Impact of Water- and Land-Based Exercise Training on Risk Factors and Vascular Function in Middle-Aged and Older Men and Women

BASIC SCIENCES

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ABSTRACT

GREEN, D. J., G. O. SILVA, K. J. SMITH, B. A. MASLEN, K. L. COX, N. T. LAUTENSCHLAGER, C. F. PESTELL, P. N. AINSLIE, A. HAYNES, and L. H. NAYLOR. Impact of Water- and Land-Based Exercise Training on Risk Factors and Vascular Function in Middle-Aged and Older Men and Women. *Med. Sci. Sports Exerc.*, Vol. 56, No. 2, pp. 230–237, 2024. **Introduction:** Exercise improves vascular function, but it is unclear whether benefits are mediated by traditional cardiovascular risk factors or whether sex differences in training effects exist in older adults. We hypothesized that exercise would improve cardiovascular risk factors, that males and females would benefit similarly, and that improvements in risk factors would correlate with changes in vascular function. **Methods:** Seventy-two healthy middle-aged/older adults (age, 62 ± 7 yr; 26%♂) were randomized to a land-walking (n = 23), water-walking (n = 25), or a nonexercise control group (C; n = 23). The exercise groups undertook supervised and monitored training three times a week for 50 min per session, across 24 wk. Blood pressure, body composition (dual x-ray absorptiometry), blood lipids and glucose, and flow-mediated brachial artery dilation were assessed in all participants at weeks 0 and 24. To maximize power for sex differences and correlation analyses, we pooled the training groups (land-walking + water-walking). **Results:** Training prevented increases in LDL and total cholesterol/HDL ratio observed in the nonexercise control group. No group by time interactions were observed for other risk factors. Sex differences in training effects existed for visceral fat (−187 ± 189 g♂ vs −15 ± 161 g♀; P = 0.006) and lean mass (−352 ± 1045 g♂ vs 601 ± 1178 g♀; P = 0.008). Improvement in flow-mediated brachial artery dilation was correlated with decreased waist girth (r = −0.450, P = 0.036), but not with other risk factors. **Conclusions:** Exercise training prevented deterioration in lipid levels, whereas sex differences existed for body composition changes with training. Improvement in vascular function was not dependent on changes in risk factors in middle-aged/older adults, suggesting that artery health may be dependent on other exercise-related stimuli. **Key Words:** CARDIOVASCULAR RISK, WALKING, EXERCISE TRAINING, ARTERY FUNCTION, ENDOTHELIUM, PREVENTION, SEX DIFFERENCES

Evidence suggests that regular exercise is associated with a lower risk of cardiovascular (CV) morbidity and mortality (1,2). A physically active lifestyle may decrease the risk of CV mortality by ~40%, compared with being inactive (3,4). This beneficial impact of physical activity has typically been ascribed to impacts on CV risk factors such as blood pressure, lipids, insulin resistance, and obesity (5). However, some evidence suggests that modification in CV risk factors explains less than 50% of the cardioprotective benefits of exercise training (6,7), suggesting the existence of a "risk factor gap." We have previously proposed that direct hemodynamic effects of exercise on the health of the artery wall may contribute to the beneficial effects of exercise, independent of any virtuous impact on other traditional risk factors (8–10). Few randomized longitudinal studies of older individuals have quantified the impact of center-based and supervised exercise training on changes in CV risk factors or assessed the association between changes in risk factors and direct measures of arterial function.

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Walking is a low-barrier mode of exercise that can be prescribed at different intensities based on speed, land surface conditions, and terrain. It is also specific to daily physical function, along with being associated with CV disease prevention (11). Moreover, water-walking (WW) has often been recommended for older adults, because of its decreased musculoskeletal loading and joint stress, and potential to reduce injuries (12). However, the effects of land-walking (LW) versus WW on most CV risk factors remain unclear.

Recent articles have also addressed the impact of sex differences in the impact of exercise on vascular function in humans. Trials undertaken in younger populations have suggested that female and male sex hormones may have distinct impacts on artery function (13–15), but few studies have directly compared the impacts of exercise training in older male and female volunteers (16). Therefore, we hypothesized that exercise would improve CV risk factors, that males and females would benefit similarly, and that improvements in CV risk factors would not correlate with changes in vascular function in middle-aged/older adults after supervised center-based exercise programs.

METHODS

Healthy sedentary (<60 min of moderate- or higher-intensity exercise per week, for at least 3 months) men and postmenopausal women (stable hormone replacement therapy included) older than 50 yr were recruited to participate in a 24-wk intervention study (17), approved by The University of Western Australia's Human Research Ethics Committee and conforming to the standards set by the Declaration of Helsinki. All participants provided written, informed consent before any assessments were performed. The study was prospectively registered in a clinical trial database before any subjects were randomized (ACTRN12614000017628).

