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Sex differences in substrate oxidation during aerobic exercise in obese men and postmenopausal obese women

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Abstract

The aim of this study was to compare substrate oxidation during aerobic exercise in obese men and postmenopausal obese women. Ten obese men (mean age, 55.4 ± 2.2 years; body mass index, 27.5 ± 0.4 kg/m^2; peak oxygen uptake [V_{O_2}peak], 44.4 ± 1.9 mL/kg fat-free mass/min; mean ± SE] and 10 postmenopausal obese women (mean age, 57.2 ± 1.2 years; body mass index, 27.9 ± 0.5 kg/m^2; VO_2peak, 39.9 ± 1.3 mL/kg fat-free mass/min) performed a 40-minute bout of cycling exercise at 50% VO_2peak. Blood samples were collected for assessment of metabolic variables and 17β-estradiol concentration at baseline and during aerobic exercise. Breath samples were collected to estimate carbohydrate and fat oxidation using a digital computer-based breath-by-breath exercise analysis system during aerobic exercise. Serum 17β-estradiol concentration was not significantly different between the men and women subjects at baseline ($P > .05$). Serum free fatty acid concentration tended to be higher in the men than in the women ($P = .07$) during the exercise, but the respiratory exchange ratio during exercise was lower in women than in men ($P < .05$). Fat oxidation adjusted for fat-free mass was higher ($P < .05$) in women than in men. These results suggest that fat utilization was higher during aerobic exercise in postmenopausal obese women than in obese men and did not depend on resting serum 17β-estradiol concentration.

1. Introduction

A number of studies have reported that substrate oxidation during acute aerobic exercise differs between men and premenopausal women. Several studies have shown that premenopausal women utilize fat to a greater extent and carbohydrate to a lesser extent than men during aerobic exercise at the same relative intensity [1-9]. This difference during aerobic exercise may reflect differences in estrogen concentration [10].

17β-Estradiol (E_2), the main circulating form of estrogen, may influence sex differences in substrate oxidation during aerobic exercise. Several studies in rats have shown that E_2 administration spares muscle and liver glycogen [11,12] and increases free fatty acid (FFA) availability for oxidation [13,14] during endurance exercise. Devries et al [15] reported that 8 days of E_2 supplementation in men lowered the respiratory exchange ratio (RER), accompanied by a change in glucose appearance and disappearance during moderate-intensity exercise. These findings imply that E_2 partly mediates sex differences in substrate oxidation during aerobic exercise.

During the transition into menopause, levels of the sex steroid hormone (ie, estrogen) decrease. Estrogen levels in postmenopausal women are equivalent to those in men [16]. The hormonal decrease that accompanies menopause may alter sex differences in substrate oxidation during aerobic exercise. Toth et al [17] reported no differences between older men and women in terms of RER and relative fat oxidation during submaximal exercise. This finding suggests that the ability to oxidize fat in women during aerobic exercise may decrease after menopause because of lower estrogen levels. Little direct information is available, however, on whether substrate oxidation during aerobic exercise differs between postmenopausal women and men.

This study was approved by the Comprehensive Human Sciences Review Board at the University of Tsukuba.

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In addition, menopause is often associated with a rise in obesity [18,19]. Because the capacity for substrate utilization may be related to the development of obesity, understanding substrate oxidation during aerobic exercise may assist in preventing obesity and in prescribing effective weight-loss strategies in obese individuals. It is therefore important to understand substrate oxidation during aerobic exercise in middle-aged obese men and postmenopausal obese women. The purpose of the present study was to compare substrate oxidation during moderate-intensity aerobic exercise in obese men and postmenopausal obese women.

