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ScienceDirect
Metabolism Clinical and Experimental 59 (2010) 1562 – 1573
Metabolism
Clinical and Experimental
www.metabolismjournal.com

A comparison of the effects of swimming and walking on body weight, fat distribution, lipids, glucose, and insulin in older women—the Sedentary Women Exercise Adherence Trial 2

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Received 28 September 2009; accepted 1 February 2010

Abstract

All types of aerobic exercise are assumed to affect cardiovascular risk similarly. There are few studies of swimming, but complex responses to water-based exercise suggest its potential for differential effects. The aim of the study was to compare the effects of swimming and walking on fitness, body weight, lipids, glucose, and insulin in older women. Sedentary women aged 50 to 70 years (N = 116), randomly assigned to swimming or walking plus usual care or a behavioral intervention, completed 3 sessions per week of moderate-intensity exercise, supervised for 6 months then unsupervised for 6 months. After 6 months, 1.6-km walk time decreased in walkers and swimmers, with greater improvement in walkers (1.0 vs 0.6 minute, P = .001). In swimmers, but not walkers, distance swum in 12 minutes increased (78.1 vs −2.2 m, P = .021). Waist and hip circumferences (80.8 vs 83.1 cm and 101.8 vs 102.4 cm; P = .023 and P = .042, respectively) and insulin area under the curve (oral glucose tolerance test) (5128 vs 5623 μU/[L 120 min], $P < .05$) were lower with swimming. Lipids did not differ between groups. At 12 months, fitness was maintained. Relative to walking, swimming reduced body weight by (1.1 kg, P = .039) and resulted in lower total and low-density lipoprotein cholesterol (0.3 and 0.2 mmol/L; P = .040 and P = .049, respectively). The magnitude of the difference in the reduction of insulin area under the curve between swimming and walking was greater at 12 months; however, the significance was attenuated (4677 vs 5240 μU/[L 120 min], P = .052). Compared with walking, swimming improved body weight, body fat distribution, and insulin in the short term and, in the longer term, body weight and lipid measures. These findings suggest that the type of exercise can influence health benefits.

1. Introduction

Body weight, body fat, and abdominal fat increase with age [1,2], whereas lipid profiles, glucose tolerance, and insulin sensitivity deteriorate [3-6]. Physical inactivity also increases with age [7,8] and is associated with obesity, atherosclerosis, cardiovascular disease (CVD), and diabetes [9,10].

Aerobic exercise has been proposed as an effective mechanism for reducing body weight and improving cardiovascular risk factors [11,12] and CVD [13]. All types of aerobic exercise, given the same intensity, duration, and frequency, have been assumed to affect these variables similarly. The variety of modes of exercise used in previous studies may partly explain inconsistent findings. The notion that different modes of aerobic exercise may influence health factors differently, although novel, has some support. For example, we have previously reported an increase in resting blood pressure with swimming, relative to walking, after 6 months [14].

Although the effects of aerobic vs resistance training on cardiovascular risk factors have been compared, to our knowledge, there has been no systematic evaluation of land-

The study was approved by the University of Western Australia Committee for Human Rights.

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0026-0495/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.metabol.2010.02.001

based walking vs water-based aerobic exercise (swimming) on body weight, fat distribution, lipids, and glucose and insulin responses. Walking and swimming are often recommended to increase physical activity and gain health benefits [15]. Walking is usually chosen [16,17]; and several studies have evaluated its effects on body weight, lipids, and, to a much lesser extent, glucose and insulin. There is little information on the effects of swimming training on these risk factors.

Although swimming has been considered of little value in weight reduction [18,19], more recent studies have shown effects on body weight and body composition similar to those seen with walking [20] and tai chi chuan [21]. In older women, head-out water-based exercise reduced total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) [22]. Physically active postmenopausal women engaging in a range of activities, including swimming, had lower fasting glucose and insulin and better glucose and insulin responses to a glucose challenge than inactive women [23].

We therefore aimed to compare the effects of moderate-intensity walking and swimming on body weight, body fat distribution, lipids, glucose, and insulin in older women. The study used 6 months of supervised and a further 6 months of unsupervised training to allow assessment of short- and longer-term outcomes.

2. Methods

2.1. Participants

The participants and study design have been described previously [14,24]. The flow of participants in the study is shown on Fig. 1. Healthy, sedentary women aged 50 to 70 years were recruited from the community. Entry criteria included being a nonsmoker, being *sedentary* (defined as doing <30 min/wk of moderate activity) for a least the previous 6 months, having a body mass index (BMI) of less than 34 kg/m^2, and being able to stay afloat and move in deep water. The women had no history of diabetes; cardiovascular, respiratory, or other chronic illness; or any musculoskeletal disorders that limited the capacity to participate in the exercise program. Difficulty in communicating in English and mental incapacity were exclusion criteria. Women were excluded if blood pressure was greater than 160/100 mm Hg; those taking antihypertensives or cholesterol-lowering medication were included.

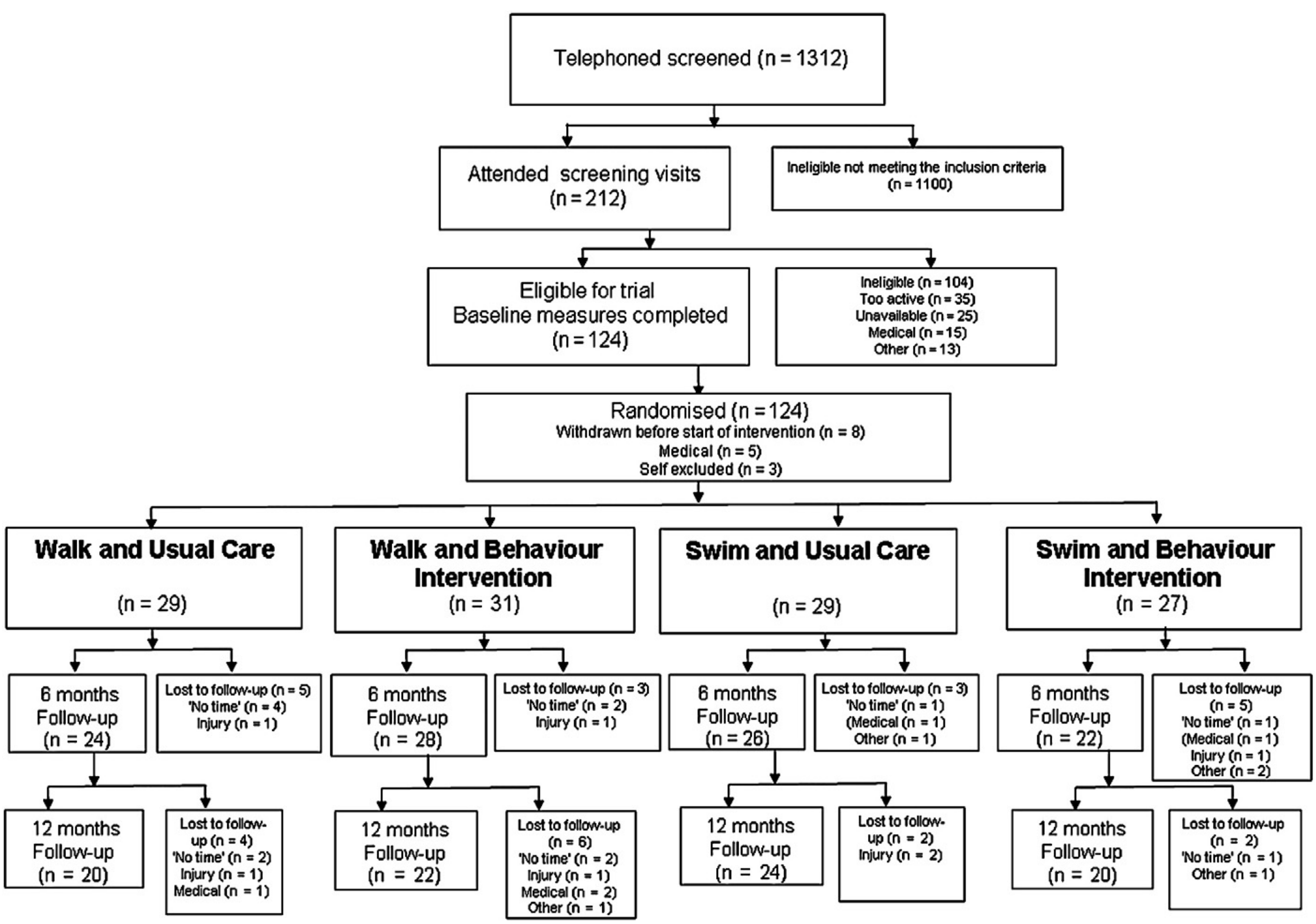

Fig. 1. Participant flow from recruitment to the end of the 12-month intervention in the Sedentary Women Exercise Adherence Trial 2 study in older women.