Upon contact from a potential participant, an initial phone interview was conducted to explain the study and to screen out ineligible participants or those not interested in further participation. After the phone interview, eligible participants progressed to a baseline screening visit. The baseline screening visit included a resting ECG and a graded treadmill exercise stress test, comprising continuous incremental stages lasting 3 min per stage, to volitional exhaustion (17). Any ECG abnormalities were communicated to study coordinators and the participant's general practitioner for follow-up, and these participants were excluded before randomization.

Exclusion criteria were smoking (or <12-month cessation), hypertension (systolic blood pressure >160 mm Hg or diastolic blood pressure >100 mm Hg), weekly alcohol intake greater than 280 $g \cdot wk^{-1}$ and/or drinking more than 40 g ethanol in one session, body mass index greater than 40 $kg \cdot m^{-2}$, and total cholesterol (TC) greater than 7.0 $mmol \cdot L^{-1}$. Participants with mild cognitive impairment; dementia or Alzheimer's disease; ischemic heart disease; angina; intermittent claudication; stroke; diabetes mellitus; persistent or frequent arrhythmias; atrial fibrillation; epilepsy; severe mental illness; liver disease; kidney disease; any joint, muscular, or spinal disorders including arthritis that prohibited moderate exercise; and other serious illnesses likely to compromise survival (e.g., cancer) were also excluded from the study. We also excluded participants using psychiatric medications such as cognitive enhancers or antiepileptics, intermittent use of nonsteroidal anti-inflammatory drugs, and regular medication for asthma or chronic obstructive airways disease, or epilepsy. Baseline outcome assessments were performed in all eligible participants, after which they were then randomized to LW, WW, or a nonexercise control group (C). The study outcomes were assessed in all participants at weeks 0 and 24.

Exercise training protocols

Exercise-trained individuals attended a research center three times a week for 50-min supervised sessions across the 24 wk (17). Exercise intensity was assessed with a heart rate monitor (Polar RS300X HR monitor; Polar Electro Oy, Espoo, Finland). Supervised warm-up and cool-down intervals were included in each session. Land-based walking took place on the University grounds as well as along the adjoining river foreshore and parkland, or on a treadmill if weather indicated. Water-based walking was in a heated (~30°C) chest deep swimming pool (20 × 30 m) located at the University. The duration and intensity of the exercise sessions increased over the course of the study, from an initial 15 min of exercise to 50 min by the end of week 24. Participants (land and water) were given a personalized target heart rate range, based on heart rate reserve calculated from their initial peak exercise test results. Each exercise session was guided by an accredited exercise scientist/physiologist (Exercise and Sports Science Australia), and heart rate was monitored and recorded every 5 min throughout the session. The second session of each week was an interval training session, with the other two sessions of continuous intensity. The intensity of training started at 40%–45% of the heart rate reserve, building to 55%–65% by week 24. Additional "make-up" sessions were provided if required, to ensure optimal adherence to the protocol.

The control group was asked to maintain their usual levels of activity (all participants were inactive at recruitment) and attended the University every 6 wk to participate in an educational seminar of approximately 1 h, on a topic that was expected to be of interest but was unrelated to physical activity, lifestyle, and health: for example, first aid skills, and computer workstation optimal ergonomic setup.

Outcomes

All outcomes were measured between 6 AM and 11 AM. Before the measurements, the participants had fasted, abstained from caffeine, and refrained from moderate/vigorous physical activity for at least 6 h.

Body composition. Height and weight were measured with the subject barefoot in lightweight clothing. The same highly accurate digital scales (CPWplus-200; Adam Equipment, Oxford, CT) were used throughout the study. Body

mass index was calculated from these values. Waist and hip girth were measured three times using a constant-tension tape (Lufkin W606PM; Cooper Industries, Houston, TX); the median measure was used for analyses. Dual x-ray absorptiometry (Prodigy Advance; GE Healthcare, Madison, WI) was used to determine visceral and whole-body percent fat, grams of fat, and lean tissue.

Blood Pressure. Blood pressure was recorded using an automated sphygmomanometer (Dinamap V100; GE Healthcare) with readings taken in the supine position every 2 mins for 20 min. Appropriate cuff sizes were used, based on arm girth measurement, and the nondominant arm was cuffed. The test was administered in a quiet, temperature-controlled room, with the investigator nearby but outside the closed door, and the display was angled away from the participant's view.