2. Materials and methods

2.1. Participants

Ten men (mean age, 55.4 ± 2.2 years) and 10 women (mean age, 57.2 ± 1.2 years) were recruited to participate in the study. Participants were recruited through advertisements in local newspapers. Obesity was defined as body mass index (BMI) greater than 25 kg/m^2, according to the criteria used in Japan [20]. All women had been postmenopausal for a minimum of 1 year, and no participant had received hormone therapy. Participants were not involved in regular exercise training (exercise day <3 times a week). Participants were nonsmokers and were not taking any medications or supplements known to affect glucose and fat metabolism. All participants had stable body mass (<3-kg body mass change) for at least the previous 2 months.

The purpose and design of the study were explained to each participant, and each participant gave informed written consent. The study conformed to the principles outlined in the Helsinki Declaration and was approved by the Comprehensive Human Sciences Review Board at the University of Tsukuba.

2.2. Body composition

Height and body mass were measured using a wall-mounted stadiometer and a digital scale, respectively. Body mass index was calculated as mass (in kilograms) divided by height squared (in square meters). Whole-body fat mass and fat-free mass (FFM) were measured by the single-frequency bioelectrical impedance method (HBF-300; Omron, Tokyo, Japan). The validity of percentage body fat estimated by the bioelectrical impedance method was confirmed before the beginning of the experiment. The correlation and standard error between percentage body fat estimated by bioelectrical impedance and by dual x-ray absorptiometry were 0.90 and 2.8%, respectively. Abdominal fat (ie, total abdominal fat area [TFA], visceral fat area [VFA], and abdominal subcutaneous fat area [SFA]) was measured by a computed tomography scan (SOMATOM AR.C; Siemens, Munich, Germany) while participants were in the supine position. A single 5-mm scan was obtained with a scanning time of 5 seconds centered at the level of the umbilicus (fourth and fifth lumbar vertebrae). The TFA, VFA, and SFA were calculated using the Fat Scan software program (N2system, Osaka, Japan) [21].

2.3. Aerobic capacity

A graded exercise test was performed on a cycling ergometer (818E; Monark, Stockholm, Sweden) to determine peak oxygen uptake (V_{O_2}peak) for each participant. After a 2-minute warm-up at 0 W, workload was increased every 1 minute by 15 W until volitional exhaustion. During the test, gas exchange (oxygen uptake [V_{O_2}] and carbon dioxide production [V_{CO_2}]) was measured breath-by-breath using a computer-based analysis system (Oxycon-α; Mijnhardt, Breda, the Netherlands); and heart rate (HR) was monitored by electrocardiography (Dyna Scope; Fukuda Denshi, Tokyo, Japan). The V_{O_2}peak was defined as the highest oxygen uptake over a period of 30 seconds and was determined according to the following criteria: (1) V_{O_2} attained a plateau (<150 mL/min) despite increasing exercise intensity, (2) the highest RER during the final stage of the incremental exercise was greater than 1.10, and (3) the highest HR measured during the last minute of exercise was greater than 90% of the predicted maximal HR (220 − age in years) [22].

2.4. Activity and diet before the experiment day

All participants refrained from strenuous physical activity and exercise training for 2 days before each measurement and were instructed to consume a standard meal (12 kcal/kg body mass; 50% carbohydrate, 30% fat, and 20% protein) and to keep a food diary on the evening before the study.

2.5. Experimental design and protocol

All participants performed 40 minutes of aerobic exercise at a load intensity of 50% V_{O_2}peak on a cycle ergometer. Gas exchange was measured to estimate total energy expenditure and fat oxidation based on V_{O_2}, V_{CO_2}, and RER. Blood samples were obtained at rest and during exercise to evaluate serum sex hormone levels and metabolic variables.

