Energy expenditure and substrate utilization in older women after strength training: 24-h calorimeter results

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AGING IS GENERALLY ASSOCIATED with a decline in resting energy expenditure (REE) in women (20, 22). The age-related decline in REE in women is partially, although not entirely, explained by the loss in fat-free mass (FFM) that occurs with aging (20, 22). Because strength training (ST) in healthy older men on 24-h energy expenditure (EE) and its components and on 24-h substrate utilization in older adults for both endurance (17, 19) and resistive training (21) to only measure 30-min REE measurement from a hood calorimeter. However, other components of EE have been shown to play a role in the regulation of energy balance. It is therefore of interest to examine the adaptive changes in each of the components of 24-h EE in response to ST.

The effects of aging and exercise on fasting and 24-h fuel utilization is an area widely unexplored. Because aging is associated with an increase in body fat (5), an intervention designed to increase fat oxidation may be beneficial in reducing obesity in the elderly. One study (19) reported an increased basal lipid oxidation after an 8-wk endurance training program in older individuals. No study has examined whether there is a shift toward greater fat utilization after an ST program. In addition, no study in the elderly has utilized an indirect room calorimeter to assess changes in daily substrate oxidation after ST. Furthermore, the use of a metabolic chamber, which continuously measures respiratory gases, is required to adequately measure 24-h fuel utilization. Therefore, the purpose of this study was to examine the effects of ST in healthy older women on 1) resting, sleeping, activity, and 24-h EE; and 2) resting and 24-h fat and carbohydrate utilization. It is our hypothesis that the increase in FFM by ST would increase EE and fat oxidation.

METHODS

Subjects

Fifteen healthy women volunteered for the study. Potential subjects were screened by history and physical examination by treadmill testing by a physician. All subjects then completed a demographic form and physical activity questionnaires to exclude subjects who exercised more than two 30-min sessions/wk. A graded exercise treadmill test was conducted to ensure that the subjects were both free of cardiovascular disease and sedentary (maximal $O_2$ consumption ($V_{O2max}$) <25 ml·kg$^{-1}$·min$^{-1}$). Thyroid function and fasting blood glucose levels were required to be normal for inclusion into the study. Thus these subjects were nonobese, nondiabetic, normoglycemic, sedentary, and healthy postmenopausal women.

Subjects were excluded from the study if they had evidence of cardiovascular disease (defined as anginal symptoms or myocardial infarction within the last 3 mo and electrocardiographic evidence of ischemia), hypertension (defined as resting systolic blood pressure >140 mmHg and resting diastolic blood pressure >90 mmHg).
blood pressure >90 mmHg), medications known to affect cardiovascular performance (such as β-blockers), anemia, diabetes, significant renal or hepatic disease, hypothyroidism, smoking, musculoskeletal problems that would hinder participation, and plans to move before the termination of the study. Estrogen replacement therapy was not an exclusion factor, and three women on estrogen (which was continued throughout the study) participated in the study. These women were all on Premarin (0.625 mg/day) for at least 4 yr. The mean number of years postmenopause was 19 yr. Because the changes in all dependent variables for the women on estrogen replacement therapy paralleled the changes observed in the women who were not on hormone replacement therapy, all the subjects were pooled into one group. All methods and procedures for the study were approved by the Institutional Review Board of the University of Alabama at Birmingham. All subjects signed appropriate informed consent forms. Fifteen healthy postmenopausal women completed the study, with EE data collected on 13 of these women (age 67 ± 1 yr, range 60–77 yr; body mass index 24.7 ± 1.0 kg/m²).

\[ \dot{V}O_2_{\text{max}} \]

\[ \dot{V}O_2_{\text{max}} \] was determined by collection of expired gases during a progressive treadmill exercise test to voluntary exhaustion. The Weibel treadmill protocol (31), which involved increases in either grade or speed every 2 min, was utilized. \( \dot{V}O_2_{\text{max}} \) was determined when two of the three following criteria were met: 1) leveling off of \( \dot{O}_2 \) consumption (\( \dot{V}O_2 \)) (<2 ml·kg⁻¹·min⁻¹) with increasing workload, 2) a respiratory quotient (RQ) >1.10, and 3) a heart rate 10 beats above or below age-predicted maximal heart rate. Repeat measurements (6 mo apart) in four adults gave an intraclass correlation coefficient of 0.96.

