The Effect of Sprint Interval Training on Body Composition of Postmenopausal Women

YATI N. BOUTCHER[1], STEPHEN H. BOUTCHER[1], HYE Y. YOO[1], and JARROD D. MEERKIN[2]

[1]School of Medical Sciences, Faculty of Medicine, University of New South Wales, AUSTRALIA; and [2]MeasureUp Ltd, AUSTRALIA

ABSTRACT

BOUTCHER, Y. N., S. H. BOUTCHER, H. Y. YOO, and J. D. MEERKIN. The Effect of Sprint Interval Training on Body Composition of Postmenopausal Women. *Med. Sci. Sports Exerc.*, Vol. 51, No. 7, pp. 1413–1419, 2019. **Introduction:** Menopause is accompanied by body composition changes that include a decrease in lean mass and aerobic fitness and an increase in fat mass. Sprint interval training (SIT) may be able to reverse these changes. **Purpose:** To examine the effect of an 8-wk SIT program on body composition and aerobic fitness of overweight postmenopausal women. **Methods:** Forty postmenopausal women were randomized into SIT (n = 20) or control (n = 20) groups. The SIT group completed three SIT sessions a week for 8 wk with each session consisting of 20 min of alternating 8-s sprints and 12-s of light pedaling. Total mass, regional lean mass, and fat mass were assessed using dual-energy x-ray absorptiometry. Maximal oxygen uptake ($\dot{V}O_{2max}$) was predicted using a submaximal test. **Results:** Total lean mass was significantly increased from pretest (48.1 ± 5.81 kg) to posttest (48.8 ± 5.96 kg) and fat mass was significantly reduced (pre, 29.5 ± 7.29 kg; post, 29.1 ± 7.61 kg) for the SIT group. Lean mass was mostly increased in the trunk (pre, 24.4 ± 2.79 kg; post, 24.8 ± 2.93 kg) and legs (pre, 15.6 ± 2.31 kg; post, 15.9 ± 2.34 kg). $\dot{V}O_{2max}$ was significantly increased from pretest (21.7 ± 4.89 mL·kg^{-1}·min^{-1}) to posttest (24.4 ± 5.96 mL·kg^{-1}·min^{-1}) for the SIT group only. **Conclusions:** The SIT intervention increased total lean mass, decreased fat mass, and increased aerobic fitness of postmenopausal women after only 8 h of actual exercise over 8 wk. **Key Words:** SPRINT INTERVAL TRAINING, LEAN MASS, FAT MASS, AEROBIC FITNESS, POSTMENOPAUSAL WOMEN

Menopause is marked by a decline in endogenous estrogen production and is accompanied by a decrease in lean mass (1), an increase in body fat (2), and a reduction in aerobic fitness (3). As these changes are strongly associated with an abnormal metabolic profile overweight postmenopausal women are at high risk for developing insulin resistance, type 2 diabetes, and cardiovascular disease (4). Consequently, interventions should be developed to enhance the body composition and metabolic health of postmenopausal women. One such intervention is aerobic exercise which typically consists of moderate-intensity steady-state exercise, repeated about 30 to 40 min·d^{-1} for 3 to 4 d·wk^{-1}, up to a 6-month period. Disappointingly, aerobic exercise programs have typically resulted in minimal fat loss (5) and no gain in the lean mass of postmenopausal women (6).

In contrast to aerobic exercise, sprint interval training (SIT) has resulted in decreased fat loss and increased lean mass in young overweight men and women. For example, a 15-wk SIT program was conducted with premenopausal women that included three 20-min sessions per week (7). Women performed an 8-s sprint followed by 12 s of low-intensity pedaling, continuously for 20 min. A control group carried out a 40-min aerobic exercise cycling protocol each session. Women in the SIT group lost 2.5 kg of subcutaneous fat, whereas no change occurred with steady state aerobic exercise. Importantly, exercising women also showed a significant 0.6 kg increase in lean mass, whereas lean mass of the steady state exercise group remained unchanged. Similar results using the same SIT protocol have been found with young overweight women (8) and young overweight men (9,10). Also, in postmenopausal women, a significant reduction in total fat mass (0.8 kg) was found after 16 wk of SIT (11). The mechanisms underlying the SIT-induced fat loss decrease effect most likely involve increased fat oxidation during and after exercise (12,13), whereas it has been suggested that mechanisms driving lean mass increase involve an increase in muscle protein synthesis (14).

Address for correspondence: Yati N. Boutcher, Ph.D., School of Medical Sciences, Faculty of Medicine, University of New South Wales, Sydney, 2052, Australia; E-mail: y.boutcher@unsw.edu.au.
Submitted for publication December 2018.
Accepted for publication January 2019.