2.2. Study design

The women (N = 116) completed a 6-week run-in period, with measurement of baseline swimming and walking fitness, body weight, girths, blood lipids, and glucose and insulin levels assessed during the last 2 weeks of this period. Women were stratified and matched for age and BMI and randomly assigned by research staff to a walking or swimming program with the addition of usual care or a behavioral intervention using computer-generated random numbers allocated and held by a statistician. As this intervention involved a supervised exercise intervention, it was not possible to blind research staff to the group assignment. After the initial 6 months of supervised group-based sessions, the women continued for a further 6 months doing the same exercise program unsupervised.

The study was approved by the University of Western Australia Committee for Human Rights. All participants gave informed written consent before participation.

2.3. Exercise intervention

Both groups completed supervised exercise 3 times per week for 6 months (24 weeks). Each session included a 10-minute warm-up and 5-minute stretching, followed by 30 minutes of swimming or walking at a moderate intensity (60%-70% heart rate reserve [HR_{Res}]), 10-minute cooling down, and 5-minute stretching. In the first 4 weeks, participants exercised at 50% HR_{res} exercise intensity then increased progressively to 60% to 70% HR_{res} at 8 weeks. During the supervised period, the women wore heart rate (HR) monitors (Polar Edge; Polar Electro, Kempele Finland); the mean of HR recorded after 15 and 30 minutes of exercise was used to determine training intensity (% HR_{res}) [14,24].

At baseline, resting supine HR and blood pressure were measured with the Dinamap 1846SX (Critikon, Tampa, FL) with 10 readings taken over 20 minutes. Baseline HR was the mean at 3 separate visits at the end of baseline. Maximum HR was taken as the highest value of the predicted maximum HR formula (220 − age) or the maximum HR on the baseline fitness tests.

Swimming was in heated indoor and outdoor swimming pools (mean water temperature, 26.5°C). As there was a variation in the participant's swimming skill, several strategies were used to minimize the effect of this variation. The women swam a variety of strokes in all sessions: front and back crawl, breaststroke, and sidestroke. Swimming fins were used for front and back crawl, particularly in the early stages of the program, to enable the women to complete 30 minutes of swimming within the prescribed intensity. As proficiency increased, more swimming was completed without the fins. Approximately 40% of the session consisted of drill work and kicking. Swimming was completed as interval training with rest periods decreasing as fitness increased. Only the time spent in swimming was counted as the time for the swimming session. Furthermore, HRs and rate of perceived exertion (RPE) were monitored during each swim session so that the intensity of the swimming was kept within the prescribed HR range for each person, minimizing any potential effect of different skill level on exercise intensity.

Walks were completed continuously around ovals and parks. During the second 6 months, the women continued their same exercise program unsupervised at a venue of their choice and measured HR manually, a skill taught during the first 6 months of the program. The swimmers were given written instructions for workouts to complete. Participants recorded their sessions including HR and RPE [25] on exercise diaries that they returned each fortnight in prepaid envelopes.

2.4. Behavioral intervention protocol

Half of the women received a behavioral intervention package to encourage adoption and adherence to an exercise program [26]; the other half had standard exercise information or "usual care."

2.5. Measurements

2.5.1. Physical fitness

The assessment of fitness has been described [14]. The 1.6-km walk test [27] was used to measure walking fitness; swimming fitness was assessed using the 12-minute swim test [28]. Maximal oxygen consumption ($\dot{V}O_{2max}$) was estimated from the time walked and HR [27]. Heart rate monitors were worn for both tests. After 6 and 12 months, women completed a walk and swim test. All fitness tests were completed at least 48 hours after the last exercise session.

2.5.2. Body weight and fat distribution

Height was measured using a fixed stadiometer with the women in bare feet. Body weight was measured with women in light clothing, without shoes, using a calibrated beam balance (Avery, Birmingham, England). Waist, hip, upper arm, forearm, chest, upper and mid thigh, and calf circumferences were measured by trained observers to the nearest 0.1 cm, using a 5-mm flexible retractable steel tape measure (Rabone, Chesterman, England). Waist circumference was measured at the level of minimum circumference and hip girth at the level of the greatest protrusion of the buttocks, and the waist-to-hip ratio (WHR) was calculated. Other circumferences were measured using standard sites [29]. Upper arm, chest, and mid thigh sites were located and marked at the start of the session. A trained observer took 3 measurements at all sites, and the median was determined.

At baseline, the women were asked to report their weight at 21 years. Mean weight gain per year was estimated from the difference between baseline weight and weight at 21 years divided by the number of years from age 21 to current age.

2.5.3. Dietary compliance and alcohol intake

Participants were asked to maintain their usual diet and alcohol intake throughout the study. A food frequency questionnaire [30] was used to assess the usual nutrient intake for the previous 3 months. Nutrient intake and percentage of the total energy intake as protein, fat, and carbohydrate were calculated using the FoodWorks 2007 software package (Xyris Software, Highgate Hill, Highgate Hill, Australia). Alcohol intake (in milliliters of ethanol per week) was calculated at baseline from consecutive 7-day retrospective diaries over 3 weeks. At the end of 6 and 12 months, the mean alcohol consumption was calculated from two 7-day diaries at each of these time points.

2.5.4. Blood lipids and lipoproteins

Blood was sampled in the morning, after an overnight fast. A scalp vein needle was inserted in the forearm, and participants rested supine for 20 minutes. Blood was sampled for cholesterol, triglyceride, and high-density lipoprotein cholesterol (HDL-C). The women were tested at the same time of the day before and after intervention with blood samples taken at least 48 hours after the last exercise session. Serum for lipids was stored at 4°C and assayed within 3 days. Serum TC and triglyceride concentrations were determined by standard methods using the Hitachi 917 Biochemical Analyzer (Roche Diagnostics, Mannheim, Germany). High-density lipoprotein cholesterol was analyzed using a commercial kit (Boehringer Mannheim, Mannheim, Germany). Low-density lipoprotein cholesterol was estimated from a modified Friedewald formula [31]. All analyses were conducted by Pathwest Laboratory, Perth, Australia.

2.6. Glucose and insulin

A standard oral glucose tolerance test (OGTT) was completed after an overnight fast. After sampling for baseline glucose and insulin, women were given a 200-mL drink of Glucotol (Orion Laboratories, Perth, Australia) containing 75 g of glucose. Further samples were drawn for glucose and insulin at 30, 60, 90, and 120 minutes after the drink. Participants were tested at the same time of the day with at least 48 hours between the last exercise session and the OGTT. Samples were stored at −80°C until analysis.

Serum glucose was assayed with an automated Technicon Axon Analyzer (Bayer Diagnostics, Sydney, Australia) using a hexokinase method (Roche Diagnostics, Indianapolis, IN). Serum insulin was analyzed by a chemiluminescent immunometric assay on the automated immunoassay analyzer Immulite 2000 (Siemens Medical Solutions Diagnostics, Los Angeles, CA). Glucose and insulin areas under the curve (AUCs) were calculated from the OGTT using the summary measures method [32].