**Body Composition**

**Total body composition.** Total body composition was assessed by hydrodensitometry. Density was measured by hydrostatic weight to the nearest 50 g in a stainless steel tank in which the subject was suspended from a LCL 20 Shear Beam Load Cell (Omega, Stamford, CT). Residual lung volume was measured simultaneously by the closed-circuit \( \dot{O}_2 \) dilution technique (34). Percent fat was determined by using the Brozek formula (3), and FFM was calculated as body mass minus fat mass. The intraclass correlation coefficient for repeated measures for nine subjects of percent fat by hydrodensitometry in our laboratory is 0.96.

**Muscle area.** For the computed tomography (CT) measurement of the midthigh, a single 5-mm scan for 2 s was made while the subject was supine with a General Electric HiLight/Advantage scanner (Milwaukee, WI). To ensure the same anatomic site was scanned, the scan was taken midway between the inguinal crease and the top of the patella. A fat tissue highlighting technique was used to determine the various tissues with different densities. The Hounsfield units were set at ±30 to ±60 for muscle. Total muscle cross-sectional area was measured for the midthigh (7).

**Dietary Analysis**

Three-day dietary food records (including 1 weekend day) were completed ~2 wk before chamber testing, both before and after the training, despite the recognized limitation of food records in older women being a tendency to underreport energy intake (11). All food records were analyzed by the Minnesota Nutrition Data System (ver. 2.4, Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN).

It was critical to control diet composition and energy intake for the days immediately before and during the 24-h EE measurements. Therefore, during the 3 days preceding baseline calorimetry studies, subjects ate a self-selected diet. This diet was recorded, and each subject replicated her diet after the ST program for the 3-day period before the second 24-h EE measurements. The average composition of this diet was 17% protein, 57% carbohydrate, 27% fat, and 6,162 kJ. Also, the subjects were given identical diets for the two 24-h testing periods before and after the ST. The energy intake for the day in the chamber was estimated by using the Harris-Benedict equation times a factor of 1.1 (13).

**EE Assessments**

**Description of the University of Alabama at Birmingham indirect room calorimeter. Room description.** Twenty-four hour EE and substrate utilization were measured in a whole-room calorimeter measuring 3.38 m long, 2.11 m wide, and 2.58 m high, resulting in a total volume of 17,500 liters. The room is equipped with a chair (fold-out bed), desk, chair, lamp, refrigerator, toilet, sink, television, videocassette recorder, telephone, and bicycle, reducing the volume to 18,300 liters. An airlock (78.1 x 33.7 cm) allows for the passage of food and materials to the subject while inside the room. Two windows (116.2 x 71.1 cm) view a large room, and a third window (54.6 x 49.5 cm) is on the door (2.07 x 0.908 m) and views the equipment operations room. The door has an air gasket that is inflated to form a seal against a smooth aluminum surface secured to the door frame.

**Temperature control.** Temperature is controlled by an air conditioning and heating system. This system involves passing air from the air conditioner (continuously on) and the two heaters through a mixing chamber to allow for a constant temperature of air to exit into the room. A temperature controller (model CN9221A, Omega) is used to maintain this constant temperature. The temperature has been shown to remain within ±0.2°C over a 24-h test. The barometric pressure is measured by a barometer (model PX961-16A5V, Omega) that is powered by the Hastings four-channel flowmeter. Humidity and temperature are also measured (model HX12, Omega). The wire connections for these instruments are connected to the equipment operations room through a water-filled trap between the room calorimeter and the equipment operations room.

