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Effect of calorie restriction on energy expenditure in overweight and obese adult women

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Abstract

Energy expenditure (EE) may decrease in subjects on hypocaloric diets, in amounts that exceed body mass loss, favoring weight regain.

Objective: **to verify if a short-term caloric restriction lowers Resting Energy Expenditure (REE) and Total Energy Expenditure (TEE) more than predicted by changes in body composition, and if this reduction of EE is related with compliance to the diet.**

Methods: **twenty-two women aged 23-44 years with a body mass index (BMI) of 25-32 kg/m^2, underwent a three-month calorie restriction treatment (20 kcal / kg initial weight) and were encouraged to increase their physical activity. At the beginning and end of the intervention, body composition (DEXA), REE, Physical Activity Energy Expenditure (PAEE) and TEE were assessed, through a combination of indirect calorimetry and actigraphy. Participants, who lost more or equal than 5% of their initial weight were considered compliant with the diet.**

Results: **in the compliant group, REE decreased, when expressed in absolute numbers or when adjusted by fat free mass (FFM) [-164 ± 168 kcal/day (10,6%) and -4,3 ± 4,6 kcal/kg FFM (10,5%)]. This decline was significantly greater than that observed in the non-compliant group [-6,2 ± 1.42 Kcal/day (0.16%) and -0,5 ± 3,4/Kg FFM (0.96%)]. FFM did not change in any of the two groups. At baseline, there was a significant correlation between FFM and REE (r = 0, 56 p < 0,05), which was lost at the end of the intervention.**

Conclusions: **compliant women showed a significant reduction in both absolute and adjusted REE, which together with the loss of correlation between REE and FFM at the end of the intervention suggests a metabolic adaptation.**

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Key words: *Energy expenditure. Adaptive thermogenesis. Calorie restriction. Obesity.*

EFECTO DE LA RESTRICCIÓN CALÓRICA SOBRE EL GASTO ENERGÉTICO EN MUJERES ADULTAS CON SOBREPESO U OBESIDAD

Resumen

El gasto energético (GE) puede disminuir en sujetos sometidos a dietas hipocalóricas, en una magnitud que excede la reducción explicada por los cambios en la composición corporal; dificultando la mantención del peso perdido.

Objetivo: **verificar si el Gasto Energético en Reposo (GER) y Total (GET) experimentan una disminución mayor a lo atribuible a cambios en la composición corporal y dependen de la adherencia al tratamiento dietario.**

Metodología: **veintidós mujeres (23-44 años) con Índice de Masa Corporal (IMC) entre 25 y 32 kg/m^2 fueron sometidas a tres meses de restricción calórica (20 kcal/kg de peso inicial) y motivadas a aumentar su actividad física. Al inicio y al final se evaluó: peso, masa grasa (MG) y masa libre de grasa (MLG) con DEXA, GER (calorimetría indirecta), Gasto Energético por Actividad Física (GEAF) y GET (actigrafía). Las participantes que perdieron ≥ 5% del peso inicial fueron consideradas como adherentes a la dieta.**

Resultados: **el grupo adherente tuvo una disminución significativa del GER absoluto [-164 ± 168 kcal/día (10,6%) y -4,3 ± 4,6 kcal/kg MLG (10,5%)]. Esta disminución fue significativamente mayor que la observada en el grupo no adherente [-6,2 ± 1.42 kcal/día (0.16%) y -0,5 ± 3,4/kg FFM (0.96%)]. La MLG no cambió en ninguno de los dos grupos. Existió asociación significativa entre MLG y GER (r = 0,56; p < 0,05) solo al inicio en el grupo total.**

Conclusiones: **las mujeres adherentes a la restricción calórica mostraron una reducción en el GER tanto absoluto como ajustado por la MLG, lo cual, junto con la pérdida de correlación entre el GER y la MLG al final de la intervención, sugieren adaptación metabólica.**

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Palabras clave: *Gasto energético. Termogénesis adaptativa. Restricción calórica. Obesidad.*

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Abbreviations

EE: Energy Expenditure.
REE: Resting Energy Expenditure.
TEE: Total Energy Expenditure.
PAEE: Physical Activity Energy Expenditure by.
BMI: Body Mass Index.
FM: Fat Mass.
FFM: Fat Free Mass.
CR: Calorie restriction.
TSH: thyroid stimulating hormone.
EV: Expiratory Volume.
VO2: Oxigen Volume.
VCO2: carbon dioxide volume.
DLW: Double labeled water method.

