Exercise and Risk Factors Associated with Metabolic Syndrome in Older Adults

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Background: Older people with elevated blood pressure (BP) often have metabolic syndrome, a clustering of central obesity, insulin resistance, dyslipidemia, and hypertension. Exercise reduces many of these risk factors. This study examined whether the benefits of exercise on cardiovascular and metabolic disease risk factors are mediated by exercise-induced changes in fitness or body composition.

Methods: Randomized controlled trial, comprising 6 months of exercise training, conducted between July 1999 and November 2003. Participants included men and women (n =115) aged 55 to 75 years with untreated systolic blood pressure (SBP) of 130 to 159 or diastolic blood pressure of (DPB) 85 to 99 mm Hg. Fitness measures included BP, lipids, lipoproteins, insulin, and glucose; peak oxygen uptake and muscle strength; and body composition measured by anthropometry, dual-energy x-ray absorptiometry, and magnetic resonance imaging.

Results: A total of 51 men and 53 women completed the trial. Exercise significantly increased aerobic and muscle fitness, lean mass, and high-density lipoprotein cholesterol and reduced total and abdominal fat. DBP was reduced more among exercisers. There were no associations among changes in fitness with risk factors. Reductions in total body and abdominal fat and increases in leanness, largely independent of weight loss, were associated with improved SBP, DBP, total cholesterol, very low-density lipoprotein cholesterol, triglycerides, lipoprotein(a), and insulin sensitivity. At baseline, 42.3% of participants had metabolic syndrome. At 6 months, nine exercisers (17.7%) and eight controls (15.1%) no longer had metabolic syndrome, whereas four controls (7.6%) and no exercisers developed it (p =0.06).

Conclusions: Although exercise improved fitness, the reductions in total and abdominal fatness and increase in leanness were more strongly associated with favorable changes in risk factors for cardiovascular disease and diabetes, including those that constitute metabolic syndrome.
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Introduction

Older people with hypertension often have metabolic syndrome, a clustering of central obesity, insulin resistance, dyslipidemia, and hypertension, that increases the risk of cardiovascular disease and type 2 diabetes.[1] Exercise is widely promoted for ameliorating risk factors, including those that comprise metabolic syndrome. The Joint National Committee (JNC) for Detection, Evaluation, and Treatment of High Blood Pressure guidelines[2] recommend exercise for reducing mild hypertension before initiating drug therapy for most individuals. General and abdominal obesity increase with aging,[3–5] and are precursors for several cardiovascular and metabolic disease risk factors.[6–10] Exercise training improves body composition, often independent of weight loss,[11,12] and may preferentially reduce abdominal visceral fat.[13–15] In the Heritage Family Study,[16] exercise reduced total and abdominal fat, and 30% of participants with metabolic syndrome were no longer classified as having it after training.[17] Exercise-induced reductions in total and abdominal obesity have been associated with improvements in insulin sensitivity, blood pressure (BP), and lipids in children.[18,19] Limited exercise studies in older adults[20–22] report waist circumference and waist-to-hip ratio reductions were associated with improvements in selected metabolic risk factors.

Senior Hypertension and Physical Exercise (SHAPE) was a randomized, controlled trial of 6 months of exercise in older people with mildly elevated BP. The present

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analyses determined whether the benefits of exercise on risk factors associated with metabolic syndrome are mediated by changes in fitness or body composition.

Methods

The study was approved by the Johns Hopkins Institutional Review Board and was conducted between July 1999 and November 2003. Informed consent was obtained from each participant.

Participants

Men and women aged 55 to 75 years, with untreated mildly elevated BP were recruited mainly through newspaper advertising. Details of selection criteria are provided elsewhere.[23] Briefly, exclusions included cardiovascular diseases or other serious illnesses, smoking, diabetes, and regular exercise of >3 metabolic equivalents for 90 minutes per week.[24] The use of medications other than antihypertensives including hormone replacement therapy (HRT) among women was allowed. For BP eligibility, participants were seen weekly, and following methods described below, were required to have systolic blood pressure (SBP) between 130 to 159 mm Hg and/or diastolic blood pressure (DBP) between 85 to 99 mm Hg during two consecutive visits and an average BP in this range over four visits. These levels correspond to prehypertension to Stage 1 hypertension by JNC 7 guidelines.[2] A total of 158 participants who had eligible BP levels underwent screening exercise testing. Exclusions based on exercise testing were ST-segment depression >1 mm, complex arrhythmias, or ischemic symptoms. A total of 115 participants were randomized to the study groups (Figure 1).

Baseline and 6-Month Measurements

Blood pressure was measured using an automated Dinamap MPS Select (Johnson & Johnson, New Brunswick NJ) following methods described elsewhere.[23] Briefly, visits were scheduled at the same time of the day for each participant, and at least 1 day after exercise. After 5 minutes of sitting rest in a quiet room, BP was measured three times 1 minute apart. If the measurements differed by more than 5 mm Hg, extra readings were obtained. The average of three consecutive readings within 5 mm Hg of each other was the examination value. BP obtained during the screening visits plus a visit during baseline testing were averaged and used as the baseline BP. The final BP was the average of BP taken twice during the last month of the study and once during the final testing period.