Biochemistry. Blood was drawn from the antecubital fossa using a 21G needle by a trained phlebotomist in the University laboratory into collection tubes (all Vacuette by Greiner Bio-One, Kremsmünster, AT). Three tubes were analyzed by a commercial pathology laboratory, for lipids (TC, triglycerides, low- and high-density lipoprotein (LDL and HDL, and the ratio of TC/HDL)), blood glucose, hemoglobin, and hematocrit.

Vascular function. Flow-mediated brachial artery dilation (FMD) assessment was conducted in a quiet, temperature-controlled thermoneutral room in accordance with well-established guidelines (18,19). Room temperature was maintained by thermostatically controlled air conditioning, set at between 24°C and 26°C for all participants. Briefly, to examine baseline brachial artery diameter and FMD, the nondominant arm was extended and positioned at an angle of ~80° from the torso. A rapid inflation and deflation pneumatic cuff (D.E. Hokanson, Bellevue, WA) was positioned on the forearm, immediately distal to the olecranon process to provide a forearm ischemia stimulus. A 10- to 15-MHz multifrequency linear array probe, attached to a high-resolution ultrasound machine (T3200; Terason, Burlington, MA), was used to image the brachial artery in the distal third of the upper arm. When an optimal image was obtained, the probe was held stable, and the ultrasound parameters were set to optimize the longitudinal, B-mode images of the lumen–arterial wall interface. Continuous Doppler velocity assessments were also obtained using the ultrasound and were collected using the lowest possible insonation angle (always <60°). After a 1-min baseline recording of brachial artery diameter and velocity (Camtasia Studio 8; TechSmith, Okemos, MI), the forearm cuff was inflated (220 mm Hg) for 5 min. Diameter and flow recordings resumed 30 s before cuff deflation and continued for 3 min thereafter. Posttest analysis of brachial artery diameter was performed using custom-designed edge detection and wall-tracking software (20). The semiautomated edge detection and wall tracking software we developed limits operator error and bias and minimizes with- and between-observer variability (20). Our CV for repeated FMD measures using this approach is ~6.7%. We follow the guidelines developed by international consortia to assist with performing FMD in a robust and repeatable way (18,19). Following these guidelines has a direct impact on the reproducibility of the technique (21).

Statistical Analysis

Analyses were conducted using SPSS version 27 (IBM Corporation, Armonk, NY) and StataSE 15 (StataCorp LLC, College Station, TX). Because of the repeated-measure nature of the data, separate linear mixed models were used to investigate the relationship between the CV risk factors, group (C, LW, and WW), and time (weeks 0 and 24) while accounting for time-invariant covariates, including age and sex, and interactions between group and time. A random intercept was included in each model to account for the repeated nature of the data. This analysis was on an intention-to-treat basis. To maximize power for sex difference analyses (two-tailed *t*-tests) and correlational analysis of vascular and risk factor variables, we pooled the exercise training groups (LW + WW); these analyses were based on completers (those with both 0- and 6-month data). Statistical significance was set at $P < 0.05$.

RESULTS

We initially contacted 911 potential participants. Of these, 241 progressed to the phone screening interview, which led to 127 participants deemed ineligible. The remaining 114 participants progressed to a baseline screening visit after which another 42 were excluded. Thus, 72 participants were recruited and randomized into the study, as detailed elsewhere (17). One of the land walking participants withdrew for personal reasons after randomization and requested their data be destroyed. The analysis of changes in risk factors before and after intervention was therefore based on 71 participants. Baseline characteristics of the participants are presented in Table 1. The overall sample age ranged from 50 to 84 yr.

Results for blood pressure and biochemistry variables are detailed below. Body composition and vascular function data have previously been published (22,23). Briefly, a reduction in central adiposity was apparent in both exercise groups, along with an increase in lower limb lean mass in the WW group (22). Vascular function results indicated that change in FMD significantly differed between the LW and the control groups (23). In addition, the focus of the present article was on possible sex differences in risk factor responses, and the relationship between the previously published vascular variables and CV risk factors. Such analyses have not previously been published. For these analyses, we pooled data from the exercise groups and conducted completers analyses. Adherence to the exercise program was similar across the exercise groups,

TABLE 1. Baseline characteristics of the C, LW, and WW groups.

Variable	C (*n* = 23; 6 M, 17 F)	LW (*n* = 23; 6 M,17 F)	WW (*n* = 25; 7 M, 18 F)
Age, yr	62 (7)	63 (7)	63 (7)
Height, cm	168 (10)	165 (8)	167 (7)
Weight, kg	73.8 (13.6)	74.4 (11.1)	76.8 (19.8)
BMI, $kg \cdot m^{-2}$	26.2 (4.1)	27.3 (3.5)	27.3 (5.6)

Data are mean (SD).
BMI, body mass index.