2.7. Statistical analysis

As the behavioral intervention did not influence cardiovascular risk factors, only comparisons between walking and swimming are presented. The SPSS statistical software (release 15.0; SPSS, Chicago, IL) was used to analyze the data. Baseline results are expressed as mean ± SD; all other results are presented as mean with 95% confidence limits (95% confidence interval [CI]). Fasting glucose, insulin, and insulin AUC were not normally distributed; these values were logarithmically transformed, and geometric means and 95% CIs were computed. Frequency counts and χ^2 analyses were used to examine cholesterol-lowering medication, demographic data, and retention. Differences in characteristics between groups at baseline were assessed using 1-way analysis of variance. Generalized linear models (GLMs), with adjustment for baseline values, were used to examine effects of the interventions on exercise adherence, exercise intensity, body weight, circumferences, fitness, diet, and lifestyle compliance. With lipid variables, GLM was adjusted for initial lipid level, age, lipid-lowering medication, use of oral contraceptives or hormonal replacement therapy, and change in body weight or waist circumference as indicated. Results were considered significant if $P < .05$. An a posteriori calculation indicated that the study had 80% power at $\alpha = .05$ to detect a difference of 1 kg body weight, 2 cm waist circumference, 0.33 mmol/L cholesterol, 0.23 mmol/L LDL-C, 10% AUC glucose, and 15% AUC insulin between the 2 exercise modes.

3. Results

Baseline characteristics of the 2 exercise groups are shown on Tables 1-4. The groups were well matched with no significant differences between the groups. Estimated mean weight gain since the age of 21 years was 0.5 (0.3) kg/y, with 94.4% of the women having gained weight during this period. Most women were postmenopausal (70.6%), and 43.4% were taking hormone replacement therapy (HRT) or oral contraceptives. Mean cholesterol was 5.2 (0.8) mmol/L, with 34.5% outside the recommended level (≥5.5 mmol/L); and 6% were taking cholesterol-lowering medication.

Table 1
Baseline demographic and fitness characteristics of the participants in the walking and swimming groups

	Walk (n = 60)	Swim (n = 56)
Age (y)	55.2 ± 4.8	55.8 ± 4.5
Height (mm)	163.4 ± 6.2	163 7 ± 5.6
BMI (kg/m^2)	26.4 ± 3.5	26.3 ± 3.0
Overweight (BMI >25 kg/m^2) (n [%])	37 (62%)	35 (63%)
Obese (BMI >30 kg/m^2) (n [%])	8 (13%)	10 (18%)
Central obesity (waist girth >84 cm) (n [%])	30 (50%)	21 (38%)
1.6-km walk time (min)	14.8 ± 1.0	14.7 ± 1.1
Swim distance (m)	291.4 ± 66.4	294.8 ± 80.2
Vo_{2max} predicted (mL/[kg min])	27.5 ± 4.1	27.5 ± 4.2
Drinkers (n [%])	53 (88%)	44 (78.6%)
Alcohol intake (mL/wk)	59.2 ± 51.3	60.5 ± 66.6
Cholesterol-lowering medication (n [%])	4 (7%)	3 (5%)
Postmenopausal (n [%])	38 (67.9%)	39 (73.6%)
Oral contraceptives/HRT (n [%])	25 (43.1%)	24 (43.6%)

Values are mean ± SD. There were no significant differences between groups at baseline.

Table 2
Unadjusted body weight, BMI, WHR, and girth measurements at baseline and at 6 and 12 months in the walk and swim groups

n1 = baseline, n2 = 6 mo, n3 = 12 mo	Walk group (n1 = 60, n2 = 49, n3 = 42)	Swim group (n1 = 56, n2 = 48, n3 = 44)	Between-group *P* value
Body weight (kg)			
Baseline (n1)	70.7 (11.1)	70.5 (8.8)	
6 mo (n2)	70.3 (10.9)	69.4 (7.4)	.181
12 mo (n3)	71.1 (10.6)	69.9 (7.9)	.042
BMI (kg/m^2)			
Baseline	26.4 (3.5)	26.3 (3.0)	
6 mo	26.2 (3.6)	25.9 (2.9)	.182
12 mo	26.3 (3.4)	26.2 (2.9)	.044
Waist girth (cm)			
Baseline	84.0 (10.6)	82.5 (8.2)	
6 mo	83.1 (10.7)	80.8 (7.1)	.027
12 mo	82.3 (9.5)	79.9 (6.8)	.080
Hip girth (cm)			
Baseline	103.0 (7.5)	103.3 (6.6)	
6 mo	102.4 (7.5)	101.8 (6.1)	.042
12 mo	102.2 (6.8)	101.7 (6.6)	.026
WHR			
Baseline	0.8 (0.1)	0.7 (0.1)	
6 mo	0.8 (0.1)	0.7 (0.1)	.183
12 mo	0.8 (0.1)	0.7 (0.1)	.722
Upper arm girth (cm)			
Baseline	30.3 (3.1)	30.6 (2.6)	
6 mo	29.7 (2.9)	29.9 (2.5)	.964
12 mo	29.5 (2.8)	29.9 (2.5)	.751
Forearm girth (cm)			
Baseline	25.2 (1.5)	25.4 (1.6)	
6 mo	24.9 (1.4)	24.8 (1.3)	.082
12 mo	24.8 (1.3)	24.8 (1.5)	.073
Chest girth (cm)			
Baseline	92.3 (7.8)	91.6 (5.4)	
6 mo	90.6 (6.9)	90.0 (5.2)	.074
12 mo	90.6 (6.4)	89.8 (5.4)	.487
Gluteal thigh girth (cm)			
Baseline	59.2 (5.4)	60.1 (4.7)	
6 mo	58.5 (5.1)	59.3 (4.6)	.614
12 mo	58.9 (5.3)	59.5 (4.9)	.061
Mid thigh girth (cm)			
Baseline	51.8 (4.5)	52.5 (4.0)	
6 mo	51.0 (4.4)	51.8 (4.0)	.886
12 mo	51.4 (4.5)	52.4 (4.7)	.954
Calf girth (cm)			
Baseline	36.4 (2.7)	36.4 (2.5)	
6 mo	36.6 (2.8)	35.8 (2.5)	.000
12 mo	36.7 (2.8)	35.8 (2.7)	.000

Values are expressed as mean (SD). There were no significant differences between the 2 exercise modes at baseline. Between-group differences were determined by GLM adjusted for baseline and other variables as described.

3.1. Retention, exercise adherence, intensity, and physical fitness

The retention, adherence to the program, and changes in fitness have been reported [24]. Briefly, at 6 months, 86% of the women were still in the program; and at 12 months, the retention rate was 74%. There was no difference in retention between the 2 modes of exercise or the behavioral vs the usual care groups. Adherence to exercise was similar in both groups. Walkers and swimmers completed, respectively, 2.4 (2.3, 2.6) sessions per week (approximately 122 min/wk) and 2.5 (2.4, 2.7) sessions per week (approximately 126 min/wk) in the first 6 months and 2.3 (2.1, 2.5) sessions per week (approximately 116 min/wk) and 2.3 (2.2, 2.5) sessions per week (approximately 117 min/wk) at 12 months. Both groups exercised in the moderate range, the walk group at 59.9% (58.0%, 61.7%) HR_{Res} and 60.9% (58.9%, 62.9%) HR_{Res} over 6 and 12 months and the swim group at 61.1% (59.2%, 63.0%) HR_{Res} and 62.5% (60.5%, 64.6%) HR_{Res}, respectively. There was no significant difference in intensity between the 2 exercise modes.

Time to walk 1.6 km and predicted VO_{2max} improved for both groups after 6 and 12 months. The time decreased by 1.0 (0.8, 1.1) minute (7%) and 0.9 (0.6, 1.1) minute (6%) for the walk group and by 0.5 (0.4, 0.7) minute (4%) and 0.6 (0.4, 0.7) minute (4%) for the swim group at 6 and 12 months, respectively. There was a significant between-group difference after 6 months (P = .001) and 12 months (P = .023). The change in predicted VO_{2max} after 6 months was significantly higher (P = .032) for the walk group (2.5 [2.0, 3.0] mL/[kg min]) than the swim group (1.7 [1.2, 2.2] mL/[kg min]). After 12 months, there was no significant between-group difference in the change in predicted VO_{2max} with values of 2.0 (1.4, 2.6) mL/(kg min) for walkers and 1.7 (1.1, 2.2) mL/(kg min) for swimmers.