Aerobic fitness was assessed as peak oxygen uptake measured on a treadmill using a SensorMedics Vmax 229 Metabolic System (SensorMedics, Inc., Yorba Linda CA). Walking began at 3 mph, at a grade of 0%, and increased by 2.5% every 3 minutes. Participants were encouraged to reach 18 or higher on the Borg Rating of Perceived Exertion scale,[25] and stopped at volitional fatigue.

Muscle fitness was assessed by a one-repetition maximum on each of seven exercises on a Hoist 6000 multistation machine (Hoist Fitness, San Diego CA). One-repetition maximum is the highest weight lifted following methods described elsewhere.[26] Total strength was the sum of the maximal weight lifted for bench press, shoulder press, seated mid-rowing, lateral pull-down, leg extension, leg curl, and leg press exercises.

Body composition was assessed by anthropometric and imaging techniques. Height and weight were measured while wearing minimal clothing. Body mass index (BMI) was calculated as weight (kg)/height squared (m^2). Waist circumference was measured at the narrowest part of the torso. Hip circumference was measured around the buttocks at the level of maximal extension. Total body percent fat and lean mass, measures of general fatness and leanness, were determined by dual-energy x-ray (DXA) absorptiometry using a GE Lunar Prodigy (General Electric Medical Systems, Milwaukee WI), using the adult medium mode. According to the manufacturer, the instrument has an in vivo coefficient of variation of <1%. Abdominal fat was measured from images obtained with a Siemens Vision 1.5T magnetic resonance imaging (MRI) system (Siemens Medical Systems, Iselin NJ). An experienced reader using the National Institutes of Health Image application (*http://rsb.info.nih.gov/nih-image*) traced and averaged three 1-cm axial plane images at one slice below, at, and above the umbilicus to determine abdominal total, visceral, and subcutaneous fat, following procedures described elsewhere.[26–28] The estimated coefficient of variation is 1.6% for subcutaneous fat and 6.5% for abdominal visceral fat.[27]

Blood samples were obtained from an antecubital vein with the subject in a seated position after an overnight fast. Samples were analyzed at Quest Diagnostic (Baltimore MD). The laboratory assessment methods have been described elsewhere.[29]

Insulin sensitivity was assessed using the Quantitative Insulin Sensitivity Check Index (QUICKI),[30,31] defined as $1/[\log (I_0) + \log (G_0)]$. A lower index indicates a greater degree of insulin resistance.

Participants were classified as having metabolic syndrome according to guidelines by the National Cholesterol Education Program's Adult Treatment Panel III.[1] The classification consists of having three or more of the following: abdominal obesity (waist circumference >102 cm in men and >88 cm in women); hypertriglyceridemia ≥150 mg/dl; low high-density lipoprotein cholesterol (HDL-C) (men <40 mg/dl and women <50 mg/dl); blood pressure >130/85 mm Hg; and high fasting blood glucose of ≥110 mg/dl.

To provide a global estimate of coronary heart disease (CHD) risk, a risk index (CHDRI) was also computed using algorithms derived from the Framingham Heart Study 12-year follow-up.[32] Participants were given a score for age, low-density lipoprotein cholesterol (LDL-C), HDL-C, and BP status. Because diabetes and smoking were study exclusions, these parameters were assigned a score of zero.

Diet and Physical Activity

The Stanford Seven-Day Physical Activity Recall survey[33] was used to assess total daily energy expenditure. Dietary data were obtained from 3-day food records, and analyzed with Nutritionist V software (First DataBank, San Bruno CA). The dietary analysis focused on total daily energy and salt intake.

Exercise Intervention

Supervised exercise was performed three times per week, and followed American College of Sports Medicine guidelines.[34] The prescribed number of sessions was 78 (3 days×26 weeks).