After an overnight fast of at least 12 hours, participants arrived at the laboratory at 8:20 AM by car or public transport. After resting for 30 minutes, blood samples were obtained from an arm vein of each participant. The exercise trial began at 9:00 AM for each participant. Participants cycled for 40 minutes at a workload corresponding to 50% V_{O_2}peak. Gas exchange was measured breath-by-breath using a computer-based analysis system (Oxycon-α) when at rest and every 10 minutes during the 40-minute cycling period. Substrate oxidation rates were calculated from the RERs averaged over 1 minute [23]. Total energy expenditure and substrate utilization were calculated every 10 minutes and were defined as the sum of energy expenditure and substrate utilization. Before all experiments, the O_2 and CO_2 sensors of this gas analyzer were checked by ethanol combustion; and the flow meter was checked by nitrogen infusion. The

validity and reliability of this gas analyzer were demonstrated in a previous study [24]. In addition, the gas analyzer was calibrated using gas of known composition before each experiment. Heart rate was monitored continuously throughout the 40-minute exercise period and was recorded at the same time as gas exchange. Blood samples (17 mL) were collected at rest and every 10 minutes during exercise.

2.6. Blood analysis

Blood samples were used to determine plasma epinephrine, norepinephrine, serum estradiol, insulin, FFA, glycerol, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglyceride (TG), and plasma glucose concentrations. Samples were divided into 8-mL tubes containing thrombin and a heparin-neutralizing agent; 7-mL tubes containing EDTA-2Na; and 2-mL tubes containing EDTA-2Na, heparin-Na, and sodium fluoride. The tubes were immediately centrifuged at approximately 3000 rpm for 10 minutes at 4°C. The 8-mL tube samples were used to analyze concentrations of serum estradiol, insulin, FFA, glycerol, TC, HDL-C, LDL-C, and TG; the 7-mL tube samples were used to analyze concentrations of plasma epinephrine and norepinephrine; and the 2-mL tube samples were used to analyze concentrations of plasma glucose. Plasma epinephrine and norepinephrine concentrations were quantified by high-performance liquid chromatography. Serum insulin concentrations were measured by radioimmunoassay. Serum estradiol concentrations were measured using an enzyme immunoassay (OXIS International, Foster City, CA). Serum FFA concentrations were analyzed by an enzymatic colorimetric (ACS-ACOD) method. Serum glycerol concentrations were also determined by an enzymatic colorimetric (GPO-DAOS) method. Serum TC concentration was measured by the cholesterol oxidase (HDAOS) method. Serum HDL-C concentration was quantified using a modified enzymatic method. Serum TG was determined enzymatically, and glucose concentrations were analyzed using a glucose-oxidase (GOD) immobilized membrane-oxygen electrode. Low-density lipoprotein cholesterol was calculated using the Friedewald equation [25]. All samples were analyzed in duplicate.

2.7. Statistical analysis

All data are expressed as mean ± SE. To compare plasma hormones and serum FFA and glycerol concentrations between sexes over time during aerobic exercise, we used a two-way repeated-measures analysis of variance, with sex and time as cofactors. A Mann-Whitney *U* test was used to compare anthropometric variables, metabolic variables, total energy expenditure, fat oxidation, and the relative contribution of carbohydrate and fat oxidation to total energy expenditure during aerobic exercise between sexes. Spearman correlation coefficients were used to determine the associations between RER and fat oxidation, and percentage fat and E_2. Statistical significance was set at a .05 level of confidence.

3. Results

3.1. Physical characteristics

Height and body mass were significantly higher ($P < .05$) in the men than in the women, but BMI did not differ between men and women (Table 1). Fat mass was similar between the men and women, whereas percentage body fat was significantly lower ($P < .05$) in the men than in the women. Fat-free mass was significantly higher ($P < .05$) in the men than in the women. Absolute VO_2peak was significantly higher ($P < .05$) in the men than in the women. The VO_2peak was similar, however, between men and women when adjusted for FFM. Total abdominal fat area was not different between men and women, whereas VFA was significantly higher ($P < .05$) and SFA was significantly lower ($P < .05$) in the men than in the women. The ratio of VFA to SFA was significantly higher ($P < .05$) in the men than in the women.