**Gas Sampling Equipment.** A reference inlet pipe with a one-way low-resistance valve allows continuous fresh air into the calorimeter. Located inside the calorimeter are three tangential blowers (on the ceiling) and two axial fans (on the walls) to allow for adequate mixing. On the ceiling of the calorimeter is a radial array of 24 copper tubes of equal length positioned to create a regular six-by-four dot matrix on the entire ceiling, allowing for equal sampling throughout the chamber. Fresh air is aspirated through the chamber by a main fan (model 116155-00, Ametek, Kent, OH) that also aspirates a continuously monitored volume of chamber air. The two sampling membrane pumps (diaphragm pump model 3N, Hartmann & Braun) forward the room and reference air to the rest of the system. The air is dried by a dehumidifier (model 450, Baldwin Environmental, Reno, NV) to 4°C and then reheated by a water-bath heater (model 5818, Haake, Germany) to 30°C. The air is delivered to the analyzers through control of four flow controllers (model HFC-202E, each 0–1 standard U/min, Hastings Bayrdist Flowmeter Controller, Hampton, VA). \( \dot{V}O_2 \) and \( \dot{CO}_2 \) production (\( \dot{V}CO_2 \)) are continuously measured by the magnetopneumatic differential \( \dot{O}_2 \) analyzer (Magnos 4G, Hartmann & Braun) and the nondispersive infrared industrial photometer differential
CO₂ analyzer (Uras 3G, Hartmann & Braun). These differential analyzers measure the differences in O₂ and CO₂ concentrations between incoming reference air and room air. The time taken for the analyzer to reach 90% of the steady-state concentration during CO₂ dilution tests was <25 s. The outputs of the CO₂ and O₂ analyzers are also connected to a strip-chart recorder for visual monitoring of the gas concentrations over time.

The data acquisition involves analog outputs of the analyzers, flowmeter, temperature, humidity, and barometric probes to be processed by a computer (WT, i486S personal computer AT compatible) via an analog-to-digital converter (La Mer, Scientific Solutions, Solon, OH), utilizing a computer acquisition program. The values for VO₂, VCO₂, and RQ are displayed every 5 min.

**CALIBRATION OF THE ANALYZERS.** The room calorimeter was calibrated before each subject’s entry into the chamber. The zero calibration is carried out simultaneously for both analyzers. The full scale is set for 0–1% for the CO₂ analyzer and 0–2% for the O₂ analyzer, with the sensitivity of the analyzers equal to 1% of full scale. A precision gas-mixing pump (model SA 27/3, Digimagix) with switchable gears is used to produce the calibration span mixtures (for CO₂: 1% CO₂; 99% reference air; for O₂: 8% N₂; 92% reference air). These mixtures are then analyzed by the CO₂ and O₂ analyzers. If differences between the sample and the known concentrations (CO₂: 1.00 ± 0.01%; O₂: 1.68 ± 0.01%) existed, appropriate adjustments were made to the analyzers.

**VALIDATION OF CALORIMETER OPERATION.** The accuracy of the room calorimeter has been assessed by testing four adult females on three separate occasions (1 wk apart). The 24-h nonprotein RQ (NPRQ) of these women was 0.88. On the basis of these assessments, the coefficient of variation (CV) for 24-h EE and 19 g for fat oxidation. The accuracy of the measurements for VO₂, VCO₂, and RQ was also determined by burning a known gas (propane; RQ 0.6) inside the room calorimeter. In three calibration tests for 24 h, the measured VO₂ was 99.5 ± 9.1% of the real VO₂ obtained by weighing the amount of propane burnt and by stoichiometric calculation of the volume of O₂ utilized. The measured VCO₂ was 100.2 ± 9.1% of the real VCO₂ (using the stoichiometric calculation of the volume of CO₂ produced), and the RQ was 100.8 ± 1.3% of the real RQ. The CV values between tests for VO₂, VCO₂, and RQ were 2.1, 2.3, and 1.2%, respectively. Thus these tests demonstrated a high level of accuracy of the room calorimeter for measuring VO₂, VCO₂, and RQ.

**Testing of subjects in the room calorimeter.** The subjects entered the room at 8 A.M. and spent 23 h in the chamber. Breakfast was served at 9 A.M. and then while the subjects were laying as still as possible for 3 h, diet-induced thermogenesis (DIT) was measured. Lunch was served after the DIT, and dinner was served at 6 P.M. Subjects were required to consume all the food given to them. During the stay in the calorimeter, the subjects were not allowed to exercise but were allowed freedom of movement at all times during the day, except during the DIT. The subjects were awakened (6:30 A.M.) the following morning, and while they were in bed, after a steady baseline was reached, REE was determined for 30 min. The subjects then exited the room. For the posttraining measures of EE, the subjects entered the room between 23 and 24 h after the last training session, with REE determined 48 h after the last exercise session.