Introduction

Caloric restriction (CR) is one of the most commonly used interventions for the management of overweight and obesity. It seems to be ineffective in the long term because individuals experience stabilization and recovery of weight, which appears to derive mainly from a metabolic adaptation or adaptive thermogenesis, which involves a decrease in Resting or other components of Energy Expenditure. These adaptations appear to be independent of the reduction in fat and fat free mass, and could represent an adaptive defense mechanism to protect depots from energy depletion[1,2,3].

The mentioned metabolic adaptations have been demonstrated by comparison of measured versus predicted resting energy expenditure (REE) or total energy expenditure (TEE), using formulas derived from linear regressions that consider REE, fat free mass (FFM) or initial fat mass (FM)[1,4-7]. FFM is the metabolically active mass and it is the main determinant of REE. It explains between 60 to 80% of its variability, while FM only contributes between 5 to 7%[4]. Other studies have used the REE /FFM ratio considering a decrease of this value as a possible indicator of metabolic adaptation[8-10].

Studies in lean and obese subjects undergoing weight loss through caloric restriction have observed metabolic adaptations either through a fall of REE or 24 hours EE. Astrup A et al, comparing a group of former obese subjects with non-obese individuals who underwent a program of calorie restriction found a 4.1% decrease in adjusted REE among the former not observing changes in the non-obese group[11]. Menozzi R et al observed a decrease of 6.5% in REE in obese women, after 1 month of severe caloric restriction (700 calories), considering FFM as the factor that explained 80% of its variability[12]. Johannsen D et al, employed a plan of calorie restriction and vigorous exercise in morbidly obese subjects, observing a decline of 6% of REE adjusted by FFM in the first 6 weeks of the intervention and 22% at week 30, when the study finished[10]. Camps S et al, in moderately obese subjects following a very low calorie diet, found a decrease of 4% in REE adjusted by FFM and FM in both the restriction and the maintenance of weight phases[13]. After 2 years of caloric restriction in normal weight subjects, Weyer et al observed a 6% decrease in 24 hours-TEE adjusted by the change in FFM and FM[5]. Similar findings were found in a longer study (6 months) in overweight subjects subjected to 25% calorie restriction with or without exercise ,showing that despite the prescription of exercise the 24 TEE decreased more than expected by changes in body composition[6]. Goele K, et al, reported a similar decline in REE adjusted by FFM (5.6%) only among women who were adherent to a 14-week intervention diet of 1000 calories/day[9].

Thus, according to the mentioned evidence, most of the studies have showed that after weight reduction induced by calorie restriction, there is a metabolic adaptation detected mainly by the decrease in REE, but there are few reports associating this decrease in REE with adherence to the intervention. Our aim was to verify whether a significant metabolic adaptation occurs in overweight or obese premenopausal women after a short-term caloric restriction (3 months), depending on compliance to the treatment. We expected to find a decrease in both REE and TEE higher than that expected by changes in body composition.

Subjects and methods

Subjects: Twenty two premenopausal women aged between 25 and 45 years with a body mass index (BMI) between 25 and 32 kg/m^2 and interested in losing weight, were initially screened at Centro de Diagnóstico of INTA (CEDINTA). Exclusion criteria were: diabetes mellitus, hypothyroidism, history of cancer, liver or kidney failure, pregnancy, use of medications that could alter the measurements, such as beta-blockers, anticonvulsants and psychotropics and a weight variation in the last months of more than 2 kg. Twenty five started the study but three women dropped out for personal reasons, so 22 completed the study. The study protocol was approved by the Ethics Committee of INTA. Each participant signed the informed consent before beginning the study. The study is registered at clinicaltrials.gov number NCT01508091.

Intervention and follow-up: The intervention consisted in the prescription of a low calorie Mediterranean type Diet (MD) (20 Kcal/Kg baseline body weight), with 5 daily meals during 3 months. Distribution of macronutrients was 50% carbohydrates, 25-30% lipids and 20 to 25% protein. The research team, to enhance compliance, provided one of these meals, to be ingested 1 to 3 times a week. It consisted in adequate portions of dried fruits (175 Kcals/serving of 30 grams), cereal bars (69 Kcals/serving of 20 grams) or whole grain cookies (153 Kcals/serving of 3 cookies). Patients were followed weekly by the research dietician or physician, recording weight and compliance