3.2. Exercise intensity

The relative intensity of exercise (percentage VO_2peak and percentage VO_2peak/FFM) was similar between the men (48 ± 2% and 48 ± 3%, respectively) and women (48 ± 3% and 48 ± 2%, respectively) (Table 2). Relative workload was not significantly different between the men (27 ± 2%) and women (22 ± 3%). Average HR during exercise was also similar between men (102 ± 4 beats/min) and women (104 ± 6 beats/min).

Table 1
Participant characteristics

	Men (n = 10)	Women (n = 10)
Age (y)	55.4 ± 2.2	57.2 ± 1.2
Height (cm)	166.9 ± 1.6	153.7 ± 1.3*
Body mass (kg)	76.7 ± 2.3	66.2 ± 2.1*
BMI (kg/m^2)	27.5 ± 0.4	27.9 ± 0.5
% Fat	28.9 ± 0.9	36.3 ± 1.1*
Fat mass (kg)	22.1 ± 0.7	24.2 ± 1.4
FFM (kg)	54.6 ± 2.1	41.9 ± 0.9*
VO_2peak		
mL/min	2432.4 ± 161.4	1673.9 ± 66.4*
mL/kg body mass/min	31.5 ± 1.4	25.3 ± 0.7*
mL/kg FFM/min	44.4 ± 1.9	39.9 ± 1.3
Workload peak (W)	188 ± 10	129 ± 4*
Abdominal fat area		
TFA (cm^2)	349.8 ± 14.3	383.8 ± 18.9
VFA (cm^2)	167.8 ± 12.7	101.5 ± 10.2*
SFA (cm^2)	182.0 ± 11.2	282.3 ± 13.4*
V/S	0.96 ± 0.10	0.36 ± 0.04*

Values are mean ± SE. BMI, body mass index; FFM, fat-free mass; TFA, total abdominal fat area; VFA, visceral fat area; SFA, abdominal subcutaneous fat area; V/S, ratio of VFA to SFA.

* Significantly different between the groups ($P < .05$).

Table 2
Exercise intensity, HR, and workload in obese men and women

	Men	Women
Relative intensity (% Vo_2peak)	48 ± 2	48 ± 3
Relative intensity (% Vo_2peak/FFM)	48 ± 3	48 ± 2
HR (beats/min)	102 ± 4	104 ± 6
Workload (W)	51 ± 5	29 ± 4*
Relative workload (%)	27 ± 2	22 ± 3

Values are means ± SE. Relative workload: workload/workload peak.
* Significantly different between the groups ($P < .05$).

3.3. Estradiol concentration and metabolic variables at rest

Serum estradiol concentration and the plasma concentrations of glucose, serum insulin, TC, HDL-C, LDL-C, and TG were similar at rest between the men and the women (Table 3).

3.4. Plasma hormone responses during exercise

Plasma epinephrine and norepinephrine concentrations increased progressively and serum insulin concentration decreased progressively during aerobic exercise in both the men and women (Table 4). Plasma epinephrine and norepinephrine tended to be higher in the men than in the women, but this difference was not statistically significant. Serum insulin concentration was not different between the men and women during exercise.

3.5. Metabolite kinetics during exercise

There was no significant sex × time interaction for changes in FFA during exercise. Serum FFA concentration tended to be higher in the men than the women, but this was not statistically significant ($P = .07$) (Fig. 1A). Serum glycerol concentration also increased progressively during exercise, but there was no significant sex × time interaction.

3.6. Substrate oxidation

There was no significant sex × time interaction for RER during exercise. However, a main group effect was evident; and the average RER during exercise was significantly lower in the women than in the men ($P < .05$) (Fig. 2). During aerobic exercise, total fat oxidation was the same in the men and in the women (118 ± 6 and 106 ± 5 kcal, respectively).