0195-9131/19/5107-1413/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000001919

Numerous studies have also found that a variety of SIT protocols have resulted in significant increases in aerobic fitness (15) probably brought about by SIT-induced central and peripheral adaptations (16). Interestingly, major changes in body composition and aerobic fitness have typically occurred after 8 wk or 8 h of SIT (9). The effect of 8 wk of SIT on the body composition and aerobic fitness of overweight postmenopausal women, however, is yet to be determined.

Therefore, the purpose of this study was to examine the effects of 20-min bouts of SIT, repeated three times weekly for 8 wk, on body composition and aerobic fitness of overweight postmenopausal females. It was predicted that SIT would result in significantly increased total lean mass, decreased fat mass, and increased aerobic fitness of postmenopausal women after 8 h of actual exercise over 8 wk.

MATERIALS AND METHODS

Participants

Forty sedentary postmenopausal women (determined by self-reported cessation of menstruation) age between 47 to 59 yr with a body mass index (BMI) of between 25 and 35 $kg·m^{-2}$ (≥23 $kg·m^{-2}$ for women of Asian descent) were recruited, consented, and randomized into SIT (n = 20) or control (n = 20) groups. A recommended appropriate power in this type of research is 0.9. Thus, based on an effect size from our previous research (7), sample sizes of 14 to 18 participants per group were estimated to provide a statistical power of 0.9 at an alpha of $P < 0.05$. Exclusion criteria included: taking medication that could interact negatively with exercise, nonnatural menopause (surgically induced), taking hormone replacement therapy, regularly exercising, and smoking. Before acceptance into the study a health history questionnaire was used to assess participants' medical history and a clearance letter from participants' general practitioner was required to confirm eligibility. A 7-d physical activity recall (17) was used to confirm a sedentary lifestyle and to estimate level of current physical activity. All participants were also required to complete a 3-d dietary form at preintervention and postintervention. This involved tabulating all foods consumed on three separate days consisting of two weekdays and one weekend day. The diets were analyzed using dietary analysis software (SERVE Nutrition Management Systems, Professional Edition, version 5.1.002, 2004, Australia). The preadmission interview included information about all procedures and requirements for the participant and informed consent was documented. This study was approved by the University of New South Wales, Australia Human Ethics committee. All procedures conformed to the standards of the Declaration of Helsinki.

Intervention

The SIT group (n = 20) exercised three sessions a week for a total of 8 wk. Each session was conducted on a Monark Ergomedic 828E exercise bike and consisted of a 5-min warm-up of light pedaling at ~50 rpm, followed by 20 min of alternating 8-s sprints at near-maximal exertion and 12-s rest periods of light pedaling, and finally ending with a 5-min cool-down of light pedaling. The SIT load was set at 80% to 85% of each participant's peak HR with a pedal cadence between 100 and 125 rpm. Recovery was set at the same amount of resistance but at a pedal cadence of 50 rpm. Participants were instructed to keep their exercise intensity at a level which ensured their average exercise HR fell below their individual peak HR. Exercise intensity was increased when participant's average HR during SIT fell below their average HR recorded during the prior four exercise sessions. Each SIT session was supervised and HR was measured using a Polar Electro HR monitor. Participant's RPE, using Borg's scale (18), was also recorded at 2-min intervals during SIT.

Measures

Anthropometric and resting measures. Height, weight, and BMI were initially collected at preadmission interview to confirm eligibility and were remeasured before intervention. Body mass index was calculated by dividing weight by height squared ($kg·m^{-2}$). A three-lead electrocardiograph was used to determine resting HR, whereas blood pressure was assessed using an automatic arm-cuff blood pressure monitor (OMRON, Bannockburn, IL). Waist circumference was assessed at the naval using a measuring tape.

Lipid and glucose levels. Participants were instructed to fast for 10 h preintervention and postintervention, when 5 mL of venous blood from the antecubital vein was taken after at least 5 min of rest in an upright sitting position. Blood lipid profiles and glucose concentrations were immediately quantified from whole blood by automated enzymatic methods (Cholestech LDX, USA).

Body composition. *Whole body dual-energy x-ray absorptiometry.* A Hologic Horizon A (SN-300616M) (Hologic Inc., Bedford, MA) fan beam dual-energy x-ray absorptiometry (DXA) device was used for the study. A single trained operator completed all whole body scans, and analyzed the results, using the QDR system software for Windows v10 Hologic software APEX 13.6.0.5 (Hologic). The operator was blinded regarding group allocation. Participants completed a single whole body scan. A QC procedure using the Hologic spine phantom was completed each morning before scanning of any participant. Every 3 months, a Hologic whole-body phantom was scanned to ensure there was no drift in whole-body values of lean mass and fat mass.