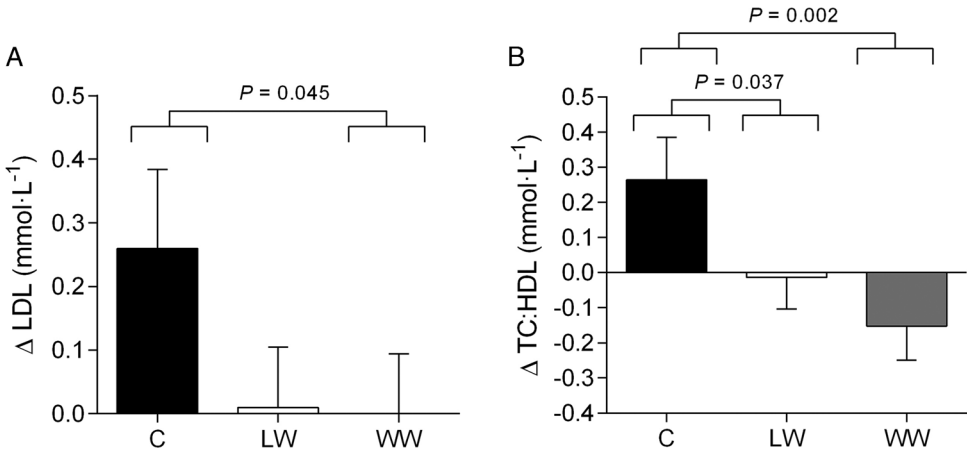

FIGURE 1—Effect of training on CV risk factors for the two exercise intervention groups. There was a significant increase in LDL in the C group compared with the WW group (A), and a significant increase in the control group compared with the LW and WW groups for the TC/HDL ratio (B) ($N = 70$). Data mean ± SEM. HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol.

with mean attendance of 83% for the LW and 79% of sessions for the WW group. Of these individuals, 70% attended more than 80% of the sessions, and 11% attended less than 50% of the sessions. Exercise intensity was also well matched, with no difference in percent heart rate reserve (% HRR) between groups over the course of the 24 wk. The intensity of exercise (% HRR) was closely matched between both exercise intervention groups, approximately 55% HRR (equivalent to ~70% maximum HR).

Effects of training on CV risk factors. LDL cholesterol and the total cholesterol (TC)/HDL ratio increased in the C group, whereas there was no such increase in the training groups, and the difference between the control and exercise groups was significant (LDL cholesterol: Fig. 1A; C: 0.26 ± 0.56 mmol·L^{-1}, LW: 0.01 ± 0.44 mmol·L^{-1}, WW: 0.00 ± 0.43 mmol·L^{-1} ($P = 0.045$, WW vs C); TC/HDL: Fig. 1B; C: 0.27 ± 0.54 mmol·L^{-1}, LW: −0.01 ± 0.41 mmol·L^{-1}, WW: −0.15 ± 0.45 mmol·L^{-1}, $P = 0.002$, WW vs C ($P = 0.037$, LW vs C)). No other group–time interaction effects were observed for CV risk factors (Table 2).

Sex differences in the impact of training on CV risk factors. Sex differences in training effects existed for visceral fat (Table 3, Fig. 2A, −187 ± 189 g♂ vs −15 ± 161 g♀; $P = 0.005$) and total body lean mass (Table 3, Fig. 2B, −351 ± 1045 g♂ vs 647 ± 1156 g♀; $P = 0.013$). There were no significant sex differences for the impact of exercise training on other CV risk factors, as shown in Table 3.

Relationships between changes in risk factors and vascular function. Table 4 shows the relationships between changes in risk factors and vascular function, for the pooled exercise groups. Twenty-three participants from the exercise groups had complete FMD for both preintervention and postintervention time points, which complied with our quality control procedures. Although improvement in FMD was correlated with a decrease in waist girth (Fig. 3: $r = -0.450$, $P = 0.036$), and there were significant effects of training on body composition, lipid levels, and vascular function, and no significant relationship existed between changes in other CV risk factors and vascular function.

DISCUSSION

There are a number of novel findings in the present study of apparently healthy middle-aged and older men and women. First, we found that supervised and center-based exercise training has a beneficial impact on lipid levels, relative to untrained

TABLE 2. CV risk factors before and after the 24-wk intervention.