Table 3
Metabolic parameters at baseline in obese men and women

	Men	Women
17β-estradiol (pmol/L)	76.6 ± 18.7	63.4 ± 17.6
Glucose (mmol/L)	5.8 ± 0.2	5.5 ± 0.1
TC (mmol/L)	5.6 ± 0.3	6.3 ± 0.3
HDL-C (mmol/L)	1.4 ± 0.1	1.5 ± 0.1
LDL-C (mmol/L)	3.5 ± 0.3	4.3 ± 0.2
TG (mmol/L)	1.4 ± 0.2	1.2 ± 0.1

Values are means ± SE. TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol, LDL-C, low-density lipoprotein cholesterol; TG, triglyceride.

Table 4
Plasma hormone concentrations at rest and during endurance exercise

	Rest	10 min	20 min	30 min	40 min
Epinephrine (pg/mL)					
Men	53 ± 11	54 ± 8	67 ± 13	74 ± 15	78 ± 15
Women	39 ± 7	41 ± 6	48 ± 7	51 ± 8	53 ± 7
Norepinephrine (ng/mL)					
Men	384 ± 41	630 ± 63	686 ± 61	798 ± 73	844 ± 73
Women	532 ± 69	657 ± 92	681 ± 93	722 ± 105	765 ± 112
Insulin (μU/mL)					
Men	9.1 ± 1.0	7.3 ± 0.9	7.2 ± 0.7	6.6 ± 0.5	6.5 ± 0.5
Women	8.5 ± 0.7	7.6 ± 0.6	7.4 ± 0.6	7.0 ± 0.8	7.4 ± 0.9

Values are means ± SE. There were significant main effects of time in all hormones ($P < .05$).

Fat oxidation adjusted for FFM was greater in the women (2.5 ± 0.1 kcal/kg FFM) than in the men (2.2 ± 0.1 kcal/kg FFM) ($P < .05$, Fig. 3). The relative contribution of fat oxidation to total energy expenditure was also higher in the women than in the men (Fig. 4). Spearman regression

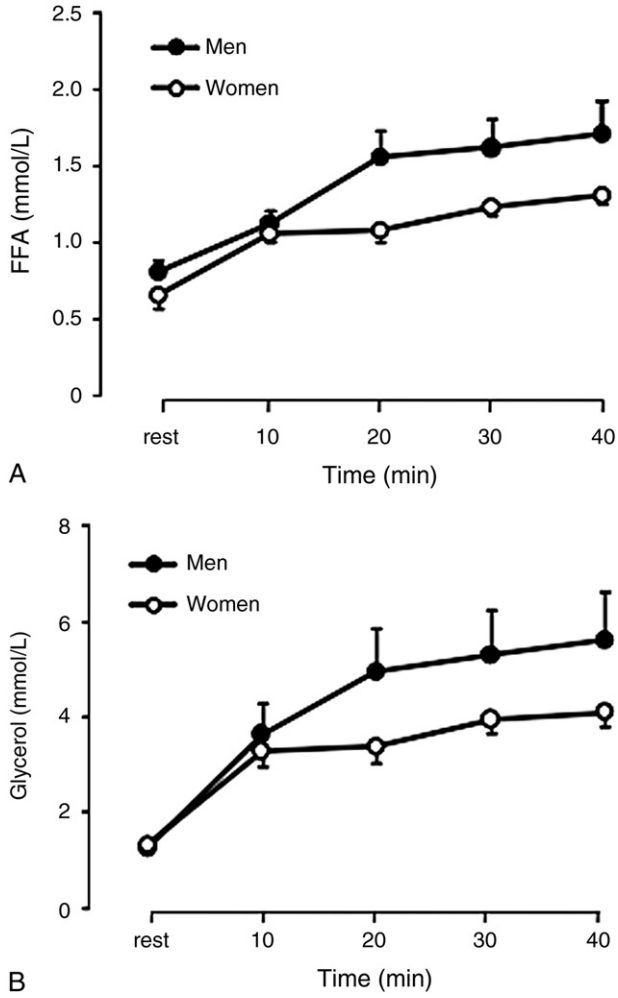

Fig. 1. Changes in serum FFA (A) and glycerol (B) concentrations in obese men (filled circles) and postmenopausal obese women (open circles) during endurance exercise. There tended to be a main group effect for FFA concentration ($P = .07$). Values are means ± SE.