Whole-body composition. The Hologic whole-body scanning dimensions was 196 cm by 68 cm. The generous breadth of the Hologic scan table ensured adequate separation of the arms from the trunk in the whole body positioning. Total mass (kg), lean mass (kg), fat mass (kg) and fat percent was calculated for the whole body and for individual regions of interest. These whole body regions were the head, upper limbs, lower limbs, and trunk. Upon analysis, the software places a matrix over the body for regional analysis. The operator

TABLE 1. Participants' physical characteristics, lipid profiles, and cardiovascular variables at preintervention and postintervention.

Variable	SIT (n = 20) Pre	SIT (n = 20) Post	Change	Control (n = 20) Pre	Control (n = 20) Post	Change
Age (yr)	54.1 (3.6)			53.3 (3.4)		
Height (cm)	164.4 (6.5)			163.2 (6.1)		
Weight (kg)	77.2 (12.3)	78.1 (12.4)	+0.9	72.4 (13.3)	73.0 (13.9)	+0.6
Waist circumference (cm)	99.3 (11.6)	100.8 (13.4)	+1.5	98.2 (15.7)	99.0 (11.6)	+0.8
BMI ($kg \cdot m^{-2}$)	28.3 (3.7)	28.7 (3.7)	+0.4	27.3 (4.1)	27.5 (4.4)	+0.2
Body fat (%)	36.9 (4.3)	36.3 (4.5)	−0.3	36.5 (5.1)	37.5 (5.1)	+1.0
Resting HR (bpm)	64 (7.6)	62 (7.4)	−2	67 (9.0)	65 (8.9)	−1
SBP (mm Hg)	120 (14.6)	123 (17.7)	+3	118 (23.2)	120 (17.2)	+2
DBP (mm Hg)	76 (8.1)	78 (11.1)	+2	75 (11.4)	75 (11.9)	0
TC ($mmol \cdot L^{-1}$)	5.88 (0.80)	5.99 (1.3)	+0.11	5.39 (1.2)	5.64 (1.3)	+0.25
HDL ($mmol \cdot L^{-1}$)	1.54 (0.42)	1.59 (0.41)	+0.05	1.28 (0.55)	1.43 (0.43)	+0.15
TRG ($mmol \cdot L^{-1}$)	1.31 (1.01)	1.29 (0.82)	−0.02	1.03 (0.53)	1.19 (0.61)	+0.16
LDL ($mmol \cdot L^{-1}$)	3.95 (0.91)	3.85 (1.30)	−0.10	3.79 (1.21)	3.62 (1.16)	−0.17
Non-HDL ($mmol \cdot L^{-1}$)	4.28 (0.85)	4.45 (1.30)	+0.17	4.19 (1.02)	4.18 (1.16)	−0.01
LDL/HDL ratio	2.82 (1.07)	2.61 (1.07)	−0.21	3.06 (1.74)	2.81 (1.16)	−0.25
Glucose ($mmol \cdot L^{-1}$)	4.93 (0.40)	4.96 (0.31)	+0.03	5.09 (0.50)	4.89 (0.50)	−0.20

TC, total cholesterol; HDL, high-density lipoprotein; TRG, triglyceride; LDL, low-density lipoprotein; SBP, systolic blood pressure; DBP, diastolic blood pressure.
Data are means with the standard deviation of the mean in parenthesis.

defines the placement of these lines: head (immediately below the mandible), trunk (enclosing the chest, midriff, and pelvis), the left and right upper limbs (the line is placed medial to the head of the humerus), and left and right legs (a line joins the outside of the thigh through to the middle of both legs by being placed through the femoral neck and lateral to the pubic ramus). Central fat, as a surrogate of visceral adipose tissue (19), was auto generated by the scanning software and the placement of the visceral adipose tissue box was checked by the operator.

Aerobic fitness. A submaximal exercise test on an electronically braked cycle ergometer (Monark 319E, Stockholm, Sweden) was used to predict maximal oxygen uptake ($\dot{V}O_{2max}$) as an indicator of aerobic fitness. After a 5-min warm-up at 15 W, the load was slowly increased by 5 W every minute while the participant was instructed to maintain 60 rpm. The test was continued until participants reached 70% of their age-estimated maximum HR, calculated through the following equation (20): maximal HR = 205.8 − 0.685 × age. Throughout the test participant's respiration gases were collected using a metabolic cart (TrueOne Model 2400; ParvoMedics Inc., Sandy, UT). Oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were used to predict $\dot{V}O_{2max}$ (21). Participants received 10 min of familiarization with the metabolic cart and electronic bike before test initiation.

Statistical Analyses

Data were analyzed using IBM's Statistical Package for the Social Sciences (SPSS v25; IBM, USA). ANCOVA was used to determine if there were statistically significant differences in recorded variables. The pretest value for each variable was used as the covariate. Results were considered statistically significant when the P value was less than 0.05. Eta-squared (η2) was used to determine effect size, with values of 0.02, 0.13, and 0.26 and above being considered to be small, medium, and large effect sizes. Data are reported as mean and SD of the mean.

