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Impact of energy restriction with or without resistance training on energy metabolism in overweight and obese postmenopausal women: a Montreal Ottawa New Emerging Team group study

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Abstract

Objective: The present study measured the impact of adding resistance training to an energy-restricted diet on the components of energy expenditure in overweight or obese postmenopausal women.

Methods: Participants (n = 137) were randomly divided into two groups: (1) a diet and resistance training (DRT) group and (2) a diet-only (DO) group. Women followed a 6-month energy-restricted diet consisting of 2,100 to 3,360 kJ less than daily needs. The DRT group also followed a resistance training program (three times a week). Resting energy expenditure (REE) was measured by indirect calorimetry. Total energy expenditure was measured with doubly labeled water. Body composition was measured by dual-energy x-ray absorptiometry.

Results: Eighty nine women were included in the analyses for this study (DRT, n = 21; DO, n = 68). REE in both groups was significantly lower after the intervention (mean difference ± SD: DO, -0.26 ± 0.4 MJ d^{-1}; DRT, -0.33 ± 0.4 MJ d^{-1}; $P \leq 0.05$). Relative REE, expressed per kilogram of lean body mass$^{0.856}$ corrected for fat mass change, remained stable in both groups. Physical activity energy expenditure remained stable in both groups (mean difference ± SD: DO, 0.02 ± 1 MJ d^{-1}, $P = 0.91$; DRT, -0.14 ± 1 MJ d^{-1}, $P = 0.64$).

Conclusions: Adding resistance training to an energy-restricted diet does not significantly alter any compartment of energy expenditure. REE is lower owing to reduction in body composition compartments, but relative REE is not significantly altered.

Key Words: Weight loss – Total energy expenditure – Physical activity – Resting energy expenditure – Exercise.

Physical activity is associated with a healthy lifestyle[1,2] and is commonly proposed to prevent weight gain,[3] promote weight loss,[4] and prevent weight regain.[5] To achieve healthy body weight and healthy body composition with an optimal impact on metabolic profile, overweight and obese women should implement a negative energy balance, which is best obtained by combining caloric restriction with regular physical activity.[6] However, during weight loss, fat mass reduction may be associated with other changes in body composition, such as loss in lean body mass (LBM),[4,7-9] which induces a reduction in resting energy expenditure (REE)[10-12] and possibly affects physical activity energy expenditure (PAEE) and total energy expenditure (TEE).[13]

Resistance training was reported to increase REE both in the short term[14-21] and in the long term, mostly through an increase in fat-free mass[22-27] and/or in sympathetic nervous system activity.[25] Those increases in fat-free mass were achieved even when participants were following an energy-restricted diet.[9,28] Even though REE is a major determinant of TEE, its increase by resistance training does not always translate into a higher TEE,[24,26,29] possibly through a compensatory reduction in daily spontaneous physical activity.[30] However, in some cases, resistance training has been reported to elicit an increase in TEE by increasing REE and the energy cost of the training.[18,22,31]

Of interest to this study, PAEE increased after a resistance training intervention in disabled or older individuals,[32,33] which is seemingly not necessarily the case for aerobic-type exercises.[34,35] A possible explanation for this is that

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improvement in physical capacity increases the ease of performing daily tasks.[36,37] To date, it is not clear whether strength gain or resistance training can affect the amount of daily physical activity performed by an individual beyond the energy cost of the activity itself.[29,38]

Using data collected during a weight loss project of the Montreal Ottawa New Emerging Team (MONET) study group,[39,40] this secondary analysis aims to measure the impact of a 26-week calorie-restricted diet with or without periodized progressive resistance training program on the components of energy expenditure, especially REE and PAEE, in overweight or obese postmenopausal women. We hypothesized that the addition of resistance training would minimize REE reduction associated with weight loss through maintenance of muscle mass (a major component of LBM) and would increase PAEE through an increased ability to undertake daily physical activity.