Table I
Characteristics of the study population at baseline (n=22)

	Variables	*Mean*, SD, range*
Anthropometric	Age (years)	32,2 ± 6,3 (23 - 44)
	Height (cm)	160,7 ± 6,3 (146 - 173)
	Weight (kg)	74,4 ± 7,9 (56 - 91,7)
	BMI (Kg/m^2)	28,1 ± 2,1 (24,4 - 31,7)
	Waist circumference (cm)	94,6 ± 6,9 (81 - 100)
Body composition	Fat Free Mass (Kg)	38,9 ± 4,2 (28,2 - 48,4)
	Fat Free Mass (%)	53,5 ± 3,1 (47,9 - 60,5)
	Apendicular FFM (kg)	17,5 ± 2, 3 (12,3 - 22,0)
	ApFFMI (FFMap/Height m^2)	6,8 ± 0,7 (5,8 - 8,2)
	Fat Mass (Kg)	31,6 ± 4,4 (23,9 - 39,1)
	Fat Mass (%)	43,4 ± 3,1 (36,1 - 48,4)
Metabolic	Matsuda Index	8,3 ± 4,7 (2,3 - 19,9)
	Triglycerides (mg/dL)**	94,5 (77-139)
	TSH (μU/mL)	2,3 ± 0,8 (0,65 - 4,05)
	Total T3 (ng/ml)	1,5 ± 0,4 (0,97 - 2,36)
	Free T3 (pg/mL)	3,3 ± 0,6 (2,2 - 4,9)
Energy expenditure	REE(Kcal/day)	1478 ± 130 (1524 -1793)
	REE/Kg	20,0 ± 1,9 (17,0 - 24,8)
	REE/ Kg FFM	38,3 ± 3,8 (32,9 - 49,2)
	PAEE (Kcal/day)	681 ± 275,1 (242 - 1174)
	TEE (Kcal/day)	2418 ± 327 (1892 - 2960)
	TEE/Kg	32,7 ± 4,7(24,7 - 42,7)
	TEE/Kg FFM	62,8 ± 10,5 (49,3 - 84,7)
	PAL (TEE/REE)	1,6 ± 0,2 (1,3 - 2,0)

*Mean, SD: Standar Deviation, **Median (interquartile range).BMI: Body Mass Index, REE; Resting Energy Expenditure, PAEE: Physical Activity Energy Expenditure, TEE: Total Energy Expenditure, ApFFMI: Apendicular FFM Index (Arms FFM+ Legs FFM/ Height m^2)

with dietary recommendations, encouraging healthy lifestyles and an increase in physical activity.

Compliance was arbitrary defined according to changes in body weight, considering compliant those participants who achieved a reduction of ≥ 5% of their initial weight and non-compliant those who did not achieve this goal. Dietary recalls were not performed due to lack of precision and under-reporting[14,15].

Measurements:

Anthropometry and body composition: Each participant underwent anthropometric measurements (height, weight, waist circumference and BMI) and body composition measurements (total, bone, fat, lean body mass and appendicular lean body mass) using a Lunar Encore double beam densitometer (DEXA), at the start and the end of the dietetic intervention.

Metabolic parameters: At baseline and after the 3-month intervention, fasting blood samples were withdrawn for the measurement of glucose, insulin, thyroid hormones, and lipoproteins and an oral glucose tolerance test (OGTT), measuring glucose and insulin levels 60, 90 and 120 min following a 75 g glucose challenge. Insulin resistance was evaluated by calculating the Matsuda-DeFronzo index[16].

Energy expenditure: REE was measured using an indirect calorimeter (Sensor Medics Vmax Encore 29) after fasting for 8-11 hours in the supine position, in thermoneutral conditions, using a transparent canopy. For about 20 minutes, the oxygen consumption and CO_2 production was measured, obtaining REE after the calorimeter showed steady state, defined as a period of 5 consecutive intervals during which the change in the volume of oxygen (VO2) and Expiratory Volume (EV) was 10% or less and the variation of the Respiratory quotient (RQ) was 5% or less.