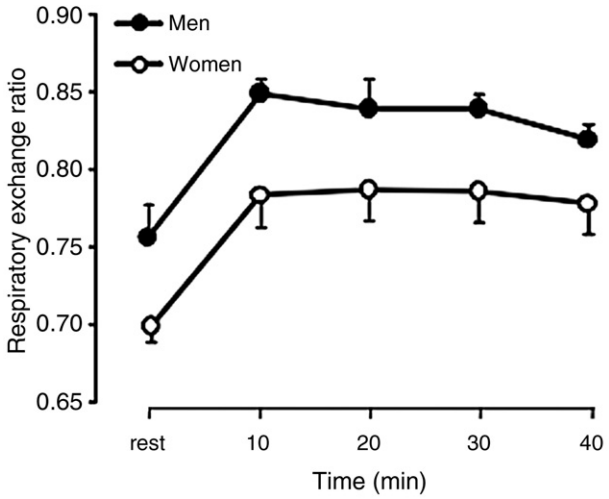

Fig. 2. Change in RER in obese men (filled circles) and postmenopausal obese women (open circles) during endurance exercise. There was a main group effect ($P < .05$). Values are means ± SE.

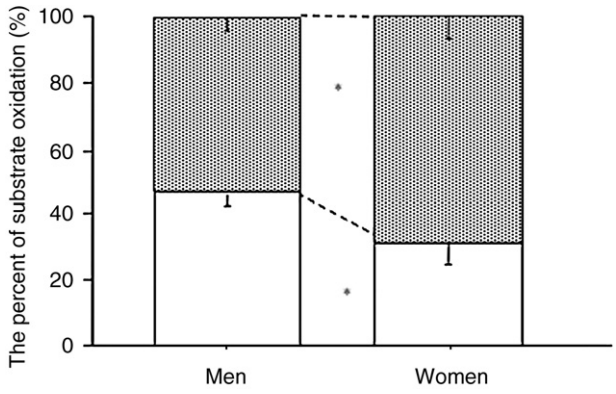

Fig. 4. Percentage of total energy expenditure from carbohydrate and fat oxidation during aerobic exercise in obese men and postmenopausal obese women. Percentages carbohydrate oxidation (hatched bar) and fat oxidation (open bar) are shown. *Significant differences between the men and women ($P < .05$). Values are means ± SE.

analysis indicated that serum E_2 concentration was not correlated with average RER ($r = 0.26$, $P = .58$) and fat oxidation adjusted for FFM ($r = -0.37$, $P = .11$) during the exercise. We observed no significant correlations between percentage fat and RER in the men ($r = -0.30$, $P = .40$) or women ($r = -0.44$, $P = .20$).

4. Discussion

The purpose of this study was to determine whether substrate oxidation is different in obese men and postmenopausal obese women matched for age, BMI, and physical fitness during moderate-intensity aerobic exercise. 17β-Estradiol concentration was similar in the men and women, whereas serum FFA concentration tended to be higher in the men. Despite these findings, RER was lower in postmenopausal obese women than in obese men. Furthermore, fat oxidation adjusted for FFM, and the contribution of fat oxidation to total energy expenditure during aerobic exercise were greater in the women than in the men.