METHODS

Study design and participants

Women were recruited by the MONET group, whose prospective 6-month weight loss study investigated the impact of a hypocaloric diet, alone or in combination with resistance training, on the body composition, metabolic profile,[39] and psychosocial profile of overweight and obese postmenopausal women. Preplanned secondary analysis also included the impact of the intervention on psychosocial profile,[40] as well as on energy metabolism, during a 6-month weight loss program. Participants were recruited through newspaper advertisements, and data were collected between 2003 and 2006. A total of 1,079 women responded to the newspaper advertisements, 936 were reachable by telephone, 252 were eligible for testing (based on inclusion criteria), and 137 accepted and met the study inclusion/exclusion criteria after medical and biological testings by the physician of the study (Fig. 1). Participants in this study were drawn from the MONET group study.[39] All participants signed an informed consent form before the initiation of the study, and all procedures were approved by the University of Montreal Research Ethics Board.

The inclusion and exclusion criteria for women in this study had been published earlier.[41] Women were eligible to participate if they met the following criteria: (1) body mass index of 27 kg meter^{-2} or higher; (2) cessation of menstruation for more than 1 year and follicle-stimulating hormone level of 30 U L^{-1} or higher; (3) sedentary (<2 h wk^{-1} of structured exercise); (4) nonsmoker; (5) low to moderate alcohol consumption (fewer than two drinks per day); (6) free of known chronic inflammatory disease; and (7) no use of menopause hormone therapy. On physical examination or biological testing, all participants had no history or evidence of the following: (1) cardiovascular disease, peripheral vascular disease, or stroke; (2) diabetes (75 g on oral glucose tolerance test); (3) known renal and liver diseases; (4) asthma requiring therapy; (5) plasma cholesterol higher than 8 mmol L^{-1}; (6) systolic blood pressure higher than 160 mm Hg or diastolic blood pressure higher than 100 mm Hg; (7) history of alcohol or drug abuse; (8) history of inflammatory disease or cancer; (9) orthopedic limitations; (10) body weight fluctuation of more than 2 kg in the last 6 months; (11) untreated thyroid or pituitary disease; and (12) medications that could affect cardiovascular function and/or metabolism.

As previously described,[39] participants (n = 137) were randomly divided into two groups: (1) a diet and resistance training (DRT) group and (2) a diet-only (DO) group. The randomization ratio was 2:1 in favor of the DO group. This

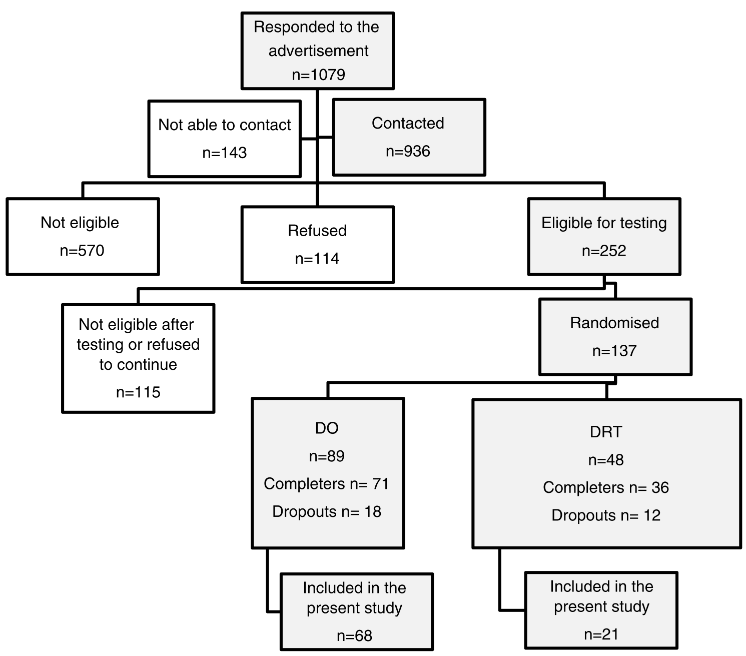

FIG. 1. Trial profile of the 6-month study. DO, diet only; DRT, diet and resistance training.