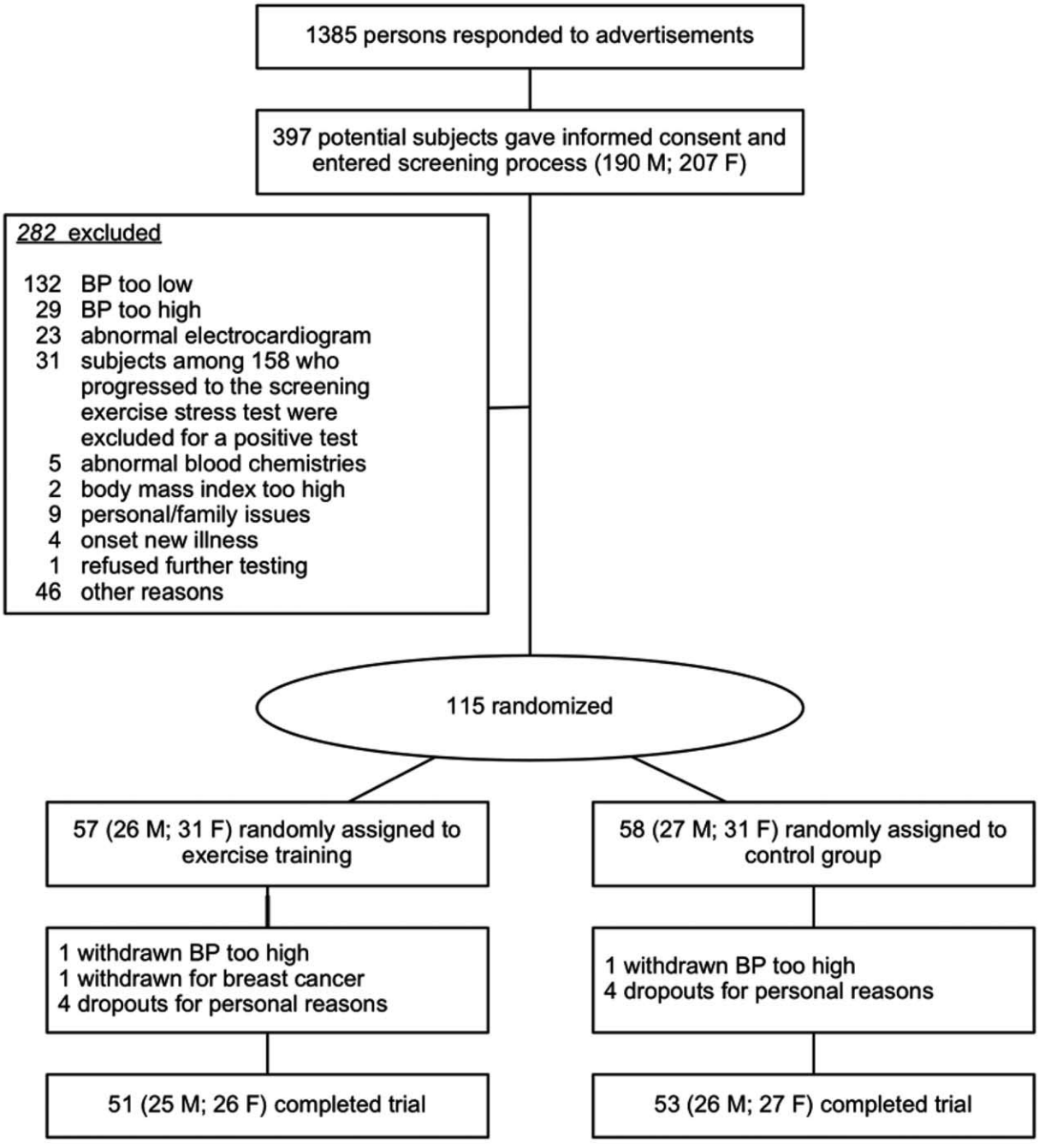

Figure 1. Flow of participants through the Senior Hypertension and Physical Exercise Study.
BP, blood pressure.

If a participant fell short of 62 sessions at 6 months (80% compliance), an extra month was allowed.

A stretching warm-up was followed by resistance training consisting of two sets of 10 to 15 repetitions per exercise, at 50% of one-repetition maximum. The same seven exercises that were used for strength testing were used for resistance training. When the participant could complete 15 repetitions of an exercise with little difficulty, the weight was increased.

Following resistance training, aerobic exercise was performed for 45 minutes. The participant could use a treadmill, stationary cycle, or stair stepper. A heart rate (HR) monitor (Polar, Inc., Lake Success NY) was worn and an alarm beeped when HR was outside the target heart range, set at 60% to 90% of maximum HR from the baseline exercise test. Emphasis was placed on maintaining HR toward the higher end of the range as tolerated. As fitness improved, the exercise workload was increased to maintain target levels.

Control Group, Diet and Activity Advice, and Safety Monitoring

All participants were given the National Institute of Aging Guidelines for Exercise (*http://www.nia.nih.gov/exercisebook*) and the American Heart Association Step I Diet (*http://*