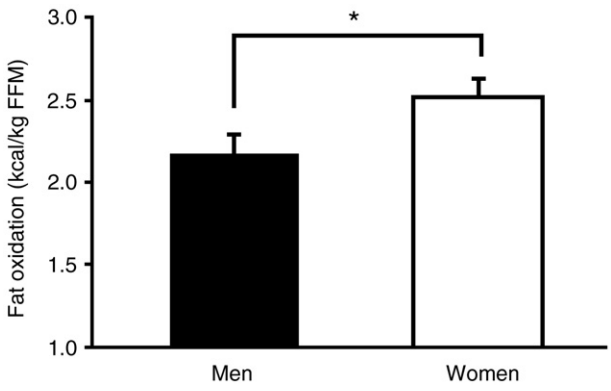

Fig. 3. Fat oxidation adjusted for FFM during aerobic exercise in obese men and postmenopausal obese women. Fat oxidation adjusted for FFM was higher in women (open bar) than in men (solid bar) ($P < .05$).

A number of studies have reported sex differences in substrate oxidation in trained or untrained men and premenopausal women during aerobic exercise [26]; however, to the best of our knowledge, the present study is the first to investigate the kinetics of serum fat concentration and substrate oxidation during aerobic exercise in obese men and postmenopausal obese women. To conduct a meaningful assessment of sex differences, we controlled for important potential confounding variables such as preexercise diet and habitual training status. Our participants were untrained and were given a standard diet based on body mass before exercise. In addition, the men and women exercised at the same relative exercise intensity. Concentrations of serum TG [27], plasma glucose, and insulin [28] may affect substrate oxidation during aerobic exercise; however, these variables were not significantly different between the men and women in the present study.

Circulating E_2 level may play a significant role in substrate oxidation during exercise [10]. Several studies in rats [11-14] and in humans [15] have shown that E_2 supplementation influences substrate selection during endurance exercise. Previous studies in humans have shown that RER is lower in premenopausal women than in men during aerobic exercise at the same relative intensity [1-9], whereas RER in older women (mean age, 66 ± 4 years) is similar to that in older men (mean age, 70 ± 4 years) during 30-minute aerobic exercise [17]. These findings suggest that E_2 accounts for sex differences in fat oxidation during aerobic exercise. In the present study, however, serum E_2 concentration at rest was similar between men and women; yet postmenopausal obese women oxidized proportionately more fat than obese men during exercise. In addition, serum E_2 concentration at rest did not correlate with average RER during the exercise. These findings are consistent with the work of Ruby et al [29], who

found that E_2 administration in amenorrheic women did not alter RER during aerobic exercise. Thus, our findings suggest that serum E_2 concentration might not always regulate sex difference in substrate oxidation during aerobic exercise. However, serum E_2 concentration increases in premenopausal women during aerobic exercise compared with that in men [3]. It is therefore possible that the increased serum E_2 concentration during aerobic exercise led to increased fat utilization in postmenopausal women. To obtain better insight into the effects of serum E_2 concentration on substrate oxidation during aerobic exercise in postmenopausal women, further research is needed to determine changes in serum E_2 concentration kinetics during aerobic exercise.

A high supply of FFA contributes to fat oxidation during exercise [30]. In the present study, although serum fat concentration tended to be higher in obese men, postmenopausal obese women derived a greater proportion of energy expenditure from fat during exercise. This finding suggests that FFA concentration in blood is not necessarily linked to fat oxidation and RER during aerobic exercise. Previous studies have also shown that RER in women with higher plasma FFA concentration during aerobic exercise is similar to that in men [31-33]. It is therefore possible that factors other than serum FFA concentration account for sex differences in RER and fat oxidation during aerobic exercise.