distribution was necessary to allow for a future follow-up study involving the DO group. Seventy-one of 89 completed the DO intervention, and 36 of 48 completed the DRT intervention. Reasons for dropping out of the study included the following: conflict with work schedule (n = 4), slow weight loss (n = 3), refusal of 6-month testing (n = 3), travel distance to the research unit (n = 3), family problems (n = 2), health reasons unrelated to the study (n = 5), minor injuries related to exercise training (n = 3), and unspecified (n = 7).

For the purposes of analyses in the present study, 68 women formed the DO group (3 of 71 participants had missing postintervention data for energy expenditure or body composition), and 21 formed the DRT group (15 of 36 participants were excluded because of poor compliance; <80% of resistance training sessions completed, including lower and upper body exercises).

All baseline and 6-month postintervention analyses were preceded by a 4-week weight stabilization period. Weight stability within plus/minus 2 kg was verified by monitoring the body weight of each woman on a weekly basis at our research unit. Before the baseline and postintervention testing periods, the weight stabilization periods were intended to reduce the short-term effects of caloric restriction on outcome measures.[42]

Energy expenditure

All measurements were completed before the beginning of the weight loss intervention and 4 weeks after its completion. During those 4 weeks, women in the DRT group trained twice a week to maintain strength. Post-weight-loss tests were conducted at least 48 hours after the last training bout. TEE was measured during a 10-day period using the doubly labeled water technique, as previously described.[43] REE was measured by indirect calorimetry using the ventilated hood technique (Delta Trac; Datex Ohmeda, Finland). In our laboratory, the intraclass correlation coefficient (two-factor random effect) for REE, determined using a test-retest condition in 19 different volunteers, was 0.92 ($P < 0.01$). Women came to the laboratory early in the morning (7:00 AM) in a fasting state. Participants were asked to lie in bed in supine position in a temperature-controlled environment (22°C) for 40 minutes. The last 30 minutes of measurements were averaged and used to calculate REE according to the Weir equation.[44] The thermic effect of food was estimated as a fraction (10%) of TEE.[45] Relative REE was expressed per kilogram of body weight$^{0.799}$. The value 0.799 was determined from the Kleiber relationship[46] by using the slope resulting from the plotting of the log-transformed values of body weight against the log-transformed values of REE. The same procedure was used for LBM, yielding a slope of 0.856.

PAEE was calculated as follows: PAEE = (TEE × 0.90) − REE.[45] PAEE is therefore defined as energy use not related to the energy costs of food ingestion and digestion and to REE.

Body composition

Body composition was measured by dual-energy x-ray absorptiometry while women lay supine, with their arms slightly distanced from the torso (version 6.10.019; General Electric Lunar Corp., Madison, WI). On test-retest analyses, the intraclass correlation coefficients (two-factor random effect) in 18 volunteers were 0.99 ($P < 0.01$) for fat mass and 0.99 ($P < 0.01$) for fat-free mass.

Nutritional intervention

Women entered into a 6-month weight loss program aimed to reduce body weight by 10%. To determine the level of caloric restriction, we subtracted 3,360 kJ from baseline REE (determined by indirect calorimetry) multiplied by a physical activity factor of 1.4, which corresponds to a sedentary state.[47] Whenever subtraction of 3,360 kJ yielded a caloric requirement of less than 4,200 kJ, the restriction was reduced (mean reduction, 2,617 kJ). Diet prescriptions ranged from 4,620 to 7,560 kJ day^{-1}. The macronutrient composition of the diets was standardized: 55%, 30%, and 15% of energy intake from carbohydrates, fats, and proteins, respectively. Each participant met with the study dietician weekly. In addition, women in both study groups were invited to meet with the study dietician bimonthly for nutrition classes (60-90 min). Themes discussed during group sessions included food groups and their caloric/nutrient content, portion sizes, self-evaluation of dietary intake and macronutrient distribution, dietary fats and portion size, and other related topics. All participants in the DO group were instructed to maintain their habitual physical activities during the weight loss protocol.