Variable	C ($n = 23$)		LW ($n = 23$)		WW ($n = 25$)	
	Week 0	Week 24	Week 0	Week 24	Week 0	Week 24
Systolic blood pressure, mm Hg[a]	114 (12)	114 (11)	121 (11)	117 (10)	130 (14)	130 (13)
Diastolic blood pressure, mm Hg[a]	68 (6)	68 (7)	70 (7)	67 (6)	74 (7)	72 (8)
Mean arterial pressure, mm Hg[a]	86 (8)	86 (8)	90 (7)	87 (7)	96 (9)	95 (9)
Heart rate, bpm[b]	59 (7)	63 (8)	61 (6)	62 (5)	61 (5)	62 (7)
Cholesterol, mmol·L^{-1}[a,b]	4.9 (1.0)	5.4 (1.0)	5.4 (0.8)	5.4 (0.7)	5.6 (0.9)	5.6 (1.0)
Triglycerides, mmol·L^{-1}	1.0 (0.4)	1.1 (0.5)	1.1 (0.4)	1.1 (0.4)	1.2 (0.8)	1.1 (0.5)
LDL, mmol·L^{-1}[c]	3.1 (0.9)	3.5 (0.8)	3.3 (0.7)	3.3 (0.6)	3.6 (0.8)	3.5 (0.9)
HDL, mmol·L^{-1}	1.4 (0.3)	1.4 (0.4)	1.5 (0.4)	1.6 (0.4)	1.4 (0.4)	1.6 (0.6)
TC/HDL[c]	3.7 (0.8)	4.0 (1.0)	3.6 (0.8)	3.5 (0.8)	4.1 (1.1)	3.9 (1.1)
Glucose, mmol·L^{-1}	5.0 (0.4)	5.0 (0.6)	5.2 (0.5)	5.1 (0.4)	5.0 (0.5)	5.0 (0.6)
Hemoglobin, g·L^{-1}	135 (11)	135 (9)	133 (10)	135 (11)	138 (12)	139 (12)
Hematocrit	0.40 (0.03)	0.40 (0.03)	0.39 (0.03)	0.40 (0.03)	0.41 (0.03)	0.41 (0.04)

[a] Significant group effect.
[b] Significant time effect.
[c] Significant interaction (group–time) effect.

TABLE 3. Female and male risk factor baseline values and group mean changes with exercise (exercise groups pooled).

Variables	Baseline		Δ Exercise Groups Pooled				
	F	M	F	M	*P* Value (F vs M)	*n* (F)	*n* (M)
$\dot{V}O_2$, L·min^{-1}[a]	1.83 (0.35)	3.09 (0.47)	0.04 (0.22)	0.05 (0.23)	0.941	28	11
$\dot{V}O_2$, mL·min^{-1}·kg^{-1}[a]	26.7 (4.5)	35.3 (6.4)	0.6 (3.0)	0.8 (3.2)	0.883	28	11
Weight, kg[a]	69.5 (13.8)	89.4 (13.1)	–0.2 (2.0)	–0.7 (2.5)	0.471	30	13
Body mass index, kg·m^{-2}[a]	26.2 (4.7)	29.2 (3.9)	–0.1 (0.7)	–0.2 (0.8)	0.531	30	13
Waist girth, cm[a]	83.5 (11.8)	100.5 (10.4)	–0.9 (3.6)	–0.9 (3.6)	0.971	30	13
Hip girth, cm	103.9 (10.5)	105.0 (6.9)	–0.8 (2.9)	1.3 (3.8)	0.059	30	13
Waist-to-hip ratio[a]	0.80 (0.05)	0.96 (0.06)	0.00 (0.03)	–0.02 (0.04)	0.126	30	13
Visceral adipose tissue, g[a]	836 (575)	1943 (830)	**–15 (161)**	**–187 (189)**	**0.005**	29	12
Total body fat, %[a]	42.2 (6.9)	32.9 (5.5)	–1.0 (1.4)	–0.5 (1.7)	0.331	30	12
Total body fat, kg	28.7 (9.9)	28.5 (8.5)	–0.63 (1.4)	–0.87 (2.2)	0.684	30	12
Total body lean mass, kg[a]	37.7 (4.7)	56.5 (5.6)	**0.65 (1.2)**	**–0.35 (1.0)**	**0.013**	30	12
Systolic blood pressure, mm Hg	123 (13)	128 (14)	–2 (9)	1 (6)	0.362	30	13
Diastolic blood pressure, mm Hg[a]	69 (6)	77 (6)	–2 (5)	–1 (7)	0.697	30	13
Mean arterial pressure, mm Hg[a]	91 (8)	97 (9)	–2 (6)	–0.3 (6)	0.394	30	13
Heart rate, bpm	62 (5)	59 (6)	2 (6)	1 (7)	0.695	30	13
Total cholesterol, mmol·L^{-1}	5.6 (0.7)	5.1 (1.0)	0.0 (0.5)	0.1 (0.5)	0.764	29	13
Triglycerides, mmol·L^{-1}	1.1 (0.8)	1.3 (0.5)	–0.02 (0.46)	0.02 (0.35)	0.784	29	13
LDL, mmol·L^{-1}	3.4 (0.7)	3.3 (0.8)	–0.01 (0.44)	0.04 (0.43)	0.738	29	13
HDL, mmol·L^{-1}[a]	1.6 (0.4)	1.2 (0.2)	0.07 (0.30)	0.078 (0.13)	0.966	29	13
TC/HDL	3.6 (1.1)	4.2 (0.8)	–0.08 (0.45)	–0.08 (0.40)	0.990	29	13
Glucose, mmol·L^{-1}[a]	5.0 (0.5)	5.4 (0.4)	–0.04 (0.41)	0.02 (0.52)	0.722	29	13
Hemoglobin, g·L^{-1}[a]	130 (7)	145 (12)	2 (6)	2 (8)	0.990	29	13
Hematocrit[a]	0.39 (0.02)	0.43 (0.03)	0.001 (0.019)	0.005 (0.019)	0.529	29	13
Baseline diameter, mm[a]	3.1 (0.41)	4.2 (0.56)	–0.03 (0.23)	–0.17 (0.16)	0.126	15	8
FMD, %	5.39 (2.20)	3.79 (2.65)	1.43 (3.80)	0.42 (3.32)	0.533	15	8