RESULTS

Participant characteristics. At pretesting and posttesting, there was no significant difference between SIT and control groups regarding height, weight, BMI, and lipid and glucose levels ($P > 0.05$; Table 1).

Age differences in women did not influence lean mass, total body fat, or aerobic fitness results.

Total and regional fat mass. After 8 wk of SIT, there was a significant reduction in the total fat mass of the SIT group by 0.4 kg, F (1, 37) = 17.4, $P \leq 0.001$, $\eta^2 = 0.32$ (Table 2). The decrease in fat mass was most pronounced in the trunk and legs (Table 2).

TABLE 2. Body composition and aerobic fitness of exercise and control groups preintervention and postintervention.

Variables	SIT (n = 20) Pre	SIT (n = 20) Post	Change	Control (n = 20) Pre	Control (n = 20) Post	Change
Total fat mass (kg)	29.5 (7.29)	29.1 (7.70)*	−0.4*	27.5 (9.08)	28.5 (9.56)	+1.00
Arm fat mass (kg)	3.85 (5.54)	3.89 (6.14)	+0.04	3.33 (11.2)	3.35 (11.1)	+0.02
Leg fat mass (kg)	11.2 (3.38)	11.0 (3.96)	−0.2*	10.6 (3.48)	10.9 (3.72)	+0.30
Trunk fat mass (kg)	14.0 (3.96)	13.8 (3.96)	−0.2*	12.7 (5.06)	13.3 (5.35)	+0.60
Visceral fat (kg)	5.58 (2.10)	5.49 (2.07)	−0.09	5.21 (2.57)	5.45 (2.49)	+0.24
Arm lean mass (kg)	4.33 (7.20)	4.34 (6.93)	+0.01	4.11 (4.92)	4.00 (5.41)	−0.11
Leg lean mass (kg)	15.6 (2.31)	15.9 (2.34)	+0.3*	14.5 (1.96)	14.3 (2.01)	−0.20
Trunk lean mass (kg)	24.4 (2.79)	24.8 (2.93)	+0.4*	22.7 (2.78)	22.5 (2.66)	−0.20
BMD (kg)	1.13 (0.09)	1.14 (0.09)	+0.01	1.12 (0.05)	1.13 (0.05)	+0.01
BMC (kg)	2.27 (0.31)	2.29 (0.31)	+0.02	2.15 (0.20)	2.17 (0.20)	+0.02

Data are means with the standard deviation of the means in parenthesis. Significant difference ($P < 0.05$) is represented by an asterisk (*).
BMD, bone mineral density; BMC, bone mineral content.

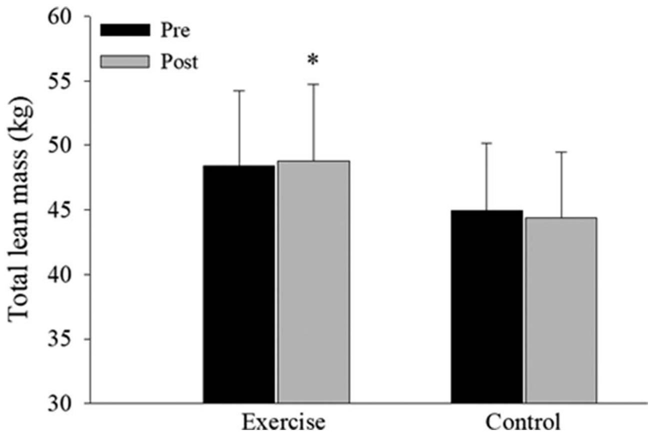

FIGURE 1—Pre- and post-total lean mass after the 8-wk SIT intervention for the exercise and control groups. *P < 0.05.

There was no significant change in waist circumference or visceral fat the SIT group (Tables 1 and 2).

Total and regional lean mass. For the SIT group, there was a significant increase in lean mass by 0.7 kg, F (1, 37) = 14.2, P = 0.001, $\eta^2 = 0.28$ (Fig. 1). The increase in lean mass was most pronounced in the trunk and legs (Table 2).

Aerobic fitness. The SIT group significantly improved predicted $\dot{V}O_2$ max, F (1, 34) = 16.2, $P \leq 0.001$, $\eta^2 = 0.32$ by 12% (Fig. 2). One exercise participant and two control participants felt unwell during the posttest and were excluded from analysis.

Resting HR and blood pressure. There was no significant change in resting HR or blood pressure before or after exercise for the SIT or Control groups, $P > 0.5$ (Table 1).