Table 1. Baseline characteristics of randomized participants in SHAPE study

	Exercise	Control	*p* value[a]
Age (years)	63.0 (61.5–64.5)	64.1 (62.4–65.8)	0.35
Aerobic and strength fitness (mean, 95% CI)			
Peak oxygen uptake, ml/kg/min	24.4 (22.9–25.9)	24.2 (22.8–25.7)	0.85
Total muscle strength	722.4 (651.6–793.4)	720.9 (649.6–792.1)	0.97
Body composition, mean (95% CI)			
Body mass index	29.4 (28.3–30.4)	29.7 (28.3–31.0)	0.75
Weight, kg	83.2 (79.1–87.3)	84.9 (79.6–90.2)	0.61
Waist circumference, cm	94.0 (90.6–97.3)	95.0 (91.1–99.0)	0.68
Waist-hip ratio	0.9 (0.9–0.9)	0.9 (0.9–0.9)	0.75
Abdominal total fat (MRI), cm^2	432.6 (399.5–465.6)	449.6 (404.2–495.0)	0.54
Abdominal visceral fat (MRI), cm^2	146.5 (127.3–165.7)	142.7 (123.7–161.6)	0.77
Abdominal subcutaneous fat (MRI), cm^2	285.1 (255.4–314.9)	305.7 (268.9–342.4)	0.38
Total body fat (DXA), %	37.9 (35.4–40.4)	37.7 (35.0–40.5)	0.54
Lean body mass (DXA), %	58.5 (56.1–61.5)	58.9 (56.2–61.5)	0.85
Resting blood pressure, mean (95% CI)			
Systolic blood pressure, mm Hg	140.3 (138.2–142.4)	141.7 (139.7–143.8)	0.33
Diastolic blood pressure, mm Hg	76.8 (74.8–78.9)	76.4 (73.9–78.9)	0.78
Lipids and lipoproteins, mean (95% CI)			
Cholesterol, mg/dl	219.9 (209.8–230.1)	209.7 (199.3–220.2)	0.16
High-density lipoprotein cholesterol, mg/dl	56.8 (51.4–62.3)	53.1 (49.1–57.2)	0.27
Low-density lipoprotein cholesterol, mg/dl	133.8 (125.1–142.5)	131.6 (122.0–141.2)	0.73
Very low-density lipoprotein cholesterol, mg/dl	29.3 (25.0–33.5)	25.0 (21.4–28.7)	0.13
Triglycerides, mg/dl	146.5 (125.2–167.8)	125.0 (106.7–143.3)	0.13
Lipoprotein(a), mg/dl	22.0 (12.4–31.5)	32.5 (21.2–43.8)	0.16
Glucose and insulin, mean (95% CI)			
Glucose, mg/dl	100.8 (97.7–103.9)	102.1 (98.9–105.3)	0.56
Insulin, mIU/ml	8.6 (7.4–9.8)	9.8 (8.2–11.4)	0.23
QUICKI	0.35 (0.34–0.36)	0.34 (0.33–0.35)	0.34
Metabolic syndrome risk factors			
Number of individual risk factors	2.3 (2.0–2.6)	2.3 (2.0–2.6)	0.90
Classifed with metabolic syndrome (%)	43.4 (0.3–0.6)	41.2 (0.3–0.1)	0.85
CHD risk index, mean % (95% CI)[b]	13.9 (11.9–15.8)	13.0 (11.2–14.8)	0.51

[a]None of the comparisons between baseline characteristics of exercise and control subjects were statistically significant.
[b]Indicates 10 year CHD risk.
CI, confidence interval; CHD, coronary heart disease; DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance image; QUICKI, Quantitative Insulin Sensitivity Check Index; SHAPE, Senior Hypertension and Physical Exercise.

www.americanheart.org) at the time of screening, and were asked to maintain their normal caloric intake during the study. Participants in both groups reported twice monthly for BP safety checks. If the SBP was >159 or DBP >99 mm Hg, the participant was assessed weekly; the participant was withdrawn if BP was above range for 4 consecutive weeks.

Statistical Analysis

Data analysis was done using JMP statistical software, version 5.1 (SAS Institute Inc., Cary NC, 2004). Between-group differences at baseline were examined by *t*-tests. The changes from baseline to 6 months were compared between groups by independent *t*-tests. Repeated-measures analysis of variance evaluated within-group changes. Pearson correlation coefficients were calculated among changes in study variables. After ruling out significant skewness, stepwise regression was used to select optimal regression models. Changes in fitness and body composition were the independent variables and changes in BP, blood parameters, and QUICKI were the dependent variables. Independent variables that were significantly associated with the designated dependent variable in the bivariate analyses were candidates for the stepwise regression. Gender was included as a candidate variable in each of these models. Contingency analysis tested for group differences in changes in metabolic syndrome classification.

Results

Complete data are available for 104 participants: 51 exercisers (25 men; 26 women) and 53 controls (26 men; 27 women) (Figure 1). Their overall mean age was 63.6 (standard deviation [SD]=5.7 years), and 87% were non-Hispanic white, 11% African American, 1% Asian American, and 1% Hispanic. Among women, 13 of 26 exercisers (50%) and 12 of 27 controls (44%) reported use of HRT. In separate analyses not shown, HRT use did not alter the results. Other medications used by participants remained stable during the study but were too varied in their use for statistical adjustment. The baseline prevalence of metabolic syndrome was 42.3%. Among participants completing the study, there were no significant group differences in baseline characteristics (Table 1). Inclusion of participants not completing the study did not alter these characteristics (data not shown).