Strength testing

Maximal dynamic voluntary strength was measured according to a 1RM (*1 r*epetition *m*aximum) protocol. After a general warm-up on a motorized treadmill, women were informed of the strength testing procedure and then properly positioned on the first testing exercise—the leg press. A light weight was set, and the participants were asked to slowly complete 10 repetitions at a comfortable range of motion. The distance of the weight displaced was recorded as the reference range of motion. After a 2-minute rest period, a heavier weight was set, and the participants were asked to complete a maximum of repetitions while maintaining the reference range of motion. If more than 10 repetitions were performed, the participants were stopped by the exercise specialist to avoid any unnecessary fatigue. The number of repetitions, the weight, and the range of motion were all recorded. If more than one repetition was completed, the weight was increased, and a second set was completed after 3 minutes of rest. The procedure was repeated until only one repetition could be completed or until five attempts were achieved. If maximal 1RM was not achieved after five attempts, the Wathen equation[48] was used to predict the maximal weight for a theoretical 1RM. Strength was measured on three exercises: a leg press (model C-203; Atlantis, Laval, Canada), a seated chest press (model P-140; Atlantis); and a lat pull-down (model D-123; Atlantis).

For the DO group, strength tests were conducted over three nonconsecutive days 1 week before the beginning of the intervention and again 1 week after the end of the 6-month intervention. For the DRT group, one strength test was performed on the first day of training. A second series of tests was completed after 3 weeks of training. On week 4, three strength testing sessions were conducted for nonconsecutive days, and the best result on each exercise was used as baseline strength. This procedure was used to dismiss any learning effect unrelated to strength gain to be able to properly measure strength variation during the 6-month period. In the DRT group, another week of testing was planned on the 15th week of training to readjust training weight. Finally, the last week of strength testing was completed on week 26. Strength results are expressed in kilograms and joules (mass lifted [kg] × distance traveled by weight [meters] × gravity [9.81 meters s^{-2}]) and presented as lower body strength (leg press) and upper body strength (chest press).

Resistance training intervention

Women in the DRT group participated in a 6-month (26-wk) progressive resistance training program. The macrocycle of training is presented in Figure 2. Participants trained three times a week every other day. During the 26-week period, a total of four recovery weeks were planned. Each recovery week consisted of two training sessions, instead of three. Each training session consisted of a general warm-up on a motorized treadmill at 65% intensity of the theoretical heart rate (220 − age). A total of six exercises were included in each training session: (1) leg press (C-203; Atlantis), (2) seated chest press (P-140; Atlantis), (3) lat pull-down (D-123; Atlantis), (4) shoulder press (model E-149; Atlantis), (5) biceps curl (model B-157; Atlantis), and (6) triceps extension (model T-163; Atlantis). A specific warm-up consisting of a set of 10 repetitions at 15 repetition maximum was completed before the training sets. Exercises were completed in the presented order. Weights were periodically adjusted according to the perceived exertion of the participants and the judgment of the exercise specialist. Initial training weight was predicted from the strength testing results according to the Brzycki table/equation.[49] Training resistance was also readjusted after each testing week using the same table. Training volume was compiled as the total amount of work completed on all exercises, expressed in megajoules, during the 6-month intervention. After the 6-month intervention, the diet and exercise group followed a strength maintenance program for 4 weeks. The maintenance program consisted of two submaximal training sessions per week. This phase was performed to alleviate the possibility of a detraining effect while the daily energy expenditure measurements were being completed.