Overall exercise HR data. The exercise program of 24 SIT cycling sessions over 8 wk was completed with 100% compliance. Over 8 wk of SIT, the average HR rate was 148 bpm (week 1, 147 bpm; week 8, 148 bpm); the average pedal cadence was 121 rpm (week 1, 117 rpm; week 8, 124 rpm); the average load was 0.7 kg (week 1, 0.55 kg; week 8, 0.85 kg); the average power output was 88.5 W (week 1, 64 W; week 8, 105 W), and the average RPE was 14.5 (week 1, 14.3; week 8, 14.7). The SIT group consistently worked at over 70% of their estimated maximum HR.

Diet. There was no significant change in macronutrient or micronutrient content before or after the intervention for the 3-d diet diary of the SIT or Control groups, $P > 0.05$. Diet for both groups was similar and total energy, averaged across groups, was 8290 ± 1726 $kJ \cdot d^{-1}$ that comprised of 45.5% carbohydrate, 18.9% protein, and 34.8% fat.

DISCUSSION

The major findings of this study were that 8 wk of SIT resulted in increased trunk and leg lean mass, decreased total fat mass, and increased aerobic fitness of postmenopausal women after only 8 h of actual exercise over 8 wk.

Lean body mass. Eight weeks of SIT resulted in a 0.7-kg increase of lean body mass. Other SIT studies have produced a similar or greater lean mass gain. It was found that there was an increase in trunk muscle mass of 0.6 kg after 15 wk of SIT in young women (7) and a significant 1.2 kg increase in lean body mass of overweight males after 12 wk of SIT (9). In type 2 diabetic postmenopausal women 16 wk of SIT produced a 0.5-kg increase in total lean mass (11). The present study extends these results by demonstrating that 8 wk of SIT can also result in an increase in the lean mass of nondiabetic but overweight postmenopausal women. Lean mass preservation or gain is especially important for postmenopausal women as it acts as a reservoir of essential amino acids that are needed to maintain the function of numerous organs (22). Lean mass also protects against type 2 diabetes mellitus development. Insulin resistance is a precursor to the development of type 2 diabetes and occurs when muscle loses its responsiveness to insulin signaling (23).

The ability of SIT to reduce insulin resistance has been well established (24), thus future research should examine the effects of SIT on the insulin resistance of postmenopausal women. Interestingly, the 0.7-kg increase in lean mass in the present study was predominately in the trunk and legs which is consistent with previous studies (7–10). The 0.7-kg total increase in lean mass after 8 h of SIT equates to an 86-g gain per hour of SIT. This increase compares favorably to that achieved after exposure to regular resistance exercise. It was found that a three times per week, hourly resistance program given to sedentary postmenopausal women for 10 wk resulted in increased total lean mass of 1.2 kg, which equated to a 40-g gain in lean mass per hour (25). Similarly, a 16-wk weight training program increased total lean mass of overweight postmenopausal women by 2 kg which also equated to a 40-g gain in lean mass per hour (26). Thus, weight training resulted in significant increases of lean mass of the arms, chest, trunk, and legs of postmenopausal women whereas SIT increased lean mass of the trunk and legs only. Future research is required to confirm the lean mass increase brought about by SIT.

This increase in lean mass supports results of prior research that has investigated the effects of high-intensity exercise on muscle characteristics and remodeling. After nine cycling high-intensity intermittent training (HIIT) sessions by young

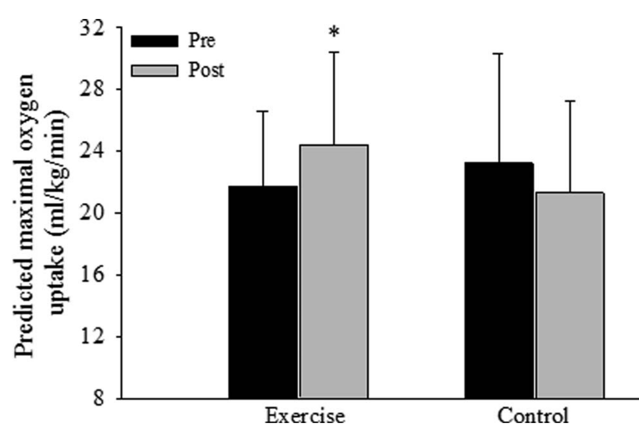

FIGURE 2—Pre- and post-predicted maximal oxygen uptake after the 8-wk SIT intervention for the exercise and control groups. *P < 0.05.