Data are mean (SD).
Values in bold denote significant differences between males and females in exercise response.
[a] Significant baseline differences between males and females.
F, female. M, male.

control participants. Second, we observed that, with the exception of some body composition variables, the effects of exercise training on CV risk factors were similar between men and women. Finally, our study suggests that changes in vascular function and health can occur independently of changes in CV risk factors in middle-aged/older participants.

In accordance with our results, previous evidence has suggested that exercise training either improves or prevents age-related deterioration in LDL cholesterol (24). More specifically, previous studies indicate that a moderate-intensity aerobic exercise program is able to increase HDL cholesterol, while preventing any increase in total and LDL cholesterol levels (24), whereas decreases in LDL cholesterol require relatively high exercise intensity and/or volume (24). It is relevant that our study enrolled participants with normal lipid profiles at baseline, as larger impacts of training are typically seen in

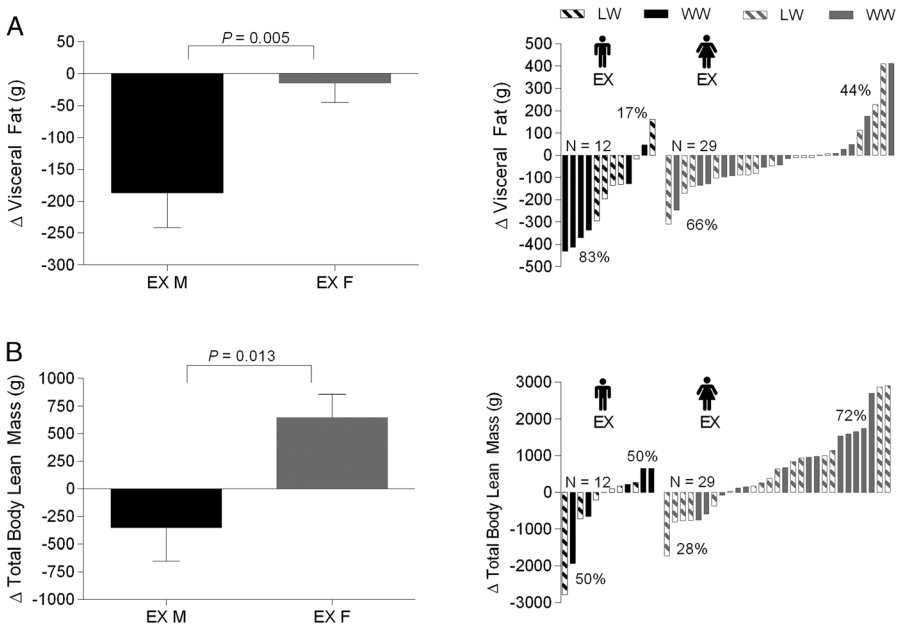

FIGURE 2—Sex differences in training effects for the two exercise intervention groups. Sex differences existed for visceral fat (A: upper panels) and total body lean mass (B: lower panels) (*N* = 41). Data mean ± SEM. EX, exercise; F, female; M, male.

TABLE 4. Correlation of change in risk factors and FMD (exercise groups pooled).