Table 2. Change in study variables from baseline in exercise and control participants

	Exercise	Control	Difference	*p* value[a]
Aerobic and strength fitness (mean, 95% CI)				
Peak oxygen uptake, ml/kg/min	4.0 (3.2–4.8)	−0.1 (−0.8–0.5)	4.1 (3.1–5.2)	**<0.001*****
Total muscle strength, lb	126.0 (109.1–142.4)	8.0 (−5.8–21.8)	118.1 (96.9–139.2)	**<0.001*****
Body composition, mean (95% CI)				
Body mass index[b]	−0.8 (−1.1–−0.5)	−0.2 (−0.4–0.1)	−0.7 (−1.1–−0.3)	**<0.001*****
Weight, kg	−2.3 (−3.1–−1.4)	−0.5 (−1.2–0.1)	−1.7 (−2.8–−0.7)	**<0.002****
Waist circumference, cm	−2.9 (−4.1–−1.7)	−0.8 (−1.8–0.1)	−2.0 (−3.6–−0.5)	**0.01***
Waist/hip ratio	−0.01 (−0.02–0.00)	−0.01 (−0.01–0.00)	0.00 (−0.01–0.01)	0.52
Abdominal total fat (MRI), cm^2	−52.5 (−66.6–38.7)	−6.5 (−20.3–7.3)	−46.0 (−65.4–−26.5)	**<0.001*****
Abdominal visceral fat (MRI), cm^2	−26.7 (−35.6–−17.9)	−3.8 (−10.8–3.3)	−23.0 (−34.2–−11.8)	**<0.001*****
Abdominal subcutaneous fat (MRI), cm^2	−25.8 (−35.1–−16.5)	−2.9 (−11.7–6.0)	−23.0 (−35.7–−10.3)	**<0.001*****
Total body fat (DXA), %	−3.5 (0.0–−2.8)	−0.2 (−0.7–0.3)	−3.3 (−4.1–−2.4)	**<0.001*****
Lean body mass (DXA), %	3.5 (2.8–4.2)	0.2 (−0.3–0.7)	3.3 (2.4–4.1)	**<0.001****
Resting blood pressure, mean (95% CI)				
Systolic blood pressure, mm Hg	−5.3 (−8.1–−2.5)	−4.5 (−6.7–−2.2)	−0.8 (−4.4–2.8)	0.65
Diastolic blood pressure, mm Hg	−3.7 (−5.1–−2.4)	−1.5 (−2.9–−0.2)	−2.2 (−4.1–−0.3)	**0.02***
Heart rate, bpm	−3.9 (−5.4–−2.4)	−2.2 (−3.8–0.5)	−1.8 (−4.1–0.5)	0.12
Lipids and lipoproteins, mean (95% CI)				
Cholesterol, mg/dl	−5.2 (−13.5–3.0)	−5.3 (−14.2–3.7)	0.0 (−12.1–12.0)	0.99
High-density lipoprotein cholesterol, mg/dl	3.0 (1.1–4.9)	−0.3 (−2.2–1.5)	3.3 (0.7–5.9)	**0.01***
Low-density lipoprotein cholesterol, mg/dl	−5.7 (−12.5–1.2)	−5.1 (−13.9–3.8)	−0.6 (−11.6–10.5)	0.92
Very low-density lipoprotein cholesterol, mg/dl	−4.0 (−7.6–−0.4)	0.2 (−2.4–2.8)	−4.2 (−8.6–0.3)	0.07
Triglycerides, mg/dl	−13.4 (−35.9–9.0)	1.2 (−11.9–14.2)	−14.6 (−40.3–11.1)	0.26
Lipoprotein(a), mg/dl	−0.9 (−3.2–1.4)	1.8 (−2.9–6.5)	−2.7 (−7.9–2.5)	0.30
Glucose and insulin, mean (95% CI)				
Glucose, mg/dl	0.2 (−2.7–3.0)	1.7 (−1.7–5.0)	1.5 (−2.8–5.9)	0.49
Insulin, mIU/mL	−0.6 (−1.8–0.5)	−0.1 (−1.7–1.5)	−0.6 (−2.5–1.4)	0.56
QUICKI	0.00 (0.00–0.01)	0.00 (−0.01–0.01)	0.01 (−0.01–0.01)	0.21
CHD risk index, mean % (95% CI)[b]	−1.0 (−1.8–−0.2)	−0.3 (−1.1–0.6)	−0.8 (−0.4–1.9)	0.18

[a]Test for between-group difference on the change from baseline.
[b]Indicates 10-year CHD risk.
*$p < 0.05$ (bolded).
**$p < 0.01$ (bolded).
***$p < 0.001$ (bolded).
CI, confidence interval; CHD, coronary heart disease; DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance image; QUICKI, Quantitative Insulin Sensitivity Check Index.

Adherence to Exercise Program

The exercise group completed an average 69 (SD=8) of the prescribed 78 sessions (88%). Eleven participants required an extra month for missed sessions. The mean HR was 135.5 beats per minute (SD=10.4) during a mean 2587 seconds (SD=55) of aerobic exercise per session. Heart rate during exercise was in the prescribed ranges 98% of the time.

