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Interindividual variations in resting metabolic rate during weight loss in obese postmenopausal women

A pilot study

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Abstract

The objective of the study was to examine if decreases in resting metabolic rate (RMR) take place early in the weight loss process and if they remain throughout the duration of the weight loss intervention. Twenty obese postmenopausal women (61.8 ± 5.9 years) participated in a 15-week weight loss program. After the fifth week, subjects were characterized as having an *increased* (>5%) or a *decreased* (<5%) RMR based on baseline values. Afterward, they were followed for an additional 10 weeks. Outcome measures were as follows: fat mass ([FM] total, trunk), lean body mass (total, trunk), RMR, resting heart rate (RHR), and physical activity level. After 5 weeks, significant decreases were observed for lean body mass, FM, and RHR ($P < .05$), whereas no overall changes in physical activity level and RMR were observed. However, on an individual basis, large variations in RMR were observed (ranging from −320 to +330 kcal/d). Analyses showed that subjects characterized as either having an increased or a decreased RMR after the fifth week maintained these adaptations at the end of intervention. Finally, subjects displaying a decreased RMR during weight loss had a significantly higher RMR and lower FM accumulations at baseline (total and trunk) compared with those with an increased RMR. Interindividual variations in RMR took place early in the weight loss process and were maintained over the duration of the weight loss program in our cohort of obese postmenopausal women. Baseline RMR, changes in RHR, and FM accumulations (total and trunk) seem to be important factors to consider when studying the effects of weight loss on RMR.

1. Introduction

Hypocaloric diets, without exercise, have been associated with decreases in lean body mass (LBM) [1], which have also been associated with reduced resting metabolic rate (RMR) [2-5]. Taken together, decreases in LBM and RMR are considered as important factors associated with weight regain after weight loss [4,6-8]. In older individuals, decreases in RMR during weight loss could be accentuated by the normal loss of muscle mass associated with aging, commonly named *sarcopenia* [9-11], which could favor even more weight regain and blunt the health improvements obtained with weight loss.

Studies conducted over the past years have identified a number of independent predictors of RMR after weight loss, such as variations in LBM [12], fat mass (FM) [5], and sympathetic nervous system (SNS) activity [12-15]. Some studies reported that change in LBM is an important independent predictor of decreases in RMR after weight loss [12,16], whereas others showed that variations in LBM explained only a small part [17-20]. Discrepancies in the literature regarding the association between changes in LBM and RMR after weight loss are perhaps the result of

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methodological differences related to subjects characteristics, techniques used to measure body composition, and study designs [6].

Studies examining the effects of weight loss on RMR mainly used protocol durations ranging from 10 to 52 weeks [3,5,19,21], and limited information is currently available regarding short-term adaptations to weight loss [5]. This aspect is important because metabolic adaptations to weight loss may occur early in the process [12]. Consequently, studies using longer weight loss program may experience difficulties in keeping a constant weight loss throughout the study and minimizing important body weight fluctuation. This aspect is of great interest because weight fluctuations can significantly and negatively affect variables of interest by the time of testing. Actually, pooling subjects in acute phase of weight loss with others in relatively weight-stable period can lead to false conclusions [22]. Numerous studies have investigated the effect of caloric restriction on RMR [5]. However, only a few have reported RMR changes during weight loss [4,23]. Therefore, possible earlier adaptations in RMR were not investigated in these studies. Consequently, it is not clear when RMR adaptations take place during weight loss.

Taken together, it is important to investigate when RMR adaptations take place during the weight loss process to (1) develop weight loss strategies aimed at maintaining RMR and eventually prevent weight regain after weight loss and (2) identify obese individuals who could experience greater decreases in RMR and consequently difficulties in losing weight during weight loss programs. This latter aspect is particularly important because the RMR represents up to 75% of total daily energy expenditure in sedentary obese individuals [24].

Thus, we conducted the present pilot study in older obese postmenopausal women with 2 main objectives. We first investigated short-term RMR adaptations after 5 weeks of weight loss. Afterward, we examined if these adaptations were attenuated or maintained after an additional 10 weeks of weight loss.