	Δ Baseline Diameter, mm	Δ FMD, %
Variables	***r* (*P*)**	***r* (*P*)**
$\dot{V}O_2$, L·min^{-1}	−0.133 (0.564)	0.169 (0.463)
$\dot{V}O_2$, mL·min^{-1}·kg^{-1}	−0.146 (0.526)	0.267 (0.241)
Weight, kg	0.150 (0.505)	−0.110 (0.627)
Body mass index, kg·m^{-2}	0.165 (0.474)	−0.098 (0.674)
Waist girth, cm	0.112 (0.619)	**−0.450 (0.036)**
Hip girth, cm	−0.004 (0.985)	−0.236 (0.290)
Waist-to-hip ratio	0.124 (0.581)	−0.214 (0.339)
Visceral adipose tissue, g	−0.081 (0.733)	−0.069 (0.772)
Total body fat, %	0.170 (0.461)	−0.354 (0.115)
Total body fat, g	0.091 (0.694)	−0.169 (0.464)
Total body lean mass, g	−0.090 (0.700)	0.206 (0.371)
Systolic blood pressure, mm Hg	−0.302 (0.172)	−0.028 (0.902)
Diastolic blood pressure, mm Hg	−0.081 (0.719)	−0.125 (0.580)
Mean arterial pressure, mm Hg	−0.171 (0.448)	−0.069 (0.759)
Heart rate, bpm	−0.212 (0.343)	0.143 (0.526)
Total cholesterol, mmol·L^{-1}	0.177 (0.442)	0.202 (0.380)
Triglycerides, mmol·L^{-1}	0.219 (0.341)	0.029 (0.899)
LDL, mmol·L^{-1}	0.077 (0.740)	0.292 (0.199)
HDL, mmol·L^{-1}	0.086 (0.710)	−0.062 (0.791)
TC/HDL	0.180 (0.434)	0.055 (0.812)
Glucose, mmol·L^{-1}	−0.323 (0.153)	0.050 (0.830)
Hemoglobin, g·L^{-1}	−0.159 (0.490)	−0.060 (0.795)
Hematocrit	−0.176 (0.445)	0.082 (0.723)

Values in bold denote significant differences between males and females in exercise response. *N* = 23.

populations with *a priori* low HDL and higher total and LDL (25). Our observation of positive changes in the ratio of TC/HDL, compared with a control group in whom lipid profiles deteriorated with time, has implications for the promotion of exercise in older healthy participants.

Our study indicates that exercise training did not significantly modify CV risk factors such as blood pressure and glucose, although in previous articles, we presented findings of beneficial impacts on body composition (22) and cardiopulmonary fitness (26). Meta-analysis indicates that aerobic exercise training can decrease blood pressure in sedentary older adults (27), although the magnitude of benefit is dependent on the baseline blood pressure values; those with higher *a priori* blood pressure exhibit larger decreases due to exercise training (28). Because our study included normotensive participants at baseline, the lack of significant decrease in blood pressure we observed is perhaps unsurprising. Similarly, aerobic training can improve blood glucose levels, but benefits are most apparent in patients with elevated basal blood glucose, such as those with diabetes or prediabetes (29,30). Furthermore, our findings indicate that beneficial effects on lipid levels were observed in response to each modality of exercise, when compared with the no-exercise condition. In summary, our findings on CV risk factors in apparently healthy middle-aged/older individuals suggest benefits for lipid levels, body composition, and fitness, but no particular short-term advantage relative to untrained control participants regarding blood pressure or glucose concentrations.

Few previous randomized controlled trials of supervised exercise training in older individuals have assessed sex differences in CV risk factors (16). In younger participants, males exhibit larger improvements in fitness after endurance training (31). Interestingly, this was not the case in our study of older participants in which men and women demonstrated similar absolute gains in $\dot{V}O_{2peak}$. However, women had lower baseline $\dot{V}O_{2peak}$ than men, such that in relative terms, their improvements were larger. Women had significantly larger lean mass increases than men, and somewhat larger improvements in FMD (a difference of ~1% in FMD was clinically (32) if not statistically significant). Interestingly, a recent study of younger adults also observed larger FMD changes in women than men (15). On the other hand, a previous study observed that men had greater increases in FMD after 8 wk of brisk walking compared with estrogen-deficient women (16). Our findings of improved vascular function after exercise contrast with some previous studies (16,33) that have trained postmenopausal women. The impacts of menopause and estradiol on arterial adaptation to exercise training have been expertly reviewed by Seals and colleagues (13), and it has been suggested that the effect of exercise training may be estrogen-dependent. Our study was limited to inclusion of postmenopausal women, but some were on stable hormone replacement therapy, and this may have impacted our vascular function results.