Table II
Change in characteristics of the study population after 3 months of calorie restriction (n=22)

	Variables	*Δ (End-Baseline)**	*p value*
Anthropometrics	Weight (Kg)	-3,9 ±3,18 (-12,6 - 1,7)	**0,000†**
	Weight change (%)	-5,3 ± 4,3 (-15,83 - 2,4)	**0,001†**
	Waist circumference (cm)	-4,9 ± 3,2 (-11 - 0)	**0,000†**
Body composition	Fat Free Mass (Kg)	0,3 ± 0,8 (-1,7 - 1,7)	0,13
	Fat Free Mass (%)	2,5 ± 1,9	0,000†
	Apendicular (FFM) (Kg)	0,2 ± 1,07	0,40
	ApFFMI (FFMap/Height m^2)	0,08 ± 0,4	0,38
	Fat Mass (Kg)	-2,7± 2,4 (-8,8 - 0,6)	**0,00†**
	Fat Mass (%)	-2,3± 1,9	**0,000†**
Metabolic	Matsuda Index	0,7± 7,7 (-16 - 24)	0,59
	Triglycerides (mg/dL)**	-18,5 (-11- 40)	**0,02††**
	TSH (μU/mL)	-0,1 ± 1,2 (-3,2 - 3,4)	0,69
	Total T3 (ng/ml)	-0,2 ± 0,3 (-0,9 - 0,3)	**0,01†**
	Free T3 (pg/mL)	-0,1± 0 ,6 (-1,05 - 1,0)	0,30
Energy expenditure	REE(Kcal/day)	-92 ± 173 (-543 - 191)	**0,02†**
	REE/Kg	-0,2 ±2,3 (-6,3 - 3,2)	0,69
	REE/ Kg FFM	-2,6± 4,5 (-13,6 - 4,9)	**0,013†**
	PAEE (Kcal/day)	283± 434 (-362 - 1264)	**0,006†**
	TEE (Kcal/day)	178 ± 430 (-460 - 1037)	0,06
	TEE/Kg	4,4± 5,7(-5,4 -18,0)	**0,0017†**
	TEE/Kg FFM	3,9± 11,2 (-15,4 - 26,9)	0,11
	PAL (TEE/REE)	0,3± 0,4 (-0,3 - 1,3)	**0,004†**

*All values are presented as mean±SD, (min-max).
**Median and interquartile range
† Difference between baseline and after treatment: p<0,05 (Paired two samples Student's t-test) †† Wilcoxon test
REE: Resting Energy Expenditure, PAEE: Physical Activity Energy Expenditure, TEE: Total Energy Expenditure, ApFFMI: Apendicular FFM Index (Arms FFM+ Legs FFM/ Height m^2)

Physical Activity Energy Expenditure (PAEE) was determined through the use of an Actiheart® accelerometer. The individual calibration of the device was carried out after performing an exercise calorimetry using a cycle ergometer to create an individual energy expenditure-heart rate (HR) curve[17]. The device is placed in the subject's chest according to manufacturer's instruction. HR, heartbeat interval and the frequency and intensity of horizontal, vertical and oblique movements, by means of an internal accelerometer. Recording was carried out every 60 seconds for a period of 3 days during weekdays and weekends. TEE was calculated through Actiheart® software data. The physical activity level (PAL) was calculated as the TEE/REE ratio. PAL between 1.4 and 1.69 is considered sedentary activity, a PAL between 1.77 to 1.99 moderate activity and PAL between 2.0 to 2.4 vigorous activity[18].

Statistical analysis: Data are expressed as mean ± standard deviation (SD) or median and interquartile range for variables with normal distribution or not normally distributed, respectively. Normality was assessed using Shapiro-Wilk test. The association between REE or TEE with FM, FFM and T3 was evaluated though Pearson correlation coefficients. Paired two samples Student's t-test was used to analyze the changes in variables with normal distribution and Wilcoxon test otherwise. Analyses were performed using the statistical program STATA 12 (Data Analysis and Statistical Software).

Results

Anthropometric, body composition, metabolic and EE characteristics at baseline are shown in table I. The

Table III
Change of anthropometric and body composition characteristics after 3 months of calorie restriction by compliance