2. Materials and methods

2.1. Subjects

Twenty sedentary obese (baseline percentage body fat, 46.4% ± 5.0% [mean ± SD]) postmenopausal women aged between 50 and 75 years (61.8 ± 5.9 years) were studied. Women were included in the study if they had stopped menstruating for more than 1 year and had a waist circumference of at least 90 cm. Participants were sedentary (<2 times a week of structured exercise), nonsmokers, and low to moderate alcohol consumers (<2 drinks per day) and had no body weight fluctuations greater than 5 kg in the previous 6 months of the study. All participants were apparently healthy and had no history or evidence on physical examination of (1) cardiovascular disease, peripheral vascular disease, or stroke; (2) diabetes; (3) high blood pressure; (4) thyroid or pituitary disease; (5) hormonal replacement therapy for the previous 6 months; and (6) medication that could affect the metabolic profile. All participants signed an informed consent document. The Ethics Committees of the Social Services and Health Centre–University Institute of Geriatrics of Sherbrooke and of the University Hospital Centre of Sherbrooke approved the pilot study.

2.2. Weight stabilization

Subjects were submitted to a 4-week weight stabilization period (within 2 kg of body weight) before and after the weight loss protocol. The goal of this approach was to stabilize, before testing, the various metabolic variables of interest that could have been altered by body weight fluctuations (>2 kg) [25].

2.3. Weight loss protocol

The present pilot study contains 2 phases. First, all subjects received the same treatment for 5 weeks (target decrease of body weight = 1% per week). Afterward, during the second phase of the study, they were randomly assigned to 1 of the 2 weight loss interventions (15 weeks of constant weight loss vs three 5-week weight loss phases separated by two 5-week weight stabilization periods [within 2 kg of body weight]). Both interventions resulted in 15 weeks of active weight loss program and had similar effects on resting heart rate (RHR), RMR, FM, and LBM. Consequently, subjects in both interventions were pooled for the present study.

The medically supervised weight loss program contained 55%, 30%, and 15% of energy intake from carbohydrates, fats, and proteins, respectively [26]. Average total daily caloric intake (kilocalories per day) was determined using a 3-day dietary record (2 weekdays and 1 weekend day at the end of the weight stabilization periods before and after weight loss) [27]. The caloric restriction was determined using baseline total daily caloric intake of each participant.

During the weight loss program, subjects were invited to participate in a weekly educational class on nutrition, health, and lifestyle habits. They were asked not to participate in an exercise program and to maintain their baseline physical activity throughout the duration of the entire protocol. Subjects completed a simplified food diary and monitored their body weight (in the morning, in a fasting state, on the same balance for the entire protocol) on a daily basis during the weight loss program. Daily body weight was recorded on a log sheet and plotted on a graph at the weekly educational class to compare the actual body weight loss with the one anticipated. Subjects were contacted by the nutritionist for a quick adjustment of their caloric intakes when actual and anticipated body weight losses were not corresponding. Caloric restriction was then adjusted weekly (when necessary) to ensure the 1% reduction of initial body weight per week. Food was self-selected with dietician supervision on macronutrient selection, without the use of commercial fasting supplements; and patients were instructed to drink water to prevent dehydration and constipation.

2.4. Body composition

Body weight was measured to the nearest 0.2 kg on a calibrated balance (SECA707, Hamburg, Germany), and height was obtained with a standard stadiometer (Takei, Tokyo, Japan). Fat mass, percentage FM, and LBM were measured using dual-energy x-ray absorptiometry (DXA; GE Medicals Prodigy Lunar Radiation, Madison, WI), as previously described [28]. Coefficients of variation in our laboratory for repeated determinations of FM and LBM in 10 adults were 0.4% and 0.5%, respectively (measured 1 week apart).

2.5. Resting metabolic rate

The test was done in the morning after a 12-hour fasting period, as previously described [28]. Subjects were asked to take no alcohol or medications and to restrain from physical activity for 24 hours before testing. They were also instructed to keep physical activity to a minimum the morning of the test. Resting metabolic rate was measured on a 30-minute period by indirect calorimetry using a respiratory mask, which was placed and sealed on the participant's face to cover mouth and nose. Resting metabolic rate (in kilocalories per day) was calculated using the Weir equation [29]. Oxygen consumption and carbon dioxide production were measured using a CCM/D metabolic cart (Medical Graphics, St Paul, MN). The coefficient of variation in our laboratory for repeated determinations of RMR in 10 adults was 2.1% (measured 1 week apart). The RMR measurement was done at baseline and after 5 and 15 weeks of weight loss.