**Calculation of EE measures.** REE, DIT, sleeping EE, activity EE, and 24-h EE were calculated (15). Measures of EE were expressed as a portion of the 24 h and also extrapolated over 24 h and expressed as kilojoules per day and kilocalories per day. RKE was calculated based on EE of subjects in the waking state and laying in bed. The calculation for DIT was as follows: 1) the average kilojoules per minute obtained for the 5-h period was determined; 2) the mean energy intakes of the entire group for breakfast (2,255 kJ) and the entire day (5,912 kJ) were calculated from food records; and 3) these values were applied to the following formula: [(kJ/min × 180 min)/2,255 kJ] × 5,912 kJ. Activity EE is defined as the difference between the daily EE and the sum of resting EE and DIT (activity EE = 24-h EE – (REE + DIT)). For the purposes of this study, sleeping EE was determined by averaging EE for the time when the subject went to sleep until she was awakened. The duration of sleep was constant between the two trials for each individual. Protein oxidation was determined from 24-h urinary urea nitrogen excretion (6). Carbohydrate and fat oxidations were then calculated from resting and 24-h NPRQ values (9).

**Strength Assessment**

Before the strength assessment, subjects were allowed two sessions to become familiar with the equipment and the exercise techniques. Upper body and lower body strength were assessed by the one-repetition maximum (1-RM) test, defined as the maximum amount of weight that could be lifted successfully one time only. Starting with a weight used in the preliminary sessions, subjects attempted lifts with gradually increasing weights (~10% at first, decreasing to 5 and 2.5% as difficulty became evident). Successive attempts were made with a 90-s rest between attempts until failure occurred. Test retest reliability in our laboratory of 1-RM testing varies from 0.95 to 0.99 depending on the type of 1-RM test (<5% variation in all tests). Approximately three to five trials were needed to reach the 1 RM both before and after training. Strength was assessed for both the upper and lower body by using six exercise machines, and the assessment was done in the following order: chest press, leg press, elbow flexion, latissimus pull down, leg extension, and leg curl. This same order was followed at the posttraining testing.

**ST Program**

ST took place for 1-h sessions, three times per week, for 16 wk. In addition to a warm-up and cool-down, the session included a whole body ST program with the subjects completing seven upper and five lower body exercises. These exercises included the leg press, chest press, latissimus pull down, elbow flexion, and elbow extension (Shulae XXL, Inshake); leg extension, leg curl, upper back row, and military press (K-300 pneumatic variable resistance machines, Keiser); hip abductor, hip adductor, and abdominal curls (Cybex). All subjects started the exercise program at 50% of 1 RM for a given exercise. After three sessions, the weight was gradually increased in the smallest increments until the subjects could comfortably perform two sets of 12 repetitions for a given exercise. To maintain the appropriate intensity for 12 repetitions, adjustments in weights were made approximately every 2 wk throughout the duration of the study to continue to promote increases in strength. Subjects alternated between upper and lower body exercises to minimize fatigue with ~2 min of rest allowed between exercises. After one set of exercises was done, the subjects completed the second set. Attendance was taken at each exercise session to monitor compliance to the program. Subjects were contacted if an exercise session was missed and were asked to make up the exercise session on the weekend if possible. All sessions were monitored by an exercise physiologist and at least one exercise leader, both of whom were certified in cardiopulmonary re-
TABLE 1. Subject characteristics before and after strength training

<table>
<thead>
<tr>
<th></th>
<th>Before Training</th>
<th>After Training</th>
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</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>67±1</td>
<td>65.8±2.7</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>65.5±2.7</td>
<td>65.8±2.7</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.7±1.0</td>
<td>25.0±0.9</td>
</tr>
<tr>
<td>VO₂max, ml·kg⁻¹·min⁻¹</td>
<td>19.3±1.0</td>
<td>18.8±1.0</td>
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<tr>
<td>Body fat, %</td>
<td>38.2±1.5</td>
<td>37.6±1.6</td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>25.4±1.9</td>
<td>25.2±2.0</td>
</tr>
<tr>
<td>Fat-free mass, kg</td>
<td>40.1±0.9</td>
<td>40.6±0.8</td>
</tr>
<tr>
<td>Thigh muscle area, cm²</td>
<td>55.2±3.1</td>
<td>60.4±2.3*</td>
</tr>
</tbody>
</table>

Values are means ± SE. BMI, body mass index; VO₂max, maximal O₂ uptake. * Significantly different from before training, P < 0.05.

suscitation. Body weight was recorded every week throughout the study at the training sessions.