Statistics

Unpaired *t* tests were used to measure initial and postintervention differences in independent variables between the two groups. CIs presented for changes in the mean were calculated according to the Welch correction for unequal variance.[50] Repeated-measures two-way analysis of variance was used with a group-by-time interaction to measure the impact of the intervention. Multiple regression analyses were used to identify the major body composition (fat mass and LBM) determinants of significant changes in energy expenditure. χ^2 analysis was used to determine if the distribution of participants (DRT and DO) between those who successfully increased PAEE and those who did not was statistically different.

Phase	General adaptations				Hypertrophy I						Strength I					Strength II				Hypertrophy II					
Week	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26
Sets per major exercices	Strength tests	3	3	Strength tests	3	3	4	4	4	2	3	3	4	4	2	Strength Tests	4	4	4	4	4	4	4	4	Strength Tests
Reps per major exercices		12	12		12	12	12	12	12	12	10	10	8	8	10		8	8	8	12	12	12	12	12	
RM per major exercices		15	12		12	12	12	12	12	12	10	10	8	8	10		8	8	8	12	12	12	12	12	
Sets per minor exercices		2	2		2	2	2	2	2	1	1	1	2	2	1		2	2	2	2	2	2	2	2	
Reps per minor exercices		12	12		12	12	12	12	12	12	10	10	10	10	10		10	10	10	12	12	12	12	12	
RM per minor exercices		15	12		12	12	12	12	12	12	10	10	10	10	10		10	10	10	12	12	12	12	12	
Rest (sec)		90	120		90	90	90	90	90	90	120	120	120	120	120		120	120	120	90	90	90	60	60	

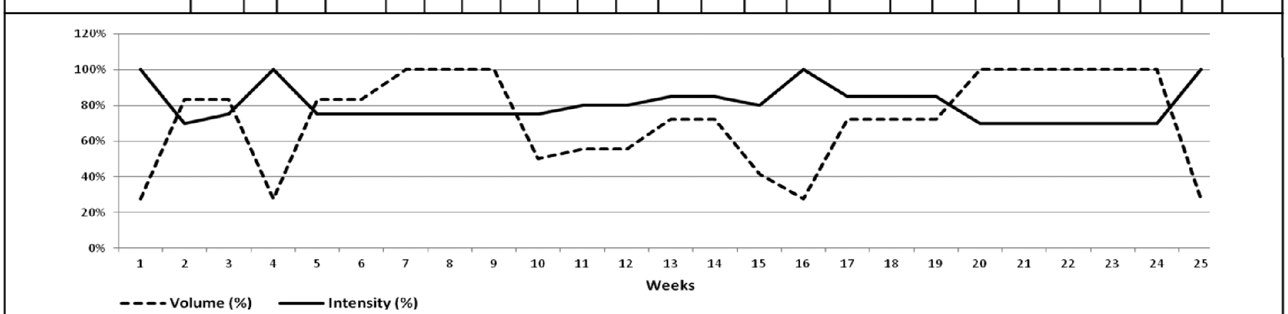

FIG. 2. Overview of the resistance training intervention. Volume and intensity are expressed as the percentage of maximal value achieved in the program. Major exercises: leg press, chest press, and lat pull-down. Minor exercises: shoulder press, triceps extension, and biceps curl. Reps, repetitions; RM, repetition maximum.

TABLE 1. *Physical characteristics of the participants*

	Mean (SD)	Minimum	Maximum
Diet only (n = 68)			
Age, y	58.3 (5)	48.8	70.5
Height, meters	1.61 (0.07)	1.44	1.78
Weight, kg	83.2 (14)	56.4	123.6
BMI, kg/m^2	32.1 (5)	26.1	45.8
Diet and resistance training (n = 21)			
Age, y	57.6 (4)	51.0	64.8
Height, meters	1.58 (0.5)	1.52	1.70
Weight, kg	82.2 (16)	62.6	130.4
BMI, kg/m^2	32.6 (5)	26.9	48.5

Values are expressed as mean (SD).
Data adapted from Brochu et al.[39]
Paired *t* test showed no significant difference for initial values.
BMI, body mass index.