Only the swim group showed an improvement in distance swum in 12 minutes: 78.1 (89.4, 66.7) m (P = .000) and 83.7 (99.5, 68.0) m (P = .000) at 6 and 12 months

Table 3
Unadjusted dietary energy intake, blood cholesterol, HDL-C, LDL-C, and triglyceride at baseline and at 6 and 12 months in the walk and swim groups

n1 = baseline, n2 = 6 mo, n3 = 12 mo	Walk group (n1 = 60, n2 = 49, n3 = 42)	Swim group (n1 = 56, n2 = 48, n3 = 42)	Between-group *P* value
Energy intake (kJ/d)			
Baseline	9464.1 (2367.5)	10 163 (2783.3)	
6 mo	9290.7 (2939.7)	9767.6 (2744.3)	.744
12 mo	8878.4 (3075.9)	9607.5 (2710.8)	.412
Cholesterol (mmol/L)			
Baseline	5.2 (0.6)	5.1 (0.8)	
6 mo	5.3 (0.7)	5.3 (0.9)	.409
12 mo	5.5 (0.8)	5.2 (0.9)	.042
HDL-C (mmol/L)			
Baseline	1.5 (0.3)	1.5 (0.3)	
6 mo	1.5 (0.3)	1.6 (0.3)	.816
12 mo	1.5 (0.3)	1.5 (0.3)	.942
LDL-C (mmol/L)			
Baseline	3.2 (0.6)	3.1 (0.8)	
6 mo	3.3 (0.7)	3.2 (0.8)	.336
12 mo	3.4 (0.8)	3.2 (0.9)	.049
Triglyceride (mmol/L)			
Baseline	1.1 (0.5)	1.0 (0.4)	
6 mo	1.0 (0.5)	1.0 (0.3)	.577
12 mo	1.1 (0.7)	1.0 (0.5)	.788

Values are expressed as mean (SD). There were no significant differences between exercise modes at baseline. Between-group differences were determined by GLM adjusted for baseline and other variables as described.

Table 4
Unadjusted fasting glucose and insulin, glucose and insulin AUC, and HOMA index measurements at baseline and at 6 and 12 months in the walk and swim groups

n1 = baseline, n2 = 6 mo, n3 = 12 mo	Walk group (n1 = 49, n2 = 49, n3 = 42)	Swim group (n1 = 47, n2 = 47, n3 = 41)	Between-group *P* value
Fasting glucose (mmol/L)			
Baseline (n1)	5.1 (5.0, 5.2)	5.1 (5.0, 5.2)	
6 mo (n2)	5.1 (5.0, 5.3)	5.2 (5.1, 5.4)	.060
12 mo (n3)	5.2 (5.1, 5.4)	5.1 (5.0, 5.2)	.306
Glucose AUC (mmol/[L 120 min])			
Baseline	857.4 (807.9, 906.9)	894.6 (833.2, 956.0)	
6 mo	864.6 (817.5, 911.7)	901.6 (836.9, 966.3)	.722
12 mo	856.2 (810.3, 902.1)	852.3 (780.5, 924.1)	.236
Fasting insulin (mU/L)			
Baseline	6.7 (5.4, 8.4)	5.7 (4.8, 6.9)	
6 mo	7.2 (5.9, 9.2)	6.5 (5.5, 7.7)	.868
12 mo	6.8 (5.6, 8.2)	6.3 (5.2, 7.7)	.951
Insulin AUC (mU/[L 120 min])			
Baseline	5818.3 (5006.1, 6763.9)	4905.6 (4119.0, 5842.5)	
6 mo	6043.6 (5256.5, 6948.6)	4787.4 (4130.4, 5447.5)	.045
12 mo	5806.3 (4993.4, 6749.5)	4314.1 (3541.6, 5256.5)	.052
HOMA index			
Baseline	1.8 (1.5, 2.1)	1.5 (1.3, 1.7)	
6 mo	1.7 (1.4, 2,0)	1.5 (1.3, 1.8)	.634
12 mo	1.9 (1.6, 2.1)	1.6 (1.4, 1.9)	.549

Values are expressed as the geometric mean (95% CI) for all measures except for glucose AUC, which is the mean (95% CI). There were no significant differences between the 2 exercise modes at baseline. Between-group differences were determined by GLM adjusted for baseline and other variables as described.

compared with the walk group: −2.2 (−8.2, 3.7) m and 5.0 (−1.7, 11.8) m, respectively.

3.2. Body weight and circumferences

Body weight, BMI, circumferences, and WHR at each time point for the walk and the swim groups are shown on Table 2. At 6 months, body weight was 0.6 (0.3, 1.5) kg lower in swimmers than in walkers; but the difference was not statistically significant (P = .181). At 12 months, a difference of 1.1 (0, 2.1) kg was statistically significant (P = .039). The unadjusted changes in body weight are shown in Fig. 2. Differences remained significant after adjustment for age, number of exercise sessions, and exercise intensity.

After 6 months, waist girth was 1.6 (0.2, 2.9) cm (P = .023) lower in swimmers than in walkers. At 12 months, waist girth was lower in swimmers by 1.5 (0, 2.9) cm; and the between-group difference was statistically significant after adjustment for exercise intensity (P = .041). Hip circumference was significantly lower in swimmers than in walkers at 6 months (0.9 [0, 1.8] cm, P = .042) and 12 months (1.1 [0.1, 2.1] cm, P = .026). Swimmers also had significantly lower calf circumference at 6 and 12 months (0.8 [0.5, 1.2] cm, P = .000 and 0.9 [0.5, 1.3] cm, P = .000, respectively). There were no significant between-group differences in WHR, chest, upper arm, forearm, or mid or gluteal thigh circumferences at 6 or 12 months.

3.3. Lipids

Table 3 shows lipid levels at baseline and at 6 and 12 months, with unadjusted changes shown in Fig. 3. There were no significant between-group differences in HDL-C or triglyceride at 6 or 12 months, or in cholesterol and LDL-C after 6 months. After 12 months, the swimmers had significantly lower cholesterol (0.3 [0, 0.5] mmol/L, P = .040) and LDL-C (0.2 [0, 0.5] mmol/L, P = .049). These differences remained significant after adjustment for change in weight or waist circumference and change in alcohol consumption.

3.4. Dietary and alcohol intake

Energy intake was unchanged, with no significant between-group differences after 6 or 12 months (Table 3). Alcohol intake also showed no significant between-group difference after 6 or 12 months.

3.5. Glucose and Insulin

Table 4 shows fasting glucose, insulin, homeostasis model assessment (HOMA)index, and glucose and insulin AUC at baseline and at 6 and 12 months. There was no significant between-group difference in fasting glucose, insulin, HOMA, or glucose AUC at 6 or 12 months (Table 4). Fig. 4 shows unadjusted changes in glucose and insulin AUC at 6 and 12 months. Insulin AUC was significantly lower in the swimmers than in walkers at 6 months: 5128.6 (4786.3, 5370.3) μU/(L 120 min) vs 5623.4 (5248.1, 6025.6) μU/(L 120 min) (P = .045). This difference remained significant after adjustment for age, exercise intensity, and change in body weight and waist circumference. After 12 months, although the insulin AUC remained lower in swimmers, the significance of the