Statistical Analyses

The t-tests were conducted between before and after training measures on all dependent variables. Analysis of covariance (ANCOVA) was completed on REE measures by using midthigh muscle area as a covariate. All data were analyzed by SPSS statistical software. All values are expressed as means ± SE.

RESULTS

Subject Characteristics

Fifteen women completed the ST protocol with over 90% compliance for the exercise sessions. Data from two EE measurements were lost because of a temporary system failure for the posttraining values. Therefore, data for all variables measured are presented with a sample size of 13. The women ranged in age from 60 to 77 yr, in body weight from 50 to 80 kg, and in body fat from 31 to 46% (Table 1). There were no significant changes in body mass, percent fat, or FFM as measured by CT (P < 0.05). The results of the strength assessments are presented in Table 2. There was a significant 47% increase in upper body strength and a 66% increase in lower body strength (both P < 0.001).

Table 2. One-repetition maximum strength values before and after strength training

<table>
<thead>
<tr>
<th></th>
<th>Before Training</th>
<th>After Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper body</td>
<td>49±2</td>
<td>72±3*</td>
</tr>
<tr>
<td>Lower body</td>
<td>106±9</td>
<td>176±11*</td>
</tr>
<tr>
<td>Total body</td>
<td>154±11</td>
<td>248±12*</td>
</tr>
</tbody>
</table>

Values are means ± SE in kg. Upper body, sum of elbow flexion, chest press, and latissimus pull down; lower body, sum of leg press, leg extension, and leg curl; Total body, sum of upper and lower body values. * Significantly different from before training, P < 0.001.

EE

Changes in each of the components of EE are shown in Table 3. Resting EE increased significantly by 9.1% (5,017±218 vs. 5,473±213 kJ/day; for 30 min, 105 ± 4.5 vs. 114 ± 4.4 kJ; P < 0.05) after training. No significant changes in DIT (359±25 vs. 393±33 kJ/day; for 180 min, 45±3.1 vs. 49±4.2 kJ) or sleeping EE (4,929±180 vs. 5,067±251 kJ/day; for a sleeping time of 485 min before and 500 min after training, 1,660±61 vs. 1,759±87 kJ) were observed. Activity EE tended to decrease (682±84 vs. 381±117 kJ/day; P = 0.193), but the change was not significant. There was also no significant change in 24-h EE (6,054±188 vs. 6,247±243 kJ/day). With use of thigh muscle cross-sectional area as a covariate, the ANCOVA showed no significant change in REE.

Table 3. Energy expenditure before and after strength training

<table>
<thead>
<tr>
<th></th>
<th>Before Training</th>
<th>After Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting</td>
<td>5,017±218</td>
<td>5,473±213*</td>
</tr>
<tr>
<td>DIT</td>
<td>359±25</td>
<td>393±33</td>
</tr>
<tr>
<td>Sleeping</td>
<td>4,929±180</td>
<td>5,067±251</td>
</tr>
</tbody>
</table>

Values are means ± SE. DIT, diet-induced thermogenesis. * Significantly different from before training, P < 0.05.

Substrate Oxidation

The changes in substrate oxidation are presented in Table 4. The resting NPRQ (0.87±0.02 vs. 0.81±0.02; P < 0.05), 24-h NPRQ (0.90±0.01 vs. 0.82±0.01; P < 0.001), DIT NPRQ (0.93±0.02 vs. 0.84±0.01; P < 0.01), and sleeping NPRQ (0.83±0.02 vs. 0.78±0.01; P < 0.01) all decreased significantly. Both resting and 24-h substrate oxidation were altered with training. The 24-h values revealed significant increases in fat oxidation (42±6 vs. 81±7 g/day; P < 0.001) and decreases in carbohydrate oxidation (180±14 vs. 113±10 g/day; P < 0.001) and protein oxidation (68±3 vs. 64±3 g/day; P < 0.05). All but one of the women...
we did find a significant increase in thigh muscle cross-sectional area measured by CT. Assuming that thigh muscle cross-sectional area is an index of total muscle mass, ANCOVA with thigh muscle area as the covariate revealed no significant change in RER. Therefore, our data suggest that the increase in REE is due, at least in part, to an increase in muscle. Alterations in protein synthesis or sympathetic nervous system activity may also help explain the alterations in EE. Increased protein synthesis is known to occur in older adults in response to resistive training (35). An increase in the rate of norepinephrine appearance has been shown to explain 17% of the variation in the increase in REE in the elderly after an endurance-training program (17). Increases in plasma norepinephrine were observed after ST in older men, suggesting that ST can increase REE and may do this by increasing basal sympathetic nervous system activity (21).