APPLIED SCIENCES

males a significant increase in muscle protein synthesis was found (27). A shorter 3-wk HIIT program examining obese men and women also demonstrated a significant HIIT-induced increase in muscle size (14). The exposure of type 2 diabetic men to 8 wk of continuous high-intensity exercise (two sessions per week for 45 min at 75% $\dot{V}O_2$peak) resulted in a 24% increase in mid-thigh cross-sectional area (28). A large increase in mitochondrial and myofibrillar protein synthesis, 24 to 28 h after one bout of continuous high-intensity exercise, has also been found (29). These studies have typically examined muscle remodeling in the legs which were actively involved in high-intensity cycle exercise. The reason behind the increase in trunk lean mass found in the present and past studies (7–10), using the 8 s/12 s sprint protocol, is unclear. In this protocol participants perform approximately 1000 sprints during the 20 min of exercise equating to approximately 3.7 miles (5.6 km) of sprint distance when extrapolated to actual cycling. The 8 min of total time of sprinting in the 8 s/12 s sprint protocol is likely to involve constant isometric contraction of the trunk muscles which may have driven the increase in lean mass. For example, 16 wk of HIIT using upper and lower body ergometers resulted in significant increases in cross-sectional area of the musculus anterolateral abdominal area (30), however, no increase was found in a group that only used lower body ergometer. Training involved eight to 12 sets of high-intensity cycling exercise for 60 s with a 60-s active rest period. Thus, future research is needed to examine the regional muscle mass effects of high-intensity interval protocols that vary in their intensity and sprint rate.

Fat mass. The SIT group reduced their total fat mass by 0.4 kg after 8 wk. This result confirms results of previous SIT studies that have also demonstrated a significant decrease in the total fat of overweight adults (7–10). The decrease in fat mass that occurred mostly in the trunk and legs, however, was smaller when compared to previous studies (7–10). In a 15-wk SIT program examining normal weight premenopausal women a reduction of 2.5 kg of subcutaneous was found (7), whereas a 12-wk SIT intervention with overweight premenopausal women resulted in a 2.6-kg decrease (8). The smaller fat loss occurring in the present study maybe a result of the shorter length of the SIT program (8 wk) and hormonal imbalance brought about by menopause that may have impeded SIT-induced fat loss (1). Genetic and behavioral factors such as compensatory eating or reductions in daily physical activity may also have influenced subcutaneous fat change (31). The possible mechanism underlying the SIT-induced fat loss effect most likely involves increased fat oxidation during and after exercise. Toward the end of a HIIT session that consisted of ten 6-s bouts of maximal sprints, an inhibition of anaerobic glycogenolysis occurred and ATP resynthesis was mainly derived from intramuscular triacylglycerol stores (16). That SIT progressively results in greater fat oxidation is also supported by Trapp et al. (32) who found increased venous glycerol levels during SIT in both trained female cyclists and untrained women. Also, it has been shown that six to seven sessions of HIT had marked increases in whole body and skeletal muscle capacity for fatty acid oxidation (33).

Visceral adipose tissue. There was no significant reduction in visceral fat after SIT in these postmenopausal women. Previous studies have shown that SIT effectively reduces visceral fat of overweight young adults. A 9.5% reduction was found after a 15-wk protocol (7) and 12 wk of SIT brought about a 17% reduction in the visceral fat of young men (9). Also, a significant reduction of visceral fat by 5.7% was found after 16 wk of SIT administered to overweight postmenopausal women (11). Why these postmenopausal women did not lose visceral fat after SIT is unclear but may involve the decrease in estrogen that accompanies menopause which causes an increase in blood levels of insulin resulting in the promotion of fat deposition and a blunting of fat oxidation (1,12). Decreased fat oxidation response to SIT in conjunction with the central redistribution of fat that accompanies menopause may have contributed to the failure of SIT to result in a decrease of visceral fat in these postmenopausal women (34). As mentioned in the previous paragraph amount of SIT exposure and behavioral compensation may also have influenced the lack of visceral fat change found in these postmenopausal women (31).

Aerobic fitness. After 8 h of SIT, the exercise group significantly improved their absolute predicted $\dot{V}O_{2max}$ by 12% which is consistent with results of a meta-analysis that indicated that SIT and other forms of interval training-induced improvements in aerobic fitness that were superior to that of traditional aerobic exercise training (15). The aerobic fitness changes found in the present study were less compared with a study that used 15 wk of SIT using the same protocol (7) where young women improved their $\dot{V}O_{2max}$ by 24%. Also, a significant 15% increase was demonstrated after a 12-wk lifestyle intervention that included SIT as the exercise component (8). That the present study found a smaller improvement in $\dot{V}O_{2max}$ compared with these other SIT interventions may be because of the shorter duration of the SIT intervention, the cardiovascular deterioration that occurs with aging and menopause, and/or the loss of estrogen occurring before and during menopause (34). Improvements in anaerobic fitness were suggested by increases in rpm, load, and power when HR stayed constant. Thus, after 8 wk of SIT participants were able to generate significantly more power at similar exercise HR.

That SIT so effectively improves aerobic fitness in a short period reflects the unique nature of SIT which comprises of significant amounts of both aerobic and anaerobic exercise (35). SIT-induced increases in aerobic fitness may be brought about by central and peripheral adaptations that include changes in autonomic function, cardiac output, mitochondrial activity, vascular, and skeletal muscle metabolic capacity (36). SIT increases in $\dot{V}O_{2max}$ are superior (15,37) or equal (36,38) to traditional aerobic endurance training despite much shorter exercising time. As the most prominent barrier to exercise has been cited as "perceived time" (39) the ability of SIT to increase aerobic fitness in minimal time may have significant clinical value as low aerobic fitness has been established as a major predictor of mortality (40).