2.6. Resting heart rate

Resting heart rate was measured in sitting position after a 5-minute resting period with a Dinamap automatic device (Critikon, Johnson & Johnson, Tampa, FL) just before the measurement of RMR, as previously described [28].

2.7. Physical activity level

To ensure that participants remained sedentary throughout the duration of the weight loss protocol, physical activity level was assessed before, after 5 weeks, and at the end of the weight loss program using the Physical Activity Scale for the Elderly questionnaire [30]. Subjects reported leisure time, household, and work-related activities during the past week. Daily activities were first scored according to intensity and duration, and then added to produce a global physical activity level (possible range of scores between 0-793).

2.8. Statistical analyses

Because of the low number of subjects in each group and abnormal distribution of various variables, nonparametric analyses were performed. Descriptive data are presented in tables as means ± SD.

Subjects were characterized as having an *increased* or a *decreased* RMR after the first 5 weeks of the weight loss program as compared with baseline values. To maximize differences between groups, we excluded subjects who were considered as having a stable RMR after the first 5 weeks (variations in RMR between −5% and +5% from baseline values, n = 4). Consequently, 8 subjects per groups were used when comparing groups.

Wilcoxon signed rank tests were used to determine the overall group effect of the first 5 weeks of the weight loss program as well as the effects of weight loss in both groups between weeks 5 to 15 and postintervention. Mann-Whitney analyses were used to compare absolute values between groups after 5 to 15 weeks and postintervention. A level of significance of $P < .05$ was used. All statistical analyses were performed with the JUMP IN version 5.1.2 statistical software program (SAS Institute, Cary, NC).

3. Results

3.1. Effects of weight loss

Body weight, body mass index (BMI), percentage FM, FM, and trunk FM decreased significantly throughout the weight loss program (all *P*s < .05) (Table 1). However, total LBM, trunk LBM and RHR decreased only during the first 5 weeks, with values remaining stable afterward (all *P*s < .05). No change was observed for RMR and physical activity level between baseline and postintervention. Despite no overall change in RMR, important interindividual variations were however observed (Fig. 1). In fact, 16 women out of 20 significantly displayed either a decreased RMR (<5% from baseline value, ranging from −82 to −322 kcal/d, n = 8) or an increased RMR (>5% from baseline value, ranging from +96 to +330 kcal/d, n = 8) after the first 5 weeks of the weight loss program. The 4 others were considered as having a stable RMR (between ±5% from baseline value). Because of the important interindividual variations in RMR in response to weight loss after 5 weeks, we compared below the effects of weight loss in subjects having an increased RMR with those having a decreased RMR.

3.2. Effects of weight loss in subjects having an increased or a decreased RMR

First, total daily caloric intake was significantly reduced in the decreased-RMR group (−507 ± 469 kcal/d, $P < .05$), whereas the change was not statistically significant in the increased-RMR group (−331 ± 457 kcal/d, $P = .17$) (Fig. 2). The difference between groups was not significantly different ($P = .35$).

Table 1
Baseline characteristics and changes in variables of interest after 5 and 15 weeks of weight loss

Variables	Baseline	5 wk	15 wk	Post
n	20	20	16	
Age (y)	61.8 ± 5.9			
Body weight (kg)	78.8 ± 9.9	74.8 ± 9.1*	69.3 ± 8.8†	68.4 ±8.7‡
BMI (kg/m^2)	31.5 ± 3.3	29.8 ± 3.2*	27.7 ± 3.2†	27.2 ± 3.3‡
% FM	46.4 ± 5.0	44.9 ± 5.3*	40.9 ± 6.0†	40.0 ± 6.0‡
Total FM (kg)	35.7 ± 7.3	32.8 ± 7.0*	27.6 ± 7.0†	26.8 ± 6.8‡
Trunk FM (kg)	18.3 ± 4.0	16.4 ± 3.9*	13.1 ± 3.7†	12.7 ± 3.8
Total LBM (kg)	40.8 ± 4.5	39.7 ± 4.2*	39.3 ± 3.6	39.3 ± 3.8
Trunk LBM (kg)	19.7 ± 2.5	19.1 ± 2.4*	18.6 ± 2.0	18.8 ± 2.1
RMR (kcal/d)	1190 ± 191	1193 ± 179	1152 ± 210	1212 ± 189‡
RHR (beat/min)	70.2 ± 3.3	63.3 ± 4.9*	64.1 ± 4.5	62.5 ± 6.7
Physical activity level (0-793)	109.4 ± 59.2	116.8 ± 65.9	122.7 ± 46.4	123.0 ± 69.4