The influence of ST on REE is controversial. In one study, decreases in REE ranging from 7 to 12% were found in young women who completed an aerobic, ST, or combined program (8). These women were on a very low-calorie diet and in negative energy balance, which probably precluded any increases in FFM and a concomitant increase in REE with training. In another investigation (2), REE did not change significantly after either an aerobic or a ST program in young men. The variable conclusions from these studies may be due to the time of REE measurement in relation to the last exercise session, the study design (i.e., combining diet and exercise), or the use of young rather than older subjects.

Twenty-four-hour EE measured in the room calorimeter appears to be low in these women. This may partly have been due to the age and FFM of our subjects. In addition, our protocol (in which no exercise was allowed in the chamber) probably contributed to the relatively low 24-h EE. Our reason for avoiding exercise in the chamber was to remove any effects of a different type of exercise (other than ST) on the EE measures. We did not observe any significant changes in 24-h EE after ST, despite an increase in REE. This is consistent with a cross-sectional comparison (24) and a longitudinal endurance-training study (11). In the cross-sectional study that examined the relationship between fitness and 24-h sedentary EE measured in a room calorimeter, no differences in 24-h EE, sleeping EE, or nonresting EE were observed between trained and untrained individuals (24). The present report of stability in 24-h EE in conjunction with the 456-kJ/day increase in REE suggests that other components of EE may have been reduced in a compensatory response that was too small to be detected. For example, Goran and Poehlman (11) found no change in total EE (measured over 10 days with doubly labeled water) after 8 wk of endurance training.
STRENGTH TRAINING AND 24-H ENERGY EXPENDITURE

The training-induced increase in fat oxidation by ~40 g/day is substantial. Although there was not a concurrent nonintervention control group, intraindividual reliability testing of the chamber demonstrates its reproducibility. Fat oxidation was comparable to fat intake before training (42 vs. 42 g/day, respectively) but was significantly different after training (81 vs. 42 g/day). The mechanisms to explain this increase in fat oxidation were not examined in this study. Energy imbalance may have contributed because a negative energy balance would require greater mobilization and utilization of free fatty acids. In terms of energy balance, 24-h EE before (6,054 kJ/day) and after (6,247 kJ/day) training did not significantly differ from the energy intake (5,912 kJ/day), but the 394-kJ/day (80 kcal/day) difference after training may have contributed to a small extent to the increase in fat oxidation. If one were to assume that all the 334-kJ deficit was derived from fat oxidation, at most only 9 g of the 39 g could be attributed to the slight negative energy balance posttraining. Change in body composition may have played a role. There was a trend for a decrease (nonsignificant) in fat mass measured by hydrodensitometry. Two factors may explain why hydrodensitometry did not detect changes in body composition with ST, namely 1) hydrodensitometry may not be a sensitive enough technique and 2) the inherent assumptions of the hydrodensitometry technique may change (i.e., the density of the FFM) with training, and failure to take these into account may "mask" real changes. However, we previously reported a significant decrease in adipose tissue in the abdomen and thigh by CT after training in these same women (27). According to data from Schutz et al. (25), a decrease in fat mass is related to a decrease in fat oxidation. In our study we found an increase in muscle mass (1.4 kg) that was related not only to the increase in resting EE but also to the increase in fat utilization. Our data suggest that muscle mass increase is associated with an increase in fat oxidation. Other possible factors related to the substrate oxidation changes may include alterations in sympathetic nervous system activity, which modulates lipid mobilization by affecting adipose tissue lipolysis. As mentioned previously, plasma norepinephrine increases after ST in older men (21).

In conclusion, ST in older women increases resting EE, which is related in part to the increase in muscle mass. ST also increases fat oxidation, which may be beneficial to the older adult.

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