The higher fat oxidation in postmenopausal obese women is linked to several factors. First, although previous studies investigating sex differences in triacylglycerol content in skeletal muscle fibers (intramuscular triacylglycerol [IMTG]) utilization have found conflicting results [7,34,35], resting IMTG may contribute to the sex difference in fat oxidation. Resting IMTG content influences IMTG oxidation during submaximal exercise [7,34,35]. The initial IMTG content is higher in premenopausal women than in men [7,34]. Furthermore, adipose tissue in skeletal muscle (as measured by computed tomography) increases with age and is more abundant in postmenopausal women than in premenopausal women [36]. The difference in resting IMTG content may therefore partly account for the higher fat oxidation in postmenopausal obese women. In contrast, Zehnder et al (2005) [35] reported that the IMTG content at rest and its depletion during moderate-intensity aerobic exercise are higher in men than in women, whereas fat oxidation is the same in men and women. These results suggest that plasma FFA usage, rather than IMTG, is higher in women than in men. Therefore, the higher fat oxidation in postmenopausal obese women may at least be due to the differences in direct IMTG utilization and/or alterations in plasma FFA usage during aerobic exercise. Second, skeletal muscle morphology, which may alter plasma FFA usage, may influence the difference in fat oxidation during exercise. Several previous studies have demonstrated that women have a greater proportion of oxidative type 1 muscle fibers [8] and fewer type 2 muscle fibers in cross-sectional area than do men [8,34,37]. In addition, women have higher muscle capillarization than do men [8]. These differences influence the delivery of plasma FFA to the skeletal muscle and may result in the higher fat oxidation observed in postmenopausal women. Finally, higher plasma epinephrine concentration in men may reduce fat oxidation in men compared with that in women. Because epinephrine stimulates glycogen breakdown in contracting muscle [38,39], men may utilize more glycogen than fat during aerobic exercise.

Differences in abdominal fat distribution are unlikely to influence substrate oxidation during aerobic exercise in obese men and women. Previous studies have found that abdominal fat distribution does not influence substrate oxidation during exercise in subjects of the same sex [40-43]. In the present study, the men and women differed in visceral fat and subcutaneous fat areas and in waist-to-hip ratio; however, these variables did not correlate with fat oxidation adjusted for FFM and average RER during aerobic exercise (data not shown). In this regard, our findings are therefore consistent with the results of previous studies [40-43].

Overall, especially in postmenopausal obese women, RERs at rest and during aerobic exercise were low in this study compared with previous studies [1-9]. The reason for this is unknown, but is likely to relate to the extended period of fasting. Fasting might cause ketogenesis and gluconeogenesis, which could lead to low RER values at rest [8]. In addition, workload might reduce RER values during aerobic exercise. Perez-Martin et al [44] demonstrated that RER at 30% workload max for 6 minutes was 0.87 ± 0.01 in overweight individuals. As obese men in the present study performed aerobic exercise at 27% workload max, RER at 15 minutes of aerobic exercise (0.85 ± 0.01) was close to the RER values of Perez-Martin et al [44]. In comparison, relative workload was low (22% workload max) in postmenopausal obese women, possibly explaining the low RER (0.78 ± 0.02) during aerobic exercise overall. Lange et al [45], however, reported that RER in older women (BMI, 26.2 ± 1.8 kg/m^2; percentage fat, 40% ± 3%) was 0.77 ± 0.02 at 30 and 60 minutes during aerobic exercise, even at 60% Vo_2max. The difference in average RER (about 0.05) during aerobic exercise between obese men and postmenopausal obese women observed in the present study is similar to that (about 0.04-0.06) observed in several previous studies [1,2,4,5,7,9]. It is therefore likely that RER values in the present study are valid and reflect sex differences in substrate oxidation during aerobic exercise.

In summary, the results of our study demonstrate that substrate oxidation during aerobic exercise differed in obese men and postmenopausal obese women. Despite the higher serum FFA concentration in the men and the same serum E_2 concentration at rest in the men and women, the RER was lower in the women than in the men. In addition, FFM adjusted for fat oxidation, and contribution of fat oxidation to total energy expenditure during aerobic exercise were higher in the women than in the men. These data suggest that fat utilization during aerobic exercise was higher in postmenopausal obese women compared with obese men and did not

depend on resting E_2 concentration. The sex differences in substrate oxidation would be due to other factors, including the amount of IMTG and/or skeletal muscle morphology.

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