Data are presented as means ± SD. Percentage FM = [(FM/body weight) * 100]. The physical activity level was assessed with the Physical Activity Scale for the Elderly questionnaire. Wilcoxon signed rank tests were used to measure the effect of weight loss.

* Significant difference between baseline and the fifth week ($P < .05$).

† Significant difference between the fifth and 15th week ($P < .05$)

‡ Significant difference between the 15th week and the fourth week of weight stabilization postintervention ($P < .05$).

Subjects displaying an increased RMR after the fifth week had higher values for percentage FM and total FM before, during, and after weight loss (P values < .05) (Table 2). Overall, both groups significantly and similarly decreased body weight, BMI, percentage FM, total FM, and trunk FM during and after the weight loss program (P values between .05 and .01). Both groups experienced significant decreases in LBM and RHR only during the first 5 weeks, with values remaining stable afterward ($P < .05$). Finally, physical activity level was kept the same between baseline and postintervention, with no difference between groups.

Compared with the decreased-RMR group, subjects displaying an increased RMR had lower values at baseline (1092 ± 151 vs 1291 ± 221, $P < .05$) and higher values after 5 weeks of weight loss (1320 ± 179 vs 1071 ± 147, $P < .05$). These metabolic adaptations after the fifth week remained stable during the intervention (15th week) and after weight loss in both groups. Finally, no difference was observed between groups after weight loss.

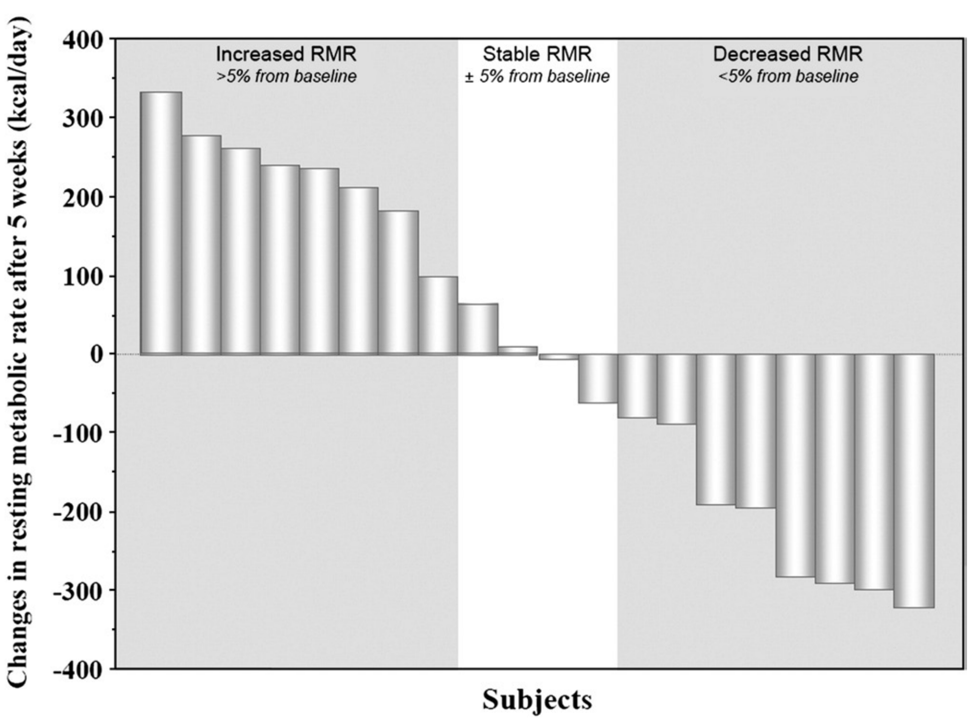

Fig. 1. Interindividual variations in RMR after 5 weeks for the 20 subjects who participated in the study.