Significance level was set at $P \leq 0.05$. All analyses were completed with SPSS for Windows (version 13.0; SPSS, Chicago, IL).

RESULTS

There were no significant differences in baseline characteristics between the two groups of participants (Table 1). The effects of the two treatments on body composition were the subject of another publication from our group[39] and are summarized in Table 2. Both treatments resulted in a similar significant ($P \leq 0.05$) weight loss. However, women randomized to the DRT group lost significantly more fat mass than women in the DO group.

Energy expenditure changes

Energy expenditure results are presented in Table 3. REE was significantly lower in both treatment groups after weight loss, with no significant difference between groups (DO, −4.5% ± 7%; DRT, −5.9% ± 7%; $P = 0.41$). Because REE was strongly correlated with weight ($r = 0.75$, $P \leq 0.05$) and LBM ($r = 0.81$, $P \leq 0.05$), relative REE expressed per kilogram of body weight (REE_{bw}) and relative REE expressed per LBM (REE_{lbm}) were compared before and after the 6-month period. REE_{bw} was maintained in the DO and DRT groups. Both groups showed a reduction in REE_{lbm}. REE_{lbm}, as an indicator of metabolic rate can be influenced by fluctuations in fat mass, more precisely, by the contribution of fat to energy metabolism.[51] Once proper corrections had been carried out for the change in fat mass, no significant difference in REE_{lbm} persisted before and after the intervention (DO REE_{lbm}: preintervention, 224 ± 2 kJ $kg_{lbm}^{-0.856}$ d^{-1}; postintervention, 217 ± 2 kJ $kg_{lbm}^{-0.856}$ d^{-1}; DRT REE_{lbm}: preintervention, 228 ± 3 kJ $kg_{lbm}^{-0.856}$ d^{-1}; postintervention, 214 ± 3 kJ $kg_{lbm}^{-0.856}$ d^{-1}; group × time interaction, $P = 0.639$).

Physical capacity changes

Physical capacity changes are presented in Table 4. A group-by-time interaction was found for strength changes after the intervention. There was a significant increase in strength in the DRT group in both lower body and upper body exercises, whereas it remained unchanged in the DO group. Absolute aerobic capacity was significantly lower after the intervention in both groups, with no group-by-time interaction. Training volume (Table 4) was not significantly correlated with any energy expenditure component change, weight loss, or fat mass loss in the DRT group.

DISCUSSION

The participants in this study completed a 6-month intervention consisting of an energy-restricted diet with or without a resistance training program. To better assess the impact of resistance training, we closely monitored and controlled the interventions. Contrary to our hypothesis, the results of the present study suggest that the combination of a resistance training intervention and caloric restriction did not significantly affect any energy expenditure component but, as observed previously, improved body composition by increasing fat mass loss.[39]

Both interventions resulted in a significantly lower absolute REE (kJ d^{-1}). Albeit significant, the reduction in REE is clinically trivial and of little interest, as evidenced by the CIs (−64 to −45 kcal d^{-1}). Our results suggest that this reduction is mostly caused by changes in body composition. The omission of fat mass as an energy-consuming factor when dividing REE by LBM to obtain a relative measurement of REE explains the reduction in REE_{lbm}. Therefore, REE_{lbm} is

TABLE 2. *Body composition changes after the 6-month hypocaloric diet intervention with or without resistance training*