Changes from Baseline

Exercisers increased their peak oxygen uptake by 16% compared with no change among controls ($p < 0.001$), and strength increased by 17% compared with a slight 1% increase among controls ($p < 0.001$) (Table 2). Exercisers lost 2.2 kg of body weight compared with a 0.5-kg loss among controls ($p < 0.01$), and reduced their body fat by 3.5% and increased their lean mass by 3.5% compared with no change among controls (each $p < 0.01$). BMI reduction was greater among exercisers by 0.7 kg/m^2 ($p < 0.01$). The reduction in total abdominal fat was greater among exercisers ($p < 0.01$). Reductions in abdominal subcutaneous, abdominal visceral fat, and waist circumference were greater among exercisers than controls (each $p < 0.01$).

After 6 months, exercisers reduced their SBP by a mean of 5.3 mm Hg and DBP by 3.7 mm Hg (each $p < 0.01$); controls reduced their SBP by a mean of 4.5 mm Hg and DBP by 1.5 mm Hg (each $p < 0.01$). The change in DBP among exercisers exceeded that of controls ($p < 0.01$). The reduction of SBP among exercisers was similar to that among controls ($p = 0.65$).

Exercisers increased their HDL-C by a mean of 3.0 mg/dl ($p < 0.01$), whereas the control group's HDL-C did not change. Significant differences within and between groups for the remaining blood parameters were not found.

The CHDRI was reduced by 1.0% among exercisers ($p = 0.01$), although this change was not significantly different from the change among controls ($p = 0.18$).

Metabolic Syndrome

Figure 2 shows the distribution of risk factors and the number of participants with metabolic syndrome at

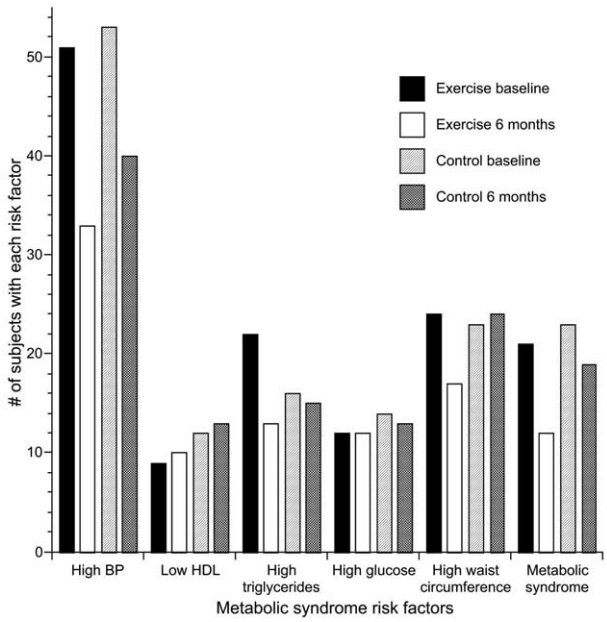

Figure 2. Frequency distribution of risk factors for metabolic syndrome, and number of participants who were classified as having metabolic syndrome at baseline and 6 months. BP, blood pressure; HDL, high-density lipoprotein cholesterol.

baseline and 6 months. After 6 months, nine exercisers (17.7%) and eight controls (15.1%) no longer had metabolic syndrome, whereas four controls (7.6%) developed it. The remaining participants did not change their classification. Group differences for the change in metabolic syndrome classification fell just short of statistical significance ($p = 0.06$). The reduction in the number of metabolic syndrome risk factors was −0.65 (95% confidence interval [CI] = −0.89–−0.40) among exercisers and −0.30 (95% CI = −0.56–−0.04) among controls ($p = 0.06$).

As shown in Table 3, the change in peak oxygen uptake correlated with the change in each body composition variable except the waist:hip ratio. The change in aerobic and strength fitness correlated with the DBP change. Increases in strength were associated with favorable changes in DXA-derived percent body fat and lean body mass, but not with anthropometric measures of fatness.

The correlates of changes in body composition with changes in BP and blood parameters are shown in Table 4. In the final regression models, the reduction in abdominal subcutaneous fat explained 7% of the SBP reduction ($p < 0.01$). The reduction in percent body fat and body weight, and the increase in percent lean mass explained 15% of the variance in DBP change ($p < 0.01$). The reduction in percent body fat explained 3% of the change in total cholesterol ($p = 0.03$). The body weight reduction explained 8% of the triglycerides reduction ($p < 0.01$). The reduction in abdominal subcutaneous fat explained 7% of the reduction in very low-density lipoprotein cholesterol ($p < 0.01$) and 7% of the reduction in lipoprotein(a) ($p < 0.01$). The reduction in abdominal visceral fat explained 6% of reduction in insulin ($p < 0.01$), whereas the reduction in abdominal total fat explained 5% of the improvement in QUICKI ($p < 0.01$).