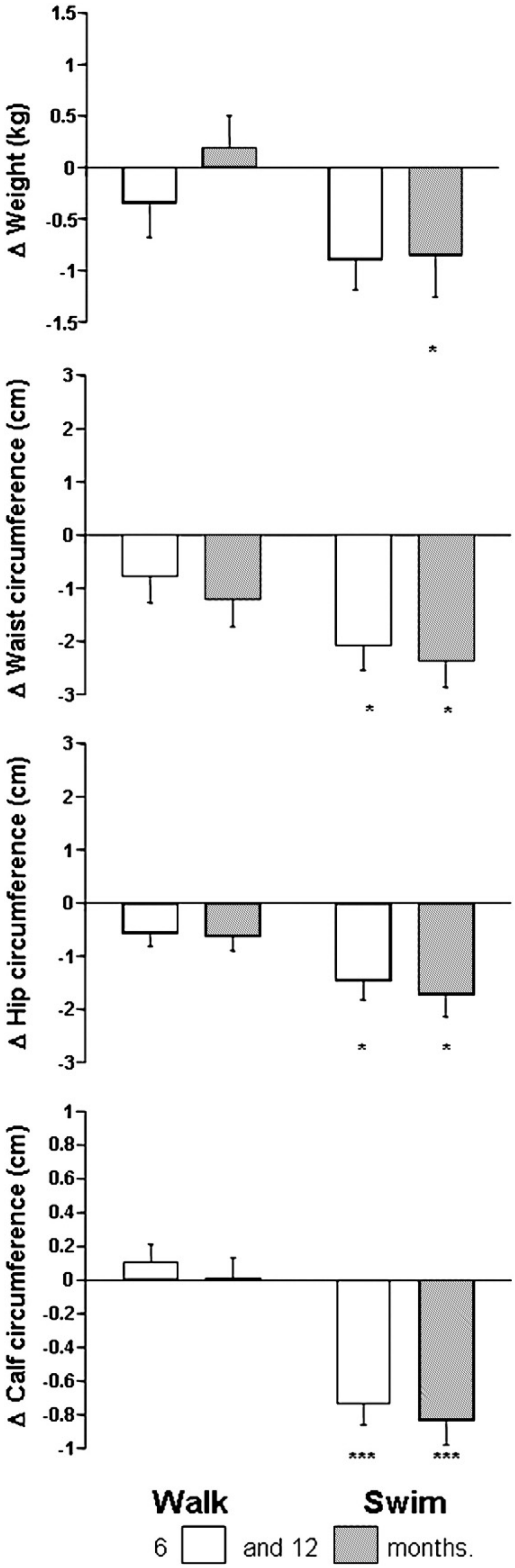

Fig. 2. Unadjusted mean (±SEM) changes from baseline in weight, waist, hip, and calf circumferences in the walk and swim groups after 6 ☐ and 12 ▧ months. Significance of GLM analysis: *$P < .05$ and ***$P < .001$.

between-group difference was attenuated: 4677.4 (4265.8, 5128.6) μU/(L 120 min) in swimmers vs 5240.1 (4897.8, 5754.4) μU/(L 120 min) in walkers (P = .052).

4. Discussion

In previously sedentary older women, walking and swimming increased fitness, with the novel finding that swimming improved cardiovascular risk factors, relative to walking, in the short and longer term. Swimming reduced insulin levels after 6 months and decreased waist, hip, and

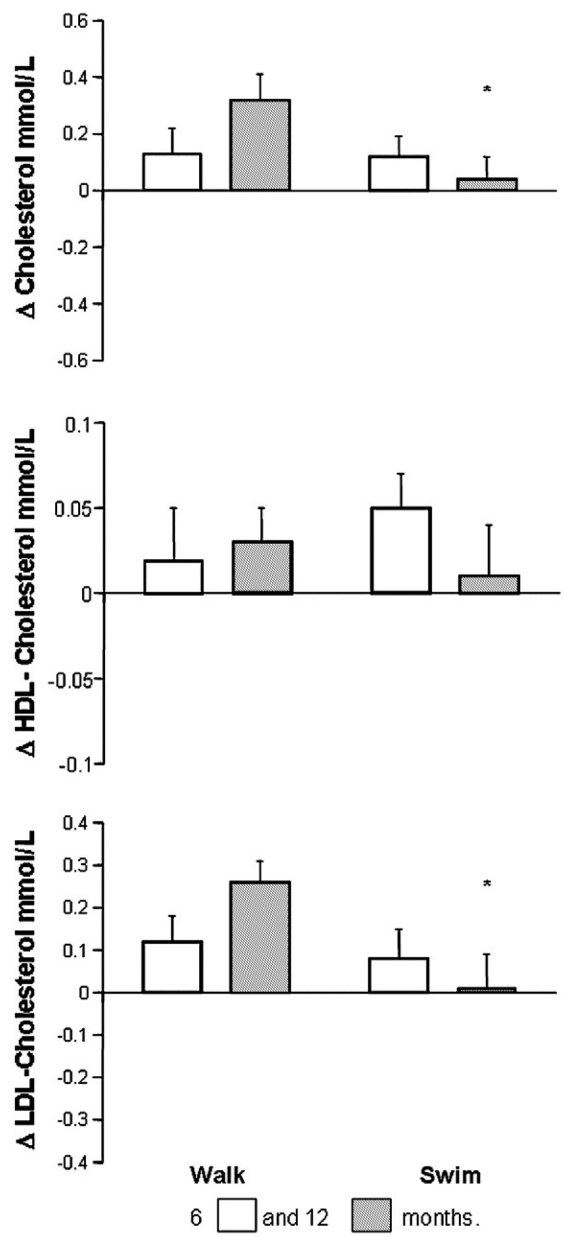

Fig. 3. Unadjusted mean (±SEM) changes from baseline in TC, HDL-C, and LDL-C in the swim and walk groups after 6 ☐ and 12 ▧ months. Significance of GLM analysis: *$P < .05$.

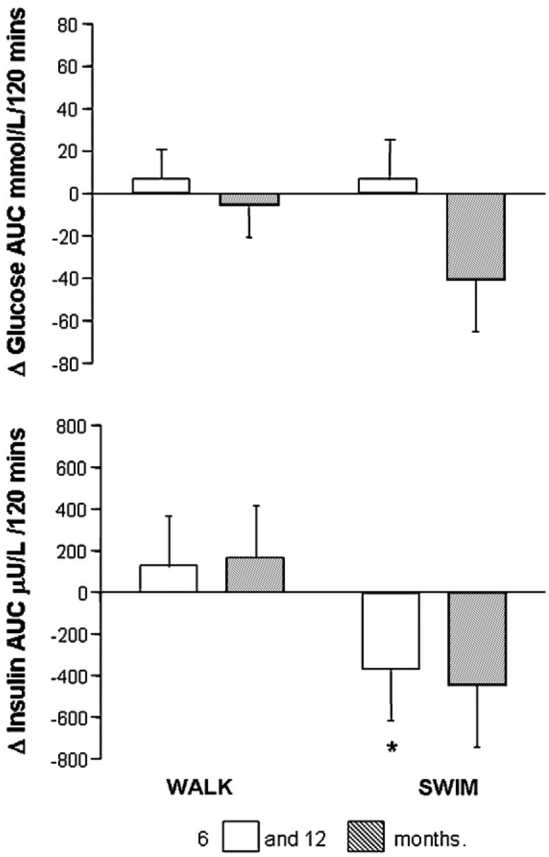

Fig. 4. Unadjusted mean (±SEM) changes from baseline in AUC glucose and insulin in the swim and walk groups after 6 □ and 12 ▧ months. Significance of GLM analysis: $*P < .05$.

calf circumferences at both 6 and 12 months. Lower body weight and lipids in swimmers were apparent only after 12 months.

For swimmers and walkers, the target was the recommended level of 150 min/wk of moderate-intensity exercise [33]. However, swimmers averaged about 117 min/wk over 12 months, a level which they found acceptable and achievable in the longer term. Even this amount produced long-term health benefits.

Weight loss with swimming has important implications for weight control programs. Previous studies have suggested that water-based activities may be less effective than land-based activities because of differences in effects on energy balance and weight loss mechanisms [18,34]. A 6-month program of daily exercise, with exercise intensity not controlled, reduced body weight by 10% in walkers and 12% in cyclists; but swimmers gained 5 lb [18], possibly explained by increased appetite and energy intake after swimming. White et al [35] reported that, 1 hour after acute bouts of immersed cycle ergometry, energy intake was increased after exercise in cold water (20°C) compared with thermoneutral water (33°C).