It has been suggested that aerobic exercise training is a valid modality to prevent age-related decline in lean mass (34); however, our findings suggest that this may be sex specific. It is perhaps germane that testosterone deficiency increases with age in men (35). Although studies indicate that resistance or circuit weight training is beneficial in older men with lower testosterone levels (36–38), it remains unclear whether

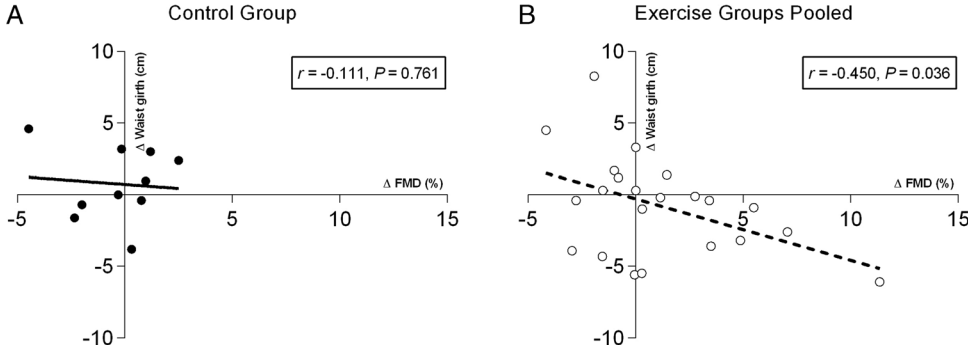

FIGURE 3—Correlations between changes in waist girth and changes in vascular function from weeks 0 to 24 (*N* = 41). There was a significant negative correlation for the exercise groups (B; *r* = −0.450, *P* = 0.036), whereby a larger decrease in waist girth was associated with higher vascular function, but the same did not occur with the control group (A; *r* = −0.111, *P* = 0.761).

walking exercise is a sufficient stimulus to induce skeletal muscle hypertrophy (22,39,40) and whether these effects may be more pronounced when comparing sexes. Despite a larger impact of training on lean mass in women, visceral fat mass decreased more in men, albeit from a higher starting level. This result is consistent with a meta-analysis that suggested that sex differences are apparent for a decrease in visceral fat after exercise training (41), with men having higher amounts of abdominal fat (42) that impact on levels of fat reduction (43). No sex differences were apparent in other CV risk factors in our study, including in those lipid variables for which changes differed significantly between intervention groups.

In previous articles, we have demonstrated that exercise-induced changes in vascular function occur independently of changes in CV risk factors (44,45). Here we reinforce this finding in the context of older apparently healthy individuals. In previous articles, we reported significant improvements in FMD (23), body composition (22), and fitness (26). This article reports that associations between FMD and risk factors, including fat, visceral fat, lean mass, fitness, blood glucose, and blood pressure, were not significant. The exception was that changes in waist circumference were negatively associated with FMD changes in the exercised but not the control participants. However, this finding was not confirmed by concordant correlations for visceral or total body fat and FMD, and our sample size was relatively modest in the control group. Taken together, our findings suggest that improvement in vascular health can result from exercise training (23), independently of mediating impacts of CV risk factors, thus implicating exercise-related episodic effects on autonomic balance (8–10) or endothelial shear stress (10,46). In support of the latter mechanism, we have demonstrated in younger healthy volunteers that exercise training in the absence of increases in shear stress fails to induce vascular adaptation (47,48), and that repeated shear stress induced independently of exercise can induce vascular adaptation (49,50). Ultimately, it is important to emphasize that, in this and previous studies, we have demonstrated that exercise training has beneficial effects on vascular function and health, even when CV risk factor changes are apparently modest.

This study has some limitations, including a relatively small sample size. However, this limitation was mitigated by randomizing participants to a within-subject experimental design and by pooling the trained individuals. Nonetheless, future studies should replicate our study in larger sample sizes, perhaps including more diverse groups of volunteers. Indeed, the participants included in this study were relatively healthy, which limits extrapolation of these results to groups with CV diseases. Also, some concerns exist regarding the measurement of visceral fat via dual x-ray absorptiometry regarding its precision and repeatability, but these were also mitigated by the repeated measures (within-subject) nature of the study. Finally, we did not have information regarding the time since the last menstrual cycle from the women who participated in this study, which somewhat limits the determination of menopausal status.

This study indicates that exercise training prevents deterioration in lipid levels in middle-aged/older adults, a beneficial effect apparent in both men and women. Some evidence for sex differences was apparent in body composition, with women demonstrating greater increases in lean body mass and men in visceral fat loss. Taken together, these findings indicate that middle-aged/older men and women both benefit from exercise training. Finally, changes in in vascular function were not dependent on changes in CV risk factors in middle-aged/older participants, implicating other stimuli such as arterial shear stress or beneficial effects on autonomic balance.

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