Table 3. Pearson correlation coefficients of changes in aerobic and strength fitness with changes in risk factors

	Peak oxygen uptake	*p* value	Total muscle strength	*p* value
Body mass index	−0.48	**<0.001*****	−0.15	0.14
Weight	−0.49	**<0.001*****	−0.16	0.11
Waist circumference	−0.29	**<0.01****	−0.11	0.27
Waist/hip ratio	−0.04	0.72	0.02	0.86
Abdominal total fat (MRI)	−0.48	**<0.001*****	−0.37	**<0.001****
Abdominal visceral fat (MRI)	−0.49	**<0.001*****	−0.30	**<0.01****
Abdominal subcutaneous fat (MRI)	−0.33	**<0.001*****	−0.33	**<0.001****
Percent body fat (DXA)	−0.54	**<0.001*****	−0.40	**<0.001****
Percent lean body mass (DXA)	0.53	**<0.001*****	0.40	**<0.001****
Systolic blood pressure	−0.04	0.68	−0.03	0.76
Diastolic blood pressure	−0.24	**0.02***	−0.23	**0.02***
Cholesterol	−0.14	0.14	−0.16	0.64
High-density lipoprotein cholesterol	0.18	0.07	0.17	0.09
Low-density lipoprotein cholesterol	−0.13	0.20	0.06	0.52
Very low-density lipoprotein cholesterol	−0.17	0.08	−0.14	0.15
Triglycerides	−0.16	0.10	−0.12	0.23
Lipoprotein(a)	−0.09	0.38	−0.11	0.38
Glucose	0.00	0.99	−0.06	0.61
Insulin	−0.01	0.90	−0.09	0.36
QUICKI	0.09	0.35	0.10	0.30

*$p < 0.05$ (bolded).
**$p < 0.001$ (bolded).
***$p < 0.001$ (bolded).
DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance image; QUICKI, Quantitative Insulin Sensitivity Check Index.

Table 4. Pearson correlation coefficients of changes in body composition with changes in risk factors

	Body mass index	Weight	Waist circumference	Waist/hip ratio	Abdominal total fat (MRI)	Abdominal visceral fat (MRI)	Abdominal subcutaneous fat (MRI)	Percent body fat (DXA)	Percent lean body mass (DXA)
Systolic blood pressure	0.12	0.17	0.12	0.03	0.27	0.18	0.27	0.17	−0.16
p value	0.23	0.09	0.23	0.74	**0.01***	0.07	**0.01***	0.08	0.09
Diastolic blood pressure	0.14	0.20	0.18	0.10	0.30	0.24	0.27	0.31	−0.30
p value	0.15	**0.05*****	0.07	0.30	**0.01***	**<0.01****	**0.01***	**<0.01****	**<0.01****
Cholesterol	0.11	0.15	0.10	0.06	0.16	0.16	0.11	0.21	−0.21
p value	0.25	0.14	0.33	0.55	0.10	0.11	0.25	**0.03***	**0.04***
High-density lipoprotein cholesterol	−0.13	−0.13	−0.13	−0.13	−0.02	−0.07	0.04	−0.14	0.14
p value	0.18	0.19	0.21	0.20	0.86	0.49	0.73	0.16	0.17
Low-density lipoprotein cholesterol	0.03	0.06	0.06	0.06	0.10	0.16	0.01	0.17	−0.17
p value	0.78	0.57	0.58	0.54	0.35	0.12	0.96	0.08	0.09
Very low-density lipoprotein cholesterol	0.29	0.31	0.20	0.09	0.24	0.10	0.31	0.22	−0.21
p value	**<0.01****	**<0.01****	0.05	0.39	**0.02***	0.32	**<0.01****	**0.03***	**0.03***
Triglycerides	0.28	0.29	0.18	0.07	0.19	0.08	0.24	0.21	−0.20
p value	**<0.01****	**<0.01****	0.08	0.47	**0.05*****	0.43	**0.01***	**0.03***	**0.04***
Lipoprotein(a)	0.10	0.12	0.02	−0.02	0.22	0.13	0.23	0.19	−0.18
p value	0.32	0.25	0.84	0.82	**0.03***	0.21	**0.02***	0.06	0.07
Glucose	0.09	0.08	−0.01	−0.06	0.05	−0.02	0.09	0.05	**−0.04**
p value	0.39	0.45	0.92	0.57	0.61	0.87	0.37	0.63	0.67
Insulin	0.11	0.09	0.13	0.08	0.31	0.27	0.24	0.04	−0.04
p value	0.26	0.38	0.19	0.42	**<0.01****	**<0.01****	**0.02***	0.66	0.71
QUICKI	−0.10	−0.08	−0.09	−0.06	−0.27	−0.22	−0.23	−0.05	0.04
p value	0.31	0.42	0.38	0.57	**<0.01****	**0.03**	**0.02***	0.64	0.64

*$p < 0.05$ (bolded).
**$p < 0.01$ (bolded).
***$p = 0.05$ (bolded).
DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance image; QUICKI, Quantitative Insulin Sensitivity Check Index.

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 ($p < 0.03$) among exercisers and 0.7 kcal/kg ($p = 0.27$) among controls. In analyses not shown, changes in habitual activity and diet did not correlate with any risk factors.

Discussion

Exercise training in older participants increased aerobic and strength fitness, reduced total and abdominal obesity, and increased lean body mass. In separate analyses not shown, there were no substantive differences by gender in the response to training or among controls.