We asked participants not to change their diet. Energy intake did not differ between exercise groups, suggesting that there was no stimulation of appetite after swimming or that swimmers successfully resisted compensatory energy intake. Water temperature in the current study was 26.5°C, as is usual in public pools used for swimming training. Although cooler than neutral mean skin temperature (about 33°C), it may have affected appetite less than water at 20°C as used by White et al [35]. Whether swimming in cooler water influences weight loss by increasing appetite and energy intake needs investigation. Weight loss programs involving aquatic activities need to take water temperature into account.

A 13-week study in middle-aged obese women compared walking on land, swimming in 27°C water, and water walking in 29°C water. Exercise intensity was similar to our study, but women exercised 4 times weekly and reduced dietary fat and refined carbohydrate. Each regimen produced similar reductions in body weight (5.9 kg) and girth measurements [20]. Differences in the target group and study design may explain the smaller weight loss in our study.

A recent meta-analysis concluded that walking at a self-selected brisk pace results in modest reductions in body weight (1.4%) and BMI [17]. We found similar changes in our study, with swimmers reducing weight by 1.4% at 6 months and 0.9% at 12 months. Walkers in our study differed from those reported in the meta-analysis, with a reduction of 0.5% at 6 months and an increase of 0.9% after 12 months. The total amount of walking may have been a factor, as the walkers in our study averaged only 116 min/wk over 12 months compared to 188.8 min/wk reported by Murphy et al [17]. Walking has not been found consistently to reduce body weight; increased body weight has been reported [36,37], possibly resulting from increased muscle mass. We were unable to assess this, as we did not measure changes in body composition in our study.

Weight loss in the swimmers, whose volume and intensity of exercise were similar to those of the walkers, may perhaps be explained by heat loss during swimming, resulting in postexercise energy expenditure. The thermoneutral range of water temperature for humans is 33°C to 35°C, and moderate cold water stress occurs in water temperature of 25°C to 32°C; core temperature falls with even moderate exercise [38]. Oxygen consumption (V_{O_2}) during swimming at submaximal speed is greater in cold water [34,39].The water temperature in the current study averaged 26.5°C. Heat produced by exercise would have been insufficient to offset cooling [39]; and in restoring core temperature after leaving the water, swimmers may have increased metabolic rate, leading to greater energy expenditure after exercise than in walkers.

Waist circumference, an indicator of central adiposity [40], is associated with dyslipidemia and insulin resistance [41] and is an independent risk factor for CVD [42]. In our study, reduction in waist circumference was significantly greater in swimmers than walkers after 6 months but not at 12 months, at which stage waist circumference had decreased in the walkers. Attrition in numbers by 12 months would have reduced power for between-group comparisons.

In a recent meta-analysis of the effects of walking on body fatness [17], only 3 studies measured waist circumference and only 1 reported a decrease. Among previously sedentary middle-aged women, short bouts of walking 5 d/wk for 10 weeks reduced body weight and waist circumference [43]. In older overweight women who walked 10 000 steps a day for 8 weeks, neither body weight nor waist circumference decreased [44]. As waist girth did not change significantly in walkers until 12 months in our study, such changes may depend on the duration of the intervention.

In our study, central and regional girths were reduced in both walkers and swimmers, with no preferential reduction in central obesity. We have previously reported no preferential loss of central fat in men [45]. However, there were differential effects of swimming to reduce waist girth in the short term and hip and calf girths in the short and longer term, possibly resulting from the use of different muscle groups in swimmers and walkers [21]. Nevertheless, a reduction in waist circumference with both modes of exercise has positive health benefits.

4.1. Insulin

Exercise-induced weight loss improved glucose tolerance and insulin action in healthy middle-aged men and women [46]. Exercise independent of weight loss increased muscle insulin sensitivity and responsiveness [47]. Walking without weight loss improved glucose tolerance, but not insulin responses to an OGTT, in older women [44]; there was no change in fasting glucose and insulin in postmenopausal women after 24 weeks of walking [48]. In our study, fasting glucose, insulin levels, and AUC glucose were not improved with either mode of exercise. One reason for the difference in findings between our study and that of Swartz et al [44] could be that the interval of 10 to 16 hours between exercise and the OGTT measured an acute effect. We evaluated participants at least 48 hours after the last exercise session, a design that provides a stronger basis for our suggestion of chronic benefits related to improvement in insulin responses with swimming.

The effects of swimming training on glucose and insulin responses are largely unknown. In young trained male and female swimmers, intense training did not influence insulin action [49]. In a cross-sectional study in postmenopausal habitual runners, swimmers, and controls, swimmers' levels of insulin sensitivity were similar to runners' despite swimmers having higher body weight and fat [50]. Swimmers also had higher insulin sensitivity than age-matched controls. Our finding of improved insulin responses to an OGTT with swimming is consistent with this report. Walking and running differ in many aspects; running is performed at a higher intensity, and runners are likely to differ from people who take up walking for health benefits. Differences between responses in walkers in our study and in runners reported by Tanaka et al [50] are not unexpected. Kang et al [51] found improved insulin responses to 2 weeks of higher-intensity (70% $\dot{V}O_2$ peak), but not lower-intensity (50% $\dot{V}O_2$ peak), exercise training in obese individuals with or without type 2 diabetes mellitus. As the intensity of swimming and walking in our study was controlled and similar, this is unlikely to explain a differential effect of swimming. A greater increase in muscle mass in swimmers and/or greater loss of abdominal fat could possibly account for differences in insulin action, as skeletal muscle is the main insulin-sensitive tissue [52]. Although we found no differences in muscle mass between the 2 exercise modes using circumferences as a surrogate measure of body fat distribution, waist circumference was reduced more in swimmers, suggesting a greater loss of abdominal fat.

It is possible that the number of muscles recruited during exercise differed between swimmers and walkers. Swimming uses more muscles of the arms, upper body, and trunk than walking and could, in this way, have contributed to improvements in insulin responses. Increased metabolism to preserve body temperature during swimming and the posttraining period, as previously stated, could also contribute to improved insulin responses in swimmers.

A diet and exercise intervention leading to selective reductions in visceral adiposity improved glucose metabolism and lipid levels [53]. In our study, differences in insulin responses were independent of changes in waist circumference.

4.2. Lipids

Both modes of exercise had minor effects on lipid levels. Our finding that HDL-C did not increase with walking is consistent with our previous findings [25] and those of others [54-56] as well as a meta-analysis of randomized controlled trials [57]. However, others have demonstrated increases in HDL-C [36,58]. The lack of improvement in HDL-C with walking may be related to lower exercise intensity [59] or higher initial levels of HDL-C [56]. The effect of exercise on HDL-C is inversely related to baseline values [60] that averaged 1.5 mmol/L in our study.

An acute bout of anaerobic swimming in trained swimmers increases HDL-C [61]; but in a cross-sectional study of postmenopausal habitual runners, swimmers, and sedentary women, HDL-C was similar in the swimmers and sedentary women [50]. Previously sedentary middle-aged adults did not increase HDL-C levels with swimming training [62]. Our findings are similar, suggesting that swimming may be less effective than other activities such as running. The intensity of the activity may be important, as vigorous-, but not moderate-, intensity swimming improved HDL-C in young trained women [63].

Six months of swimming and walking training did not improve TC or LDL-C levels in our study. However, after 12 months, although the swimmers did not reduce TC or LDL-C, the increase was less than in walkers. In meta-analysis, walking was associated with lower LDL-C [57]. We did not observe such a reduction, possibly explained by the intensity of the activity. We have demonstrated lower TC and LDL-C after 6 months of vigorous-, but not moderate-, intensity exercise (predominantly walking) in middle- and older-aged previously sedentary women [64].

Our finding of a long-term effect of swimming on TC and LDL-C is consistent with a cross-sectional study reporting lower TC and LDL-C in swimmers compared with sedentary individuals [50]. Head-out water-based exercise reduced TC and LDL-C in older women [22]. Favorable changes in lipids depend on intensity and duration [8]; and as we used moderate-intensity swimming, longer-term activity may be needed. This differential effect of swimming may also relate to thermoregulatory responses to swimming in water that is below the thermoneutral range.