One of the limitations of this study is that the majority of women were Caucasian and thus results may not be generalizable to other ethnic groups. Also, women were primarily recruited from University staff and thus were more likely to be better educated than the general population. Also, it would have been beneficial to include an aerobic exercise training group in the study design. Although SIT compared to aerobic training has demonstrated superior changes in fat and lean mass and aerobic fitness of premenopausal women (32) this effect has not been verified in postmenopausal women.

CONCLUSIONS

The present study has shown that only 8 h of actual exercise over 8 wk resulted in a significant increase in total lean mass, a decrease in total fat mass, and an increase in aerobic fitness of overweight postmenopausal women. These results suggest that a brief interval sprinting program may be efficacious for reversing negative body composition and aerobic fitness decrease in postmenopausal women.

The authors wish to thank Michelle Lin, Diana Liu, Georgia Redmayne, Aengus Tran, Tornike Janjgava, Susan Li, Daniel Zhang, Tze Yuen Ho, Vrischika Chabella, and Alexandra Gleeson for help with data collection and participant exercise training.

None of the authors had a personal or financial conflict of interest. The study received no sources of funding. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by ACSM.

Funding: The study received no sources of funding.

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this article.

Y. B. organized participant recruitment, the testing timetable, statistical analyses, study design, and article development. S. B. was responsible for the study design and article development. H. Y. helped with data collection, participant exercise training, and article development. J. M. organized and analyzed DXA scans. All authors had full access to the data. The final article was approved by all authors.

REFERENCES

1. Abildgaard J, Pedersen AT, Green CJ, et al. Menopause is associated with decreased whole body fat oxidation during exercise. *Am J Physiol Endocrinol Metab*. 2013;304(11):E1227–36.
2. Santosa S, Jensen MD. Adipocyte fatty acid storage factors enhance subcutaneous fat storage in postmenopausal women. *Diabetes*. 2013; 62(3):775–82.
3. Mercuro G, Saiu F, Deidda M, et al. Impairment of physical exercise capacity in healthy postmenopausal women. *Am Heart J*. 2006; 151(4):923–7.
4. Messier V, Malita FM, Rabasa-Lhoret R, et al. Association of cardiorespiratory fitness with insulin sensitivity in overweight and obese postmenopausal women: a Montreal Ottawa new emerging team study. *Metabolism*. 2008;57:1293–8.
5. Ross R, Dagnone D, Jones PJ, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial. *Ann Intern Med*. 2000;133(2):92–103.
6. Lai CC, Tu YK, Wang TG, et al. Effects of resistance training, endurance training and whole-body vibration on lean body mass, muscle strength and physical performance in older people: a systematic review and network meta-analysis. *Age Ageing*. 2018;47(3):367–73.
7. Trapp EG, Chisholm DJ, Freund J, et al. The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. *Int J Obes*. 2008;32(4):684–91.
8. Dunn SL, Siu W, Freund J, et al. The effect of a lifestyle intervention on metabolic health in young women. *Diabetes Metab Syndr Obes*. 2014;7:437–44.
9. Heydari M, Freund J, Boutcher SH. The effect of high-intensity intermittent exercise on body composition of overweight young males. *J Obes*. 2012;2012:480467.
10. Gahreman DE, Heydari M, Boutcher YN, et al. The effects of green tea extract consumption and high-intensity intermittent exercise on fat oxidation exercise and body composition of overweight men. *Nutrients*. 2016;8:510.
11. Maillard F, Rousset S, Pereira B, et al. High-intensity interval training reduces abdominal fat mass in postmenopausal women with type 2 diabetes. *Diabetes Metab*. 2016;42(6):433–41.
12. Isacco L, Duché P, Boisseau N. Influence of hormonal status on substrate utilization at rest and during exercise in the female population. *Sports Med*. 2012;42(4):327–42.
13. Gibala MJ, Little JP, van Essen M, et al. Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. *J Physiol*. 2006; 575(3):901–11.
14. Blue MNM, Smith-Ryan AE, Trexler ET, Hirsch KR. The effects of high intensity interval training on muscle size and quality in overweight and obese adults. *J Sci Med Sport*. 2018;21:207–12.
15. Bacon AP, Carter RE, Ogle EA, et al. VO_2max trainability and high intensity interval training in humans: a meta-analysis. *PLoS One*. 2013;8(9):e73182.
16. Gaitanos GC, Williams C, Boobis LH, Brooks S. Human muscle metabolism during intermittent maximal exercise. *J Appl Physiol*. 1993; 75:712–9.
17. Sallis JF, Buono MJ, Roby JJ, Micale FG, Nelson JA. Seven-day recall and other physical activity self-reports in children and adolescents. *Med Sci Sports Exerc*. 1993;25:99–108.
18. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14(5):377–81.
19. Kamel EG, McNeill G, Van Wijk MC. Usefulness of anthropometry and DXA in predicting intra-abdominal fat in obese men and women. *Obes Res*. 2000;8:36–42.
20. Robergs RA, Landwehr R. The surprising history of the "HRmax=220-age" equation. *J Exerc Physiol*. 2002;5:1–10.
21. Fairbarn MS, Blackie SP, McElvaney NG, et al. Prediction of heart rate and oxygen uptake during incremental and maximal exercise in healthy adults. *Chest*. 1994;105(5):1365–9.
22. Wolfe RR. The underappreciated role of muscle in health and disease. *Am J Clin Nutr*. 2006;84(3):475–82.
23. Reaven GM. The insulin resistance syndrome: definition and dietary approaches to treatment. *Annu Rev Nutr*. 2005;25:391–406.
24. Perry CG, Heigenhauser GJ, Bonen A, et al. High-intensity aerobic interval training increases fat and carbohydrate metabolic capacities in human skeletal muscle. *Appl Physiol Nutr Metab*. 2008;33(6): 1112–23.
25. Rossato LT, Nahas PC, de Branco FMS, et al. Higher protein intake does not improve lean mass gain when compared with RDA recommendation in postmenopausal women following resistance exercise protocol: a randomized clinical trial. *Nutrients*. 2017;9:1007.
26. Trevisan MC, Burini RC. Resting metabolism of post-menopause women submitted to a training program with weights (hypertrophy). *Rev Bras Med Esporte*. 2007;13(2):116–9.
27. Scalzo RL, Peltonen GL, Binns SE, et al. Greater muscle protein synthesis and mitochondrial biogenesis in males compared with females during sprint interval training. *FASEB J*. 2014;28(6):2705–14.
28. Boudou P, Sobgwi E, Mauvais-Jarvis F, et al. Absence of exercise-induced variation in adiponectine levels despite decreased abdominal obesity and improved insulin sensitivity in type 2 diabetic men. *Eur J Endocrinol*. 2003;149(5):421–4.