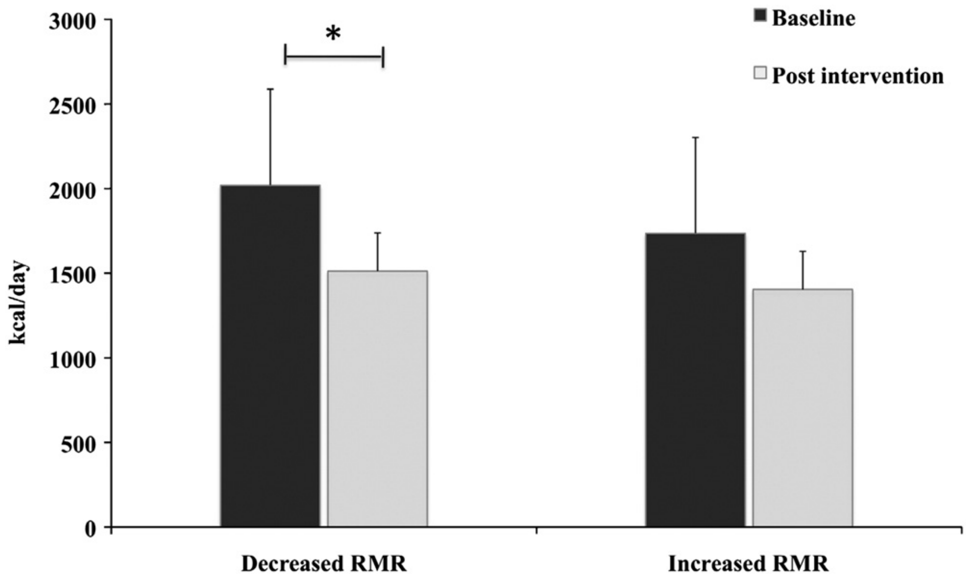

Fig. 2. Total daily caloric intake at baseline and after weight loss in both groups. *$P < .05$. Wilcoxon signed rank tests were used to quantify changes within each group.

3.3. Comparisons between the 15th week of weight loss and the fourth week of weight stabilization after intervention

A significant decrease in body weight was observed between the 15th week of weight loss (acute effect of weight loss) and the fourth week of weight stabilization period after intervention (chronic effect of weight loss) in both groups ($P < .05$). Despite these observations, both groups were considered as weight stable based on the criteria used for weight stabilization periods (within 2 kg body weight as indicated in "Materials and methods"). The decreased-RMR group displayed a significant decrease in percentage FM, total FM, and trunk FM during the weight stabilization period ($P < .05$). Finally, analyses also revealed that RMR remained stable in both groups during that period (decreased-RMR group: +76.5 ± 136.6 kcal/d, $P = .12$; increased-RMR group: +30.4 ± 130.8 kcal/d, $P = .11$), with no difference between groups.

Table 2
Changes in body composition and physiologic measures after 5 and 15 weeks of weight loss in subjects characterized as having an increased or a decreased RMR after the first 5 weeks