4.3. Strengths and limitations of the study

The strengths of our study include randomization to exercise mode, standardization of the amount of exercise, careful monitoring of the volume and intensity of exercise, minimization and monitoring of change in dietary and alcohol intake, and standardization of testing procedures. By taking measurements at least 48 hours after the last bout of exercise, we minimized the likelihood that results were due to the acute effects of exercise. The longitudinal design of our study allowed comparison of short- and longer-term effects as well as evaluation when the participants were in their own environment, not in contact with research staff.

Although our study used manual HR measurements in the unsupervised 6 months of our study, both groups were trained to measure HR during the supervised period. Our use of circumferences rather than more refined methods that differentiate subcutaneous and visceral fat limited our ability to show changes in body composition and body fat distribution. Attrition over time, reducing the sample size, would have affected the power of the study. Our diet questionnaire may not have been sensitive enough to detect small changes in energy intake. However, we found a differential effect of swimming to reduce body weight, although the same questionnaire was used by both groups.

As we recruited only older women, results may not be applicable to men or to younger populations; but improvements in metabolic profiles with exercise are similar in both sexes [8]. We included a few women taking cholesterol-lowering medication, which could have modified the effects of exercise on lipid levels. The proportion taking these drugs was similar in walkers and swimmers, and we monitored changes. Oral contraceptives or HRT, used by some 43% of women, could have affected the lipid, insulin, and glucose responses to exercise. However, analyses adjusted for the use of lipid-lowering agents, oral contraceptives, or HRT did not alter our findings.

This study in previously sedentary older women demonstrates that moderate-intensity swimming compared with walking at the same intensity confers greater benefits in terms of body weight and body fat distribution as well as lipid profiles and insulin responses, independent of change in body weight and abdominal obesity. Although the amount of swimming was below the recommended level, long-term persistence resulted in important health benefits. We have previously reported that swimming compared with walking resulted in an increase in blood pressure in this same group of women [14], although they were, on average, normotensive and remained so. The health benefits demonstrated here could counterbalance or even outweigh this increased blood pressure.

The mechanisms for the differential effect of swimming are unclear, but could relate to differences between the activities of swimming and walking and/or the environment in which swimming takes place. If the thermoregulatory response to cold water explains the effects of swimming, this has implications for the planning of water-based programs that target weight loss and improvements in cardiovascular risk factors.

Acknowledgment

This research was supported by a grant from the Western Australian Health Promotion Foundation. Dr Burke was supported by the West Australian Institute for Medical Research and a grant from the National Health and Medical Research Council for the Clinical Research Centre for Excellence of Cardiovascular and Cerebrovascular Disease. We thank Penny Rogers for her role in the collection of blood samples for this project and Amanda Derbyshire for the anthropometric measures and her role as walk leader.

References

[1] Kohrt WM, Obert KA, Holloszy JO. Exercise training improves fat distribution patterns in 60- to 70-year old men and women. J Gerontol 1992;47:M99-M105.

[2] Ryan AS, Nicklas BJ. Age-related changes in fat deposition in mid-thigh muscle in women: relationships with metabolic cardiovascular disease risk factors. Int J Obes Relat Metab Disord 1999;23:126-32.

[3] Shimokata H, Muller DC, Fleg JL, Sorkin J, Ziemba AW, Andres R. Age as an independent determinant of glucose tolerance. Diabetes 1991;40:44-51.

[4] Short KR, Vittone JL, Bigelow ML, Proctor DN, Rizza RA, Coenen-Schimke JM, et al. Impact of aerobic training on age-related changes in insulin sensitivity and muscle oxidative capacity. Diabetes 2003;52: 1888-96.

[5] Harris MI, Flegal KM, Cowie CC, Eberhardt MS, Goldstein DE, Little RR, et al. Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults. The Third National Health and Nutrition Examination Survey, 1988-1994. Diabetes Care 1998;21:518-24.

[6] Boden G, Chen X, DeSantis RA, Kendrick Z. Effects of age and body fat on insulin resistance in healthy men. Diabetes Care 1993;16: 728-33.

[7] Schoenborn CA, Adams PF, Barnes PM, Vickerie IL, Schiller JS. Health behaviours of adults: United States, 1999-2001. Vial Health Stat 10 2004;219:1-79.

[8] Thune I, Njolstad I, Lochen M-L, Forde OH. Physical activity improves the metabolic risk profiles in men and women. Arch Intern Med 1998;158:1633-40.

[9] Wilson PW, D'Agostino RB, Sullivan L, Parise H, Kannel WB. Overweight and obesity as determinants of cardiovascular risk: the Framingham experience. Arch Intern Med 2002;162:1867-72.

[10] Calle EE, Thun MJ, Petrelli JM, Rodriguez C, Heath Jr CW. Body mass index and mortality in a prospective cohort of U.S. adults. N Engl J Med 1999;341:1097-105.

[11] Horion ES. Exercise and physical training: effects on insulin sensitivity and glucose metabolism. Diabetes Metab Rev 1986;2:1-17.

[12] Seals DR, Hagberg JM, Hurley BF, Eshani AA, Holloszy JO. Effects of endurance training on glucose tolerance and plasma lipid levels in older men and women. JAMA 1984;252:645-9.

[13] Thompson PD, Buchner D, Pina IL, Balady GJ, Williams MA, Marcus BH, et al. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Physical Activity). Circulation 2003;107:3109-16.

[14] Cox KL, Burke V, Beilin LJ, Grove JR, Blanksby BA, Puddey IB. Blood pressure rise with swimming versus walking in older women: the Sedentary Women Exercise Adherence Trial 2—SWEAT2. J Hypertens 2006;24:307-14.

[15] Mazzeo RS, Cavanaugh P, Evans WJ, Fiatarone M, Hagberg J, McAuley E, et al. ACSM position stand on exercise and physical activity for older adults. Med Sci Sports Exerc 1998;30:992-1008.

[16] Dunn AL, Garcia ME, Marcus BH, Kampert JB, Kohl HW, Blair SN. Six-month physical activity and fitness changes in Project Active, a randomised trial. Med Sci Sports Exerc 1998;30:1076-83.

[17] Murphy MH, Nevill AM, Murtagh EM, Holder RL. The effect of walking on fitness, fatness and resting blood pressure: a meta-analysis of randomised, controlled trials. Prev Med 2007;44:377-85.

[18] Gwinup G. Weight loss without dietary restriction: efficacy of different forms of aerobic exercise. Am J Sports Med 1987;15:275-9.

[19] Bailey C. Smart exercise: burning fat, getting fit. Boston: Houghton Mifflin Company; 1994. pp. 139-44.

[20] Gappmaier E, Lake W, Nelson AG, Fisher AG. Aerobic exercise in water versus walking on land: effects on indices of fat reduction and weight loss of obese women. J Sports Med Phys Fitness 2006;46: 564-9.

[21] Yu TY, Pei YC, Lau YC, Chen CK, Hsu HC, Wong AM. Comparison of the effects of swimming and tai chi chuan on body fat composition in elderly people. Chang Gung Med J 2007;30:128-34.

[22] Takeshima N, Rogers ME, Watanabe E, Brechue WF, Okada A, Yamada T, et al. Water-based exercise improves health-related aspects of fitness in older women. Med Sci Sports Exerc 2002;34:544-51.

[23] Stevenson ET, Davy KP, Seals DR. Hemostatic, metabolic, and androgenic risk factors for coronary heart disease in physically active and less active postmenopausal women. Arteroscler Thromb Vasc Biol 1995;15:669-77.

[24] Cox KL, Burke V, Beilin LJ, Derbyshire AJ, Grove JR, Blanksby BA, et al. Short- and long-term adherence to swimming and walking programs in older women—the Sedentary Women Exercise Adherence Trial (S.W.E.A.T. 2). Prev Med 2008;46:511-7.

[25] Borg GAV. Psychological bases of physical exertion. Med Sci Sports Exec 1982;14:377-81.