	Preintervention	Postintervention	Mean difference	95% CI
Diet only (n = 68)				
Weight, kg	83.1 (14)	78.1 (14)	−5.0 (5)[a]	−6.1 to −3.8
Lean body mass, kg	43.0 (7)	42.1 (6)	−0.9 (2)[a]	−1.5 to −0.3
Fat mass, kg	37.7 (9)	33.7 (9)	−4.0 (4)[a,b]	−4.9 to −3.2
Bone mass, kg	2.45 (0.4)	2.42 (0.3)	−0.03 (0.2)	−0.08 to 0.02
Diet and resistance training (n = 21)				
Weight, kg	82.2 (16)	76.6 (18)	−5.6 (5)[a]	−8.9 to −3.2
Lean body mass, kg	41.3 (6)	41.4 (6)	0.04 (2)	−0.6 to 0.7
Fat mass, kg	38.5 (11)	32.9 (13)	−5.6 (5)[a,b]	−7.7 to −3.5
Bone mass, kg	2.42 (0.4)	2.38 (0.4)	−0.04 (0.1)	−0.1 to 0.02

Values are expressed as mean (SD).
Data adapted from Brochu et al.[39]
[a]Repeated-measures analysis of variance. Differences from preintervention values ($P \leq 0.05$).
[b]Group differences ($P \leq 0.05$).

TABLE 3. *Energy expenditure changes after the 6-month hypocaloric diet intervention with or without resistance training*

	Preintervention	Postintervention	Mean difference	95% CI
Diet only (n = 68)				
REE, MJ d^{-1}	5.5 (1)	5.3 (1)	−0.26 (0.4)[a]	−0.35 to −0.16
REE_{bw}, kJ $kg^{-0.799}$ d^{-1}	162 (14)	163 (14)	0.28 (10)	−2.59 to 2.03
REE_{lbm}, kJ $kg_{lbm}^{-0.856}$ d^{-1}	221 (17)	215 (23)	−6.7 (16)[a]	−11.0 to −2.86
PAEE, MJ d^{-1}	3.81 (1)	3.83 (1)	0.02 (1)	−0.3 to 0.4
TEE, MJ d^{-1}	10.4 (2)	10.1 (2)	−0.27 (2)	−0.6 to 0.1
Diet and resistance training (n = 21)				
REE, MJ d^{-1}	5.4 (1)	5.1 (1)	−0.33 (0.4)[a]	−0.5 to −0.2
REE_{bw}, kJ $kg^{-0.799}$ d^{-1}	162 (16)	162 (13)	−0.5 (11)	−5.6 to 4.6
REE_{lbm}, kJ $kg_{lbm}^{-0.856}$ d^{-1}	225 (15)	211 (12)	−14 (16)[a]	−21.4 to −6.8
PAEE, MJ d^{-1}	4.1 (1)	4.0 (1)	−0.14 (1)	−0.7 to 0.5
TEE, MJ d^{-1}	10.6 (2)	10.1 (2)	−0.5 (2)	−1.2 to 0.2

Values are expressed as mean (SD).
REE, resting energy expenditure; REE_{bw}, relative REE expressed per kilogram of body weight; REE_{lbm}, relative REE expressed per lean body mass; PAEE, physical activity energy expenditure; TEE, total energy expenditure.
[a]Repeated-measures analysis of variance. Differences from preintervention values ($P \leq 0.05$).

not a valid representation of energy metabolism and should be used with caution, especially when changes in fat mass occur. According to our observations, there was no significant decrease in relative REE, suggesting no long-term negative impact of energy deficit on relative REE.

Although we did not observe any long-term increase in REE in the DRT group, it is possible, however, that resistance training may have induced a short-term effect on REE after each training session (sessions 14-21). The repeated training sessions during the 6 months could have provided the participants a beneficial increase in REE through increased energy requirements for recovery.[19] The theoretical increase in oxygen consumption generated mainly by the cost of recovery after training might influence energy balance in favor of greater energy deficit and greater fat oxidation.[16] We can only estimate the energy expended during the hours after each session; however, according to Melby et al[20] and Dolezal et al,[19] REE could be increased by as much as 7% to 9% for approximately 15 hours postexercise. Over the entire duration of the intervention, this could add up to approximately 21 MJ in favor of the DRT group. If we add an estimated 840 kJ for a single training session,[52] we have roughly 63 more megajoules in favor of the DRT group.