	Decreased RMR				Increased RMR			
	Baseline	5 wk	15 wk	Post	Baseline	5 wk	15 wk	Post
n	8	8	8		8	8	8	
Age (y)	63.9 ± 6.3				60.0 ± 5.1			
Body weight (kg)	74.9 ± 10.0	71.0 ± 8.9†	65.0 ± 7.7‡,*	64.0 ± 7.5§,*	81.4 ± 7.0	77.1 ± 6.7†	72.0 ± 5.8‡	71.0 ± 5.6§
BMI (kg/m^2)	30.2 ± 2.2	28.3 ± 2.0†	26.1 ± 1.5‡	25.7 ± 1.5§	32.5 ± 3.6	30.8 ± 3.4†	29.0 ± 3.1‡	28.1 ± 3.2§
% FM	43.2 ± 3.9*	41.8 ± 3.8†,*	36.6 ± 4.6‡,*	35.5 ± 4.1§,*	48.9 ± 5.6	47.8 ± 6.3†	44.2 ± 6.1‡	43.1 ± 6.5
Total FM (kg)	31.6 ± 6.3*	28.9 ± 5.8†,*	23.2 ± 5.1‡,*	22.1 ± 4.5§,*	38.9 ± 7.1	36.0 ± 7.1†	30.6 ± 6.7‡	29.9 ± 6.6
Trunk FM (kg)	16.0 ± 3.4	14.2 ± 3.2†,*	10.7 ± 3.0‡,*	10.2 ± 2.5§	19.7 ± 3.7	17.9 ± 3.9†	14.6 ± 3.3‡	14.0 ± 3.8
Total LBM (kg)	41.1 ± 4.4	39.8 ± 3.7†	39.6 ± 3.6	39.6 ± 3.8	40.1 ± 3.0	38.7 ± 3.2†	38.6 ± 2.1	38.7 ± 2.4
Trunk LBM (kg)	20.1 ± 2.5	19.3 ± 2.1†	19.0 ± 2.1	19.0 ± 2.2	19.4 ± 1.7	18.5 ± 2.0	18.3 ± 0.9	18.3 ± 1.0
RHR (beat/min)	71.6 ± 3.3	61.2 ± 6.2†	65.6 ± 5.0	65.2 ± 6.9	68.7 ± 3.1	65.4 ± 4.0†	63.0 ± 4.7	60.5 ± 7.3
RMR (kcal/d)	1291 ± 221*	1071 ± 147†,*	1075 ± 219	1152 ± 195	1092 ± 151	1320 ± 179†	1226 ± 219	1234 ± 207
Physical activity level (0-793)	107.4 ± 27.9	113.0 ± 43.4	133.5 ± 31.1	125.4 ± 41.0	95.9 ± 40.4	114.8 ± 73.0	107.8 ± 45.0	110.2 ± 84.5

Data are presented as means ± SD. The physical activity level was assessed with the Physical Activity Scale for the Elderly questionnaire. Mann-Whitney analyses were used to compare groups at baseline, 5 weeks, 15 weeks, and postintervention. Wilcoxon signed rank tests were used to measure the effect of weight loss (1) between baseline and the fifth week, (2) between the fifth and the 15th week, and 3) between the 15th week and the fourth week of weight stabilization postintervention.

* Significant difference between groups at baseline, 5 weeks, 15 weeks, and postintervention ($P < .05$).

† Significant difference between baseline and 5 weeks (within group, $P < .05$).

‡ Significant difference between 5 and 15 weeks (within group, $P < .01$).

§ Significant difference between the 15th week and the fourth week of weight stabilization postintervention ($P < .05$).

4. Discussion

In the present study, we found no significant decrease of RMR in the overall cohort after a weight loss intervention. This observation is in agreement with other studies [31,37-39]. Although this may suggest that all subjects maintained a stable RMR throughout the weight loss protocol, the large standard deviation (±179 kcal/d) led to the further examination of individual data and the finding that a number of subjects experienced a decrease in RMR, whereas others showed an increase in RMR. This result is in agreement with those of del Genio et al [31] who also reported no significant change in RMR after caloric restriction but a large standard deviation of ±382 kcal/d. Altogether, these data support large interindividual variability in the response of RMR to weight loss.