[26] Cox KL, Burke V, Gorely TJ, Beilin LJ, Puddey IB. Controlled comparison of retention and adherence in home- vs center-initiated exercise interventions in women ages 40-65 years: the S.W.E.A.T. Study (Sedentary Women Exercise Adherence Trial). Prev Med 2003;36:17-29.

[27] Kline GM, Porcari JP, Hintermeister R, Freedson PS, Ward A, McCarron RF, et al. Estimation of VO_{2max} from a one-mile track walk, gender, age, and body weight. Med Sci Sports Exerc 1987;19:253-9.

[28] Cooper K. The aerobics way. New York: Bantam Books; 1977.

[29] Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual. Champaign (Ill): Human Kinetics Books; 1988.

[30] Ireland P, Jolley D, Giles G, O'Dea K, Powles J, Rutishauser I, et al. Development of the Melbourne FFQ: a food frequency questionnaire for use in an Australian prospective study involving an ethnically diverse cohort. Asia Pacific J Clin Nutr 1994;3:19-31.

[31] Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low density lipoprotein cholesterol in plasma without the use of ultracentrifuge. Clin Chem 1972;18:499-505.

[32] Matthews JNS, Altman DG, Campbell MJ, Royston P. Analysis of serial measurements in medical research. Br Med J 1990;300: 230-5.

[33] Haskell WL, Lee I-M, Pate R, Powell KE, Blair SN, Franklin BA, et al. Physical activity and public health: updated recommendations for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39:1423-34.

[34] Nadel ER, Holmer I, Bergh U, Astrand PO, Stolwijk JA. Energy exchanges of swimming man. J Appl Physiol 1974;36:465-71.

[35] White LJ, Dressendorfer RH, Holland E, McCoy SC, Ferguson MA. Increased caloric intake soon after exercise in cold water. Int J Sport Nutr Exerc Metab 2005;15:38-47.

[36] Duncan JJ, Gordon NF, Scott CB. Women walking for health and fitness. How much is enough? JAMA 1991;266:3295-9.

[37] Hardman AE, Jones PRM, Norgan NG, Hudson A. Brisk walking improves endurance fitness without changing body fatness in previously sedentary women. Eur J Appl Physiol Occup Physiol 1992;65:354-9.

[38] Claybaugh JR, Keize S, Elsner R. Physiological systems and response to conditions of hyperbaria. In: Tipton CM, Sawka MN, Terjung RL, Tate CA, editors. ACSM's advanced exercise physiology. Baltimore: Lippincott, Williams & Wilkins; 2003.

[39] Fujishima K, Shimizu T, Ogaki T, Hotta N, Kanaya T, Ueda T. Thermoregulatory responses to low-intensity prolonged swimming in water at various temperatures and treadmill walking on land. J Physiol Anthropol 2001;20:199-206.

[40] Han TS, Leer EM, Seidall JC, Lean MEJ. Waist circumference action levels in the identification of cardiovascular risk factors: prevalence study in a random sample. BMJ 1995;311:1401-5.

[41] Van Pelt RE, Evans EM, Schectman KB, Eshani AA, Kohrt WM. Waist circumference vs body mass index for prediction of disease risk in postmenopausal women. Int J Obes 2001;25:1183-8.

[42] Zhu SK, Wang ZM, Heshka S, Heo M, Faith MS, Heymsfield SB. Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds. Am J Clin Nutr 2002;76:743-9.

[43] Murphy MH, Hardman AE. Training effects of short and long bouts of brisk walking in sedentary women. Med Sci Sports Med 1998;30: 152-7.

[44] Swartz AM, Strath SJ, Bassett Jr DR, Moore JB, Redwine BA, Groer M, et al. Increasing daily walking improves glucose tolerance in overweight women. Prev Med 2003;37:356-62.

[45] Cox KL, Burke V, Morton AR, Beilin LJ, Puddey IB. The independent and combined effects of 16 weeks of vigorous exercise and energy restriction on body mass and composition in free-living overweight men—a randomised controlled trial. Metabolism 2003;52:107-15.

[46] Weiss EP, Holloszy JO. Improvements in body composition, glucose tolerance, and insulin action induced by increasing energy expenditure or decreasing energy intake. J Nutr 2007;137:1087-90.

[47] Holloszy JO. Exercise-induced increase in muscle insulin sensitivity. J Appl Physiol 2005;99:338-43.

[48] Moreau K, DeGarmo R, Langley J, McMahon C, Howley E, Bassett Jr D, et al. Increasing daily walking lowers blood pressure in post menopausal women. Med Sci Sports Exerc 2001;33:1825-31.

[49] Tyndall GL, Kobe RW, Houmand JA. Cortisol, testosterone, and insulin action during intense swimming training in humans. Eur J Appl Physiol Occup Physiol 1996;73:61-5.

[50] Tanaka H, Clevenger CM, Jones PP, Seals DR, DeSouza CA. Influence of body fatness on the coronary risk profile of physically active postmenopausal women. Metabolism 1998;47:1112-20.
[51] Kang J, Robertson R, Hagberg J, Kelley D, Goss F, Da SS, et al. Effect of exercise intensity on glucose and insulin metabolism in obese NIDDM patients. Diabetes Care 1996;19:341-9.
[52] DeFronzo RA, Ferrinnini E, Sato Y, Felig P, Wahren J. Synergistic interaction between exercise and insulin on peripheral glucose uptake. J Clin Invest 1981;68:1468-74.
[53] Fujioka S, Matsuzawa Y, Tokunaga K, Kawamoto T, Kobatake T, Keno Y, et al. Improvements of glucose and lipid metabolism associated with selective reduction of intra-abdominal visceral fat in premenopausal women with visceral fat obesity. Int J Obes 1991;15: 853-9.
[54] Hinkleman LL, Nieman DC. The effects of a walking program on body composition and serum lipids and lipoproteins in overweight women. J Sports Med Phys Fitness 1993;33:49-58.
[55] Santiago MC, Leon AS, Serfass RC. Failure of 40 weeks of brisk walking to alter blood lipids in normolipemic women. Can J Appl Physiol 1995;20:417-28.
[56] Tully MA, Cupples ME, Chan WS, McGlade K Young IS. Brisk walking, fitness and cardiovascular risk: a randomized controlled trial in primary care. Prev Med 2005;41:622-8.
[57] Kelley GA, Kelley KS, Tran ZV. Walking lipids and lipoproteins: a meta-analysis of randomized controlled trials. Prev Med 2004;38: 651-61.
[58] Hardman AE, Hudson A. Brisk walking and serum lipid and lipoprotein variables in previously sedentary women—effect of 12 weeks of regular brisk walking followed by 12 weeks of detraining. Br J Sports Med 1994;28:261-6.
[59] Stensel DJ, Brookewavell K, Hardman AE, Jones PRM Norgan NG. The influence of a 1-year program of brisk walking on endurance fitness and body composition in previously sedentary men aged 42-59 years. Eur J Appl Physiol Occup Physiol 1994; 68:531-7.
[60] Leon AS, Sanchez OA. Response of blood lipids to exercise training alone or combined with dietary intervention. Med Sci Sports Exerc 2001;33(Suppl 6):S502-515.
[61] Ohkuwa T Itoh H. High density lipoprotein cholesterol following anaerobic swimming in trained swimmers. J Sports Med Phys Fitness 1993;33:200-2.
[62] Tanaka H, Bassett Jr DR, Howley ET. Effects of swim training on body weight, carbohydrate metabolism, lipid and lipoprotein profile. Clin Physiol 1997;17:347-59.
[63] Smith MP, Mendez J, Druckenmiller M, Kris-Etherton PM. Exercise intensity, dietary intake, and high-density lipoprotein cholesterol in young female competitive swimmers. Am J Clin Nutr 1982;36: 251-5.
[64] Cox KL, Burke V, Morton AR, Gillam HF, Beilin LJ, Puddey IB. Long-term effects of exercise on blood pressure and lipids in healthy women aged 40-65 years: the Sedentary Women Exercise Adherence Trial (SWEAT). J Hypertens 2001;19:1733-43.