The relationship between resistance training and spontaneous physical activity or PAEE has not been thoroughly explored, primarily because of methodological issues. It has been previously demonstrated that an increase in strength was positively related to an increase in functional capacity in individuals with certain physical limitations.[36,53,54] Thus, we sought to determine whether increasing strength in overweight or obese individuals increases PAEE by improving their capacity to perform daily tasks and activities, thus partly alleviating the burden created by excessive body weight. Our results, however, suggest that PAEE was not altered in either group after the 6-month intervention. The narrow CI observed (−0.27 to 0.33 MJ d^{-1}) when data were pooled suggests the limited clinical impact of the intervention on PAEE.

A possible explanation for the lack of change in PAEE may be that the level of strength gain achieved through resistance training in this study was not sufficient to induce changes in activities of daily living or, more probably, that initial strength was already sufficient to successfully complete daily chores. On the other hand, the study design may have affected these results. TEE measurements by doubly labeled water were performed approximately 2 weeks before the beginning of the intervention and at least 48 hours after the last resistance training session of the weight maintenance period (4 wk, two training sessions per week), therefore excluding the energy cost of training. Thus, it is possible

TABLE 4. *Physical capacity changes after the 6-month hypocaloric diet intervention with or without resistance training*

	Preintervention	Postintervention	Mean difference	95% CI
Diet only				
Aerobic capacity, L min^{-1} (n = 54)	1.49 (0.3)	1.38 (0.3)	−0.1 (0.2)[a]	−0.05 to −0.2
Lower body strength, kg (n = 18)	147.4 (39)	143.8 (37)	−3.6 (30)[b]	−18.7 to 11.5
Upper body strength, kg (n = 21)	41.5 (7)	40.4 (7)	−1.2 (4)	−3.2 to 0.8
Diet and resistance training				
Aerobic capacity, L min^{-1} (n = 20)	1.49 (0.3)	1.38 (0.3)	−0.1 (0.2)[a]	−0.2 to 0.01
Lower body strength, kg (n = 21)	151.5 (46)	193.2 (49)	41.7 (45)[a,b]	20.8 to 62.7
Upper body strength, kg (n = 20)	38.0 (8)	52.3 (9)	14.3 (6)[a,b]	11.4 to 17.2
Volume, MJ (n = 21)	–	273.8 (55)	–	–
Relative volume, MJ kg_{lbm}^{-1} (n = 21)	–	6.66 (1)	–	–

Values are expressed as mean (SD).
Lower body strength, leg press exercise; upper body strength, leg press exercise.
[a]Paired *t* test. Differences from preintervention values ($P \leq 0.05$).
[b]Repeated-measures analysis of variance. Group-by-time interaction ($P \leq 0.05$).

that there was an energy expenditure difference during the interventions between the two groups that was not captured because of the timing of measurements. The energy cost of resistance training is not as high as those of aerobic or weight-bearing exercises[52,55,56] but could still account for a higher daily energy expenditure.[38] This small difference could possibly lead to a modification of the nature of weight loss (LBM vs fat mass), such as the tendency observed in the present study.

The similarities observed between the DO group and the DRT group placed into perspective the relevance of a high-intensity high-volume resistance training to a weight loss intervention. It is possible that a resistance training intervention consisting of a lower-intensity but equal-volume regimen could provide similar body composition benefits and be more accessible. The relatively small number of participants in the DRT group who completed 80% of the resistance training program (n = 21) might have contributed to the absence of differences in energy expenditure observed in this group of participants. Factors associated with dropouts and poor compliance to the resistance training program (as described in "Methods") must be taken into consideration when a training program for obese postmenopausal women is developed.

CONCLUSIONS

In our population of overweight or obese postmenopausal women, progressive resistance training combined with energy-restricted diet results in significant strength gain but does not significantly influence REE or PAEE. REE change is trivial after the 6-month intervention and stable when corrected for body composition changes. In both groups, the change in PAEE—not in REE—is the greatest predictor of changes in TEE.

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