-than-expected SBP reduction in exercisers. First, there is a progressive increase in arterial stiffness with aging that contributes to systolic hypertension.^{16,17} This elevated arterial stiffness is primarily due to a replacement of elastic fibers in the large arteries by less distensible collagen and calcium. These aging changes in arterial structure may not be amenable to modification by exercise training. Consistent with this concept, exercise training did not statistically significantly change aortic stiffness in our study. Ferrier et al¹⁸ also found that exercise training did not improve arterial compliance in persons with systolic hypertension. Hence, older individuals may be resistant to reducing their SBP despite improvements in fitness and fatness. Contrary to SBP, we found a greater reduction in DBP among exercisers despite their normal baseline DBP of 76 mm Hg.

Second, controls also reduced their BP. Controls were not truly a "nontreatment" group because they received usual care advice regarding activity and diet. Self-reported activity levels did not change statistically sig-

nificantly among controls, caloric and dietary sodium intakes were unchanged in both groups, and changes in diet did not correlate with BP changes. Unavoidably, research volunteers are a motivated group, and controls likely made some changes in lifestyle behaviors that were not detected by our methods.

Third, the BP reduction among controls may reflect the ongoing monitoring inherent to a clinical trial. This monitoring included multiple testing and BP safety check visits. Multiple BP determinations may have resulted in regression to the mean in both groups. Blumenthal et al¹⁹ found a similar reduction in BP between exercise and control participants who were randomized to 4 months of exercise training. Seals and Reiling²⁰ also observed a placebo effect on resting BP in older control participants in an exercise trial. The placebo effect reduces the power of our study to detect group differences in BP reductions. Thus, the factors that affect BP are multiple, pervasive, and difficult to quantify and pose a challenge in attributing reductions in BP solely to exercise training.

We found that exercise produced substantial improvements in body composition despite modest reductions in body weight. A reduction of 3.5% in the percentage of body fat was accompanied by a 3.5% increase in lean body mass, and there were notable reductions in abdominal subcutaneous and visceral fat. Our study confirms findings of reduced abdominal obesity in exercise-trained older women.²¹ A novel observation herein is that men who exercised had reductions of 23% in abdominal visceral fat, 10% in abdominal subcutaneous fat, and 17% in abdominal total fat. These changes, with minimal weight loss, exceeded reductions in abdominal obesity reported in younger men after 20 weeks of training.²²

Combining data from all participants, we found that BP reductions correlated with several changes in body composition and fitness. The reduction in abdominal subcutaneous fat emerged as the strongest correlate of SBP change, and the reductions in body weight and total fat and the increase in lean mass emerged as the strongest correlates of DBP change. Nevertheless, each of the improvements in body composition and fitness are important. Overall, the amount of change in BP accounted for

was a modest 8% for SBP and 17% for DBP. Although there were clinically important reductions in BP, the mechanism by which BP is reduced (either exercise or nonspecific placebo effects) has yet to be fully elucidated.

As noted in the 2004 American College of Sports Medicine position stand on exercise and hypertension,¹ there have been too few studies thus far to make definitive conclusions regarding sex effects on BP responses to exercise. An important observation in the present study is that there were no sex differences in BP reductions. The only significant sex differences found among change scores were greater gains in strength and a greater reduction in abdominal visceral fat in men. Overall, older women achieved similar benefits from exercise as men.

This study has several strengths. The participants had untreated hypertension, and the 4-week screening period selected participants with stable levels of BP. To minimize measurement bias, BP was measured using an automated device by nurses otherwise uninvolved with the participants. There was excellent attendance and adherence to the exercise prescription and a noncompletion rate of only 10%. A study limitation is that the SBP decreased in the control group, which reduced the power to ascertain exercise-induced BP changes.

Because so many adults are at risk for, or have, hypertension,²³ these results have broad clinical implications. Declines in SBP and DBP occurred in both groups, with a greater reduction in DBP occurring in exercisers. Nevertheless, the similar SBP reduction in exercisers and controls precludes attribution of the reduction in SBP solely to exercise training. The lack of improvement in aortic stiffness suggests that older persons may be resistant to exercise-induced improvements in SBP. Despite modest reductions in body weight and body mass index, there were noteworthy reductions in general and abdominal obesity and increased lean body mass. These improvements in body composition, more so than changes in fitness, correlated with reductions in BP. These findings suggest that changes in body composition seem to be an important pathway by which exercise training improves cardiovascular health in older men and women.

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Correction

Error in Table. In the Original Investigation by Stewart et al titled "Effect of Exercise on Blood Pressure in Older Persons: A Randomized Controlled Trial," published in the April 11, 2005, issue of the ARCHIVES (2005;165: 756-762), there was an error in Table 4. The side headings "Abdominal total fat" and "Abdominal visceral fat" should be exchanged, keeping the values where they are.