	Variables	Compliant (n=12)		Non-compliant (n=10)	
		Δ End- Baseline*	p value	Δ End-Baseline*	p value
Anthropometric	Weight (Kg)	-6,1± 2,3 (-12,6 - -3,8)	**0,000†¶**	-1,3 ± 1,5 (-3,5 - 1,7)	**0,003†**
	Weight change(%)	-8,3± 3,1 (5,1 - 15,8)	**0,000†¶**	-1,6 ± 2,1 (-2,4 - 4,3)	**0,000†**
	Waist circumference (cm)	-6,7 ± 3,0 (-11 - -2)	**0,000†¶**	-2,9± 1,9 (-7 - 0)	**0,001†**
Body composition	Fat Free Mass (Kg)	0,1±0,8 (-1,7 - 1,2)	0,61	0,4± 0,7 (-0,5 - 1,7)	0,08
	Fat Free Mass (%)	3,8± 1,5 (1,6 - 6,2)	0,000†¶	0,9 ± 0,7 (-0,5 - 2,1)	0,004†
	Apendicular FFM (Kg)	-0,2 ± 0,5 (-1,2 - 0,5)	0,23	-0,2± 1,5 (-4,5 - 0,8)	0,67
	Ap FFMI (FFMap/Height m^2)	-0,8 ± 1,9 (-4,4 - 1,6)	0,19	-0,9 ± 6,2 (-1,8 - 3,1)	0,66
	Fat mass (Kg)	-4,4 ± 2,0 (-8,8 - -0,4)	**0,000†¶**	-0,7± 0,7 (-1,5 - 0,6)	**0,007†**
	Fat mass (%)	-3,6±1,6 (-6,0 - -0,13)	**0,000†¶**	-0,8±0,8 (-2,0 - 0,6)	**0,014†**

* All values are presented as mean ± SD, (min - max).
**Median and interquartile range
† Difference between baseline and after treatment: p<0,05 (Paired two samples Student's t-test)
†† Wilcoxon test.
¶: difference between baseline and after treatment means between groups (unpaired *t* test)

effect of 3 months of caloric restriction on the total group is shown in table II. Weight decreased by 5.3 ± 4.3% (p<0.05), with a fat loss of 2.3 ± 1.9% (p<0.05), without changes in FFM and appendicular FFM. There was a significant reduction in waist circumference, triglyceride and total triiodothyronine levels (p<0.05). REE and REE/kg FFM significantly decreased from baseline (5,6% and 6,2% respectively, p<0,05). At baseline, there was a significant correlation between FFM and REE (r = 0,56 p<0,05), which was not present at the end of the intervention (r= 0.30, p>0,05).

Twelve participants were considered compliant with dietary restriction (54%), as defined in material and methods. The effect of 3 months of caloric restriction according to the compliance to the treatment is shown in tables III and IV. Weight and fat loss were significant in both groups; the compliant group achieved a weight loss of 8.3% and a fat loss of 3.6 ± 1.6%. FFM did not change in any of the groups. Absolute and REE/Kg FFM significant decreased only in the compliant group by -164 ± 168 kcal/day (10.6%), and -4.3 ± 4.6 kcal/kg FFM (10.5%), respectively p<0.05. PAEE significantly increased only in the non-compliant group, whereas TEE and PAL increased significantly only in this group (p<0.05). When adjusting TEE/kg of body weight a significant increase was observed in both groups (p<0.05). A positive association between REE and FFM was observed only at baseline in the compliant group (r = 0.65, p<0.05).

Discussion

The significant decrease in weight, FM and both absolute (10.6%) and adjusted by FFM REE (10.5%) shown in women who complied with a low calorie Mediterranean Diet type for 3 months, are even higher than those reported by Goele K et al, whose intervention was similar in population and duration to ours[9]. With a diet of 1000 calories women who were compliant, showed significant decrease in absolute REE and REE/Kg FFM by 5.7% but those patients did not

Table IV
Change in metabolic and energy expenditure characteristics after 3 months of calorie restriction by compliance