The participants, in many ways, represent the "typical" older American with mild hypertension, many of whom are overweight, and at risk for cardiovascular disease and diabetes. Although the mean values for lipids, lipoproteins, insulin, and glucose at baseline were not abnormal, there was wide variation among individuals. At baseline, 42% of participants met the criteria for metabolic syndrome.

Despite substantial improvements in fitness and body composition, the improvements in risk factors when analyzed by group were modest. HDL-C improved with exercise training, and exercisers reduced their SBP significantly, but so did controls. Only DBP was reduced significantly more among exercisers. The reductions in BP and waist circumference, and the increase in HDL-C resulted in a change in prevalence of metabolic syndrome that favored the exercisers versus controls, reaching $p = 0.06$.

Similar to the Heritage Family Study,[35] there was considerable individual variation in the responses of risk factors to exercise. The improvements in fitness in these older participants were essentially unrelated to changes in BP, lipids and lipoproteins, and insulin sensitivity. The lack of associations of changes in risk factors with changes in fitness has been reported in some,[36] but not all studies.[37]

Some studies[20,38] have reported that improvements in risk factors are related to exercise-induced weight loss rather than improved fitness. In the present study of older people, a novel observation was that risk factor improvements were mediated by exercise-induced improvements in body composition, largely independent of weight loss. Where relationships with risk factors were found, significant adjusted determinants were DXA-derived percent and lean body mass and MRI-derived abdominal obesity. Only the triglycerides reduction was explained by weight loss alone. Notably, the imaging techniques revealed relationships among risk factors and components of body composition that would have been unrecognized if the study relied on anthropometric measures. For example, anthropometric measures of general or abdominal adiposity were not associated with reductions in SBP, total cholesterol, HDL-C, lipoprotein(a), insulin, or QUICKI. The present results confirm that exercise training, through its beneficial influences on body composition, improves several cardiovascular and metabolic disease risk factors. It has been suggested that differences in fat distribution may confer distinct metabolic risks.[39] These data are consistent with observations that reduction in abdominal visceral fat is closely associated with improved insulin resistance.[39] Furthermore, reductions in general and abdominal subcutaneous fatness may be more closely associated with reductions in BP and lipids and lipoproteins. Research with large sample sizes is needed to definitely discern the existence of such patterns in older persons.

These results have several clinical implications. A recent study found that participants with hypertension and metabolic syndrome had an almost double cardiovascular event rate than those without, independent of traditional cardiovascular risk factors.[40] The improvements in body composition as mediators of desirable changes in several risk factors, and a favorable change in the prevalence of metabolic syndrome in the present study denote the efficacy of exercise as an important component of primary prevention. These results also denote a dose–response relationship, albeit modest, of improvements in body composition with disease risk factors. Future studies should explore greater doses of exercise in older persons to ascertain if larger improvements in fitness and fatness further reduce risk factors associated with metabolic syndrome.

The Framingham CHDRI was included to provide a global estimate of 10-year CHD risk.[32] However, its utility for evaluating exercise efficacy is limited herein because participants had only mildly elevated BP, did not have diabetes or smoked, and age is the greatest contributor to CHD risk in older people. Nevertheless, the 1% reduction in CHDRI among exercisers may be important, given the modest 13% risk at baseline.

This study has several strengths. The noncompletion rate among exercisers was low (10%), and was mostly due to unrelated personal reasons. There were no exercise-related adverse outcomes. The use of DXA and MRI revealed associations of changes in body composition with risk factors that might have been otherwise missed. A limitation is that recruiting subjects primarily for mild hypertension limited our ability to show greater changes in the other risk factors. SBP fell among controls, which reduced the power to ascertain exercise-induced BP changes. Because research volunteers who respond to advertisements are generally motivated individuals, controls may have made lifestyle changes that could not be accounted for by our methods for assessing diet and activity.

What This Study Adds . . .

Older adults often have metabolic syndrome, a clustering of central obesity, insulin resistance, dyslipidemia, and hypertension.

In this study, while 6 months of exercise training improved aerobic and strength fitness, reductions in general and abdominal fatness and increases in lean mass were more strongly related to improvements in risk factors associated with metabolic syndrome.

Results suggest that body composition improvements are an important pathway by which exercise reduces cardiovascular and diabetes risk in older adults.

In summary, 6 months of exercise in older persons increased their fitness and lean mass, and reduced their total and abdominal fat, largely independent of weight loss. Although only DBP and HDL-C improved more among exercisers, favorable changes in body composition were independently associated with improvements in SBP, DBP, total cholesterol, very low-density lipoprotein cholesterol, triglycerides, lipoprotein(a), and insulin sensitivity. The benefits of exercise were mediated more through improvements in body composition than fitness. The favorable change in the prevalence of metabolic syndrome among the exercisers fell just short of statistical significance. Overall, these results provide evidence for the role of exercise for managing multiple risk factors, including those that constitute metabolic syndrome. If prescribed, and with compliance, exercise training has the potential to reduce or delay cardiovascular disease and diabetes incidence in our aging population.

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