29. Di Donato DM, West DW, Churchward-Venne TA, et al. Influence of aerobic exercise intensity on myofibrillar and mitochondrial protein synthesis in young men during early and late postexercise recovery. *Am J Physiol Endocrinol Metab*. 2014;306(9):e1025–32.
30. Osawa Y, Azuma K, Tabata S, et al. Effects of 16-week high-intensity interval training using upper and lower body ergometers on aerobic fitness and morphological changes in healthy men: a preliminary study. *Open Access J Sports Med*. 2014;4(5):257–65.
31. Boutcher SH, Dunn SL. Factors that may impede the weight loss response to exercise-based interventions. *Obes Rev*. 2009;10(6):671–80.
32. Trapp EG, Chisholm DJ, Boutcher SH. Metabolic response of trained and untrained women during high-intensity intermittent cycle exercise. *Am J Phys Regul Integr Comp Phys*. 2007;293(6):R2370–5.
33. Talanian JL, Galloway SD, Heigenhauser GJ, et al. Two weeks of high-intensity aerobic interval training increases the capacity for fat oxidation during exercise in women. *J Appl Physiol (1985)*. 2007; 102(4):1439–47.
34. Abdulnour J, Doucet E, Brochu M, et al. The effect of the menopausal transition on body composition and cardiometabolic risk factors: a Montreal-Ottawa new emerging team group study. *Menopause*. 2012;19(7):760–7.
35. Boutcher SH. High-intensity intermittent exercise and fat loss. *J Obes*. 2011;2011:868305.
36. Giannaki C, Aphamis G, Sakkis P, et al. Eight weeks of a combination of high intensity interval training and conventional training reduce visceral adiposity and improves physical fitness: a group-based intervention. *J Sports Med Phys Fitness*. 2016;56(4):483–90.
37. Milanović Z, Sporiš G, Weston M, et al. Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO2max improvements: a systematic review and meta-analysis of controlled trials. *Sports Med*. 2015;45:1469–81.
38. Macpherson RE, Hazell TJ, Olver TD, et al. Run sprint interval training improves aerobic performance but not maximal cardiac output. *Med Sci Sports Exerc*. 2011;43(1):115–22.
39. Stutts WC. Physical activity determinants in adults. Perceived benefits, barriers, and self efficacy. *AAOHN J*. 2002;50(11):499–507.
40. Blair SN. Physical inactivity: the biggest public health problem of the 21st century. *Br J Sports Med*. 2009;43:1–2.

APPLIED SCIENCES