The scientific literature often reports decreases in RMR during and after weight loss [5]. Interestingly, our numerous measures of RMR during weight loss showed that changes in RMR after 5 weeks, regardless of the direction (increased or decreased), were maintained up to the 15th week of the weight loss intervention as well as after the weight stabilization period following weight loss. To our knowledge, no study yet has reported similar results. Differences in RMR adaptation between groups could be explained by different factors. First, studies reported that the decrease in LBM is an important and independent predictor of changes in RMR after weight loss [12,16]. However, controversies still exist regarding the relationship between LBM and RMR after caloric restriction [2-5]. It has been proposed that variations in RMR do not bear a linear relationship with LBM loss [17,18,20]. Based on our results, this hypothesis of the relationship between LBM and RMR must be ruled out because both groups displayed similar changes in LBM during weight loss despite opposite responses in RMR after weight loss. The second factor that may explain our results is the level of obesity. For example, women displaying an increased RMR were also fatter at baseline and during and after weight loss in comparison with the decreased-RMR group. These results seem to be in agreement with previous studies showing a positive relationship between RMR and FM [5,21,32]. Interestingly, studies also reported a positive association between trunk FM and SNS activity [32-34], which could contribute to an increased RMR. This hypothesis seems to be confirmed in the present study because we showed that women who displayed an increased RMR also had greater trunk FM accumulations (14.2 ± 3.2 vs 17.9 ± 3.9, $P < .01$) and lower decreases in RHR after 5 weeks of weight loss program (−3.3 ± 2.9 vs −10.4 ± 4.6, $P = .01$) compared with those who displayed a decreased RMR. This finding may suggest a modification in the SNS activity early in the weight loss process. Studies that investigated the relationship between SNS activity and caloric restriction reported a positive association between weight loss and changes in SNS activity [14,35]. Poirier et al [14] showed that declines in SNS activity after weight loss contributed to the decrease in RHR and RMR. This may explain, in part, the difference in RMR between groups in the present study. Clinically, our results suggest that women having lower FM accumulations (total and at the trunk level) and higher baseline RMR are at greater risk of experiencing greater decreases in RMR during weight loss, which could favor long-term weight regain and blunt the health improvements obtained with weight loss. Studies are however needed to investigate this hypothesis.

Another interesting result relates to the fact that both groups of subjects lost the same amount of fat tissue during the weight loss program. Based on RMR responses, we would normally expect to see differences in food intake to explain these results. Actually, total daily caloric intake was significantly reduced in the decreased-RMR group, whereas no significant change was observed in the increased-RMR group (with no difference between groups) (Fig. 2). In other words, the decreased-RMR group needed to eat about 1200 kcal/wk less than the increased-RMR group to compensate for the lower RMR and to lose the same amount of fat tissue after the weight loss program. Data regarding daily energy intake must be however considered with caution because obese individuals have a tendency to underestimate and underreport their caloric intake [36]. However, this potential bias is negligible because both groups were obese. Considering our results and the methodology used to achieve weight loss goal, values reported for daily energy intake in both groups seem realistic.

Some limitations of this study should be discussed. First, the number of subjects does not allow generalizing our results to the general population. Second, we used RHR as a proxy measure of SNS activity, as proposed by Poirier et al [14]. In addition, data at the fifth and 15th weeks were not obtained after a weight stabilization period. Consequently, these data represent the acute effects rather that the chronic effects of weight loss on RMR [25]. However, several features of our experimental approach enhance the value of our findings. First, the duration of the protocol and the limited number of subjects allowed us to closely and individually monitor them each week during the weight loss program. This approach eliminated the potential effect of important fluctuations in body weight on RMR, RHR, and LBM by the time of testing. This point is crucial because maintaining a constant rate of weight loss can be challenging or almost impossible in large-scale studies or during longer weight loss intervention. Second, all measures were done before, during, and after the study, which gave us the opportunity (1) to see what happened throughout the weight loss process and (2) to determine if changes observed soon after the beginning of the weight loss intervention were maintained after weight loss. Third, the rate of weight loss used (1% of initial body weight per week) allowed us to induce a relative weight loss stimulus equivalent for all subjects. Fourth, data at baseline and after weight loss were obtained after a weight stabilization period, thus eliminating the effects of important weight fluctuations on variables of interest. Fifth, after adjustment for FM due to difference between groups, baseline RMR was significantly correlated with changes in RMR at 5 weeks ($r = -0.67$, $P < .01$) and 15 weeks ($r = -0.54$, $P < .05$) (result not shown). Consequently, we can discard the hypothesis that variations observed in RMR are fortuitous. The latter result combined with the excellent coefficient of variation reported in our laboratory for RMR lends credibility to our findings. Finally, results observed are persistent throughout the duration of the study in both groups, which indicate that our results cannot be considered accidental because the observed effect is maintained over the course of the following 10 weeks.

In conclusion, the present pilot study showed large interindividual variations in RMR during and after the 15-week weight loss program in obese postmenopausal women. Baseline RMR, changes in RHR, and total and trunk FM accumulations seem to be important factors to consider when studying the effects of weight loss on RMR. Our results also showed that variations in RMR took place early in the weight loss process and were maintained at the end of the intervention. Further studies are needed to confirm our results.

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