	Variables	Compliant (n=12)		Non-compliant (n=10)	
		Δ End- Baseline*	p value	Δ End-Baseline*	p value
Metabolic	Matsuda Index	1,1±10,2 (-16 - 24,6)	0,639	0,2±3,2 (-2,9 - 8,5)	0,833
	Triglycerides (mg/dL)**	-17,5 (-42,5- 5,5)	0,136	-20 (-37-11)	0,092
	TSH μU/mL	-0,4±1,1 (-3,2 a 0,8)	0,272	0,2±1,3 (-1,5 a 3,4)	0,616
	Total T3 (ng/ml)	-0,2± 0,3 (-0,9 a 0,3)	0,06	-0,1±0,2 (-0,5 a 0,3)	0,09
	Free T3 (pg/mL)	-0,2 ±0 ,6(-1,1 a1,0)	0,3606	-0,09 ± 0 ,6 (-1,0 a 0,9	0,6385
Energy expenditure	REE (Kcal/day)	-164 ±168 (-543 a 45)	**0,006†¶**	-6,2± 142 (-219 a 191)	0,893
	REE/ Kg	-0,6 ± 2,7 (-6,3 a 3,2)	0,45	0,3± 1,8 (-2,3 a 3,1)	0,62
	REE /Kg Fat Free Mass	-4,3± 4,6 (-13,6 a 0,9)	**0,008¶**	-0,5 ± 3,4 (-5,5 a 4,9)	0,67
	PAEE (Kcal/day)	230 ±489(-362 a1264)	0,13	346,5 ±374 (-362 a 907)	**0,01†**
	TEE (Kcal/day)	68± 415 (-460 a 800)	0,58	309 ±431 (-460 a 1037)	**0,04†**
	TEE/kg	3,9 ± 5,3 (-4,0 a 13,1)	**0,02†¶**	5,0 ± 6,4 (-5,4 a 18,0)	**0,03†**
	TEE/Kg FFM	1,0 ±10,2(-14,2a 17,3)	0,74	7,4± 11,8 (-15,5 a 26,9)	0,07
	PAL (TEE/REE)	0,3± 0,4 (-0,3 a 1,3)	0,06	0,3±0,3 (-0,3 a 0,7)	**0,02†**

* All values are presented as mean ± SD, (min - max).
**Median and interquartile range.
† Difference between baseline and after treatment: p<0,05 (Paired two samples Student´s t-test)†† Wilcoxon test.
¶: difference between baseline and after treatment means between groups (unpaired *t* test).
REE: Resting Energy Expenditure, PAEE: Physical Activity Energy Expenditure, TEE: Total Energy Expenditure.

preserve FFM as in the present study[9]. Another longer term study (6 months) in obese population undergoing a low calorie diet without exercise, showed a loss of FFM and a significant decrease in REE (3%) after adjusting for FFM and FM[19]. In our study we also observed a fall in total triiodothyronine, which is one of the factors involved in the metabolic adaptation to caloric restriction. Similar findings have been reported by several studies[5,6,10,20].

Comparably to the present study, Johansenn D et al found a decrease of adjusted REE in morbidly obese population, employing a 30% caloric restriction accompanied by a plan of vigorous exercise for 7 months. After the initial 6 weeks, FFM was preserved and REE/FFM decreased only 6%. At the end of the study (30 weeks) there was a loss of FFM and the decrease of REE/Kg FFM reached 20%[10]. Lazzer S et al, in their study with a moderate caloric restriction accompanied by aerobic and anaerobic exercise for 9 months in obese adolescents who did not lose FFM, also showed a decrease of 6% in REE adjusted by changes in FFM[21].

The preservation of FFM observed in our study could be due to increased physical activity (significant in non-compliant group). Studies have shown that weight reduction interventions accompanied by moderate and intense physical activity can contribute to the preservation of FFM especially strength endurance exercise or the combination of aerobic exercise plus strength exercise. In fact, it seems that the resistance exercise has better results than aerobic in overweight and obese people, given the physical constraints and that these patients have poor compliance to protocols of aerobic exercise and better compliance to resistance exercise[22].

Another factor that can contribute to the preservation of FFM is related with the macronutrient content of the diets, specifically with the protein content. We prescribed a high protein content [20 to 25% of Total Caloric Value (TCV) or 1.0 to 1.3 g/kg of initial weight]. Dietary protein is necessary to synthetize skeletal muscle and an increased intake may enhance nitrogen retention and muscle hypertrophy[22]. Recent studies have shown that caloric restriction with high protein intake aid in FFM maintenance. Soenen S et al, in overweight and obese men and women determined the effect of the protein content in the preservation of FFM, comparing two hypocaloric diets with different protein content (0,8 g/kg vs. 1,2 g/kg) by 6 months. Both diets showed a FFM-sparing effect, which was initially stronger in the diet with higher protein content[23]. In contrast, there are interventions combining very low calorie and low protein diets with resistance exercise that has shown loss in FFM[22].

One possible explanation of the preservation of FFM is because the metabolic profile of the macronutrients. The hormonal responses associated with high-carbohydrate, low protein diets may induce physiological events favoring FFM catabolism. A high intake of carbohydrates produces a rise in insulin which promotes the uptake of glucose and triacylglycerol in the liver and adipose tissue, reduces glycogenolisis and lipolysis and suppresses the post-absorptive appearance of glucose and fatty acid. This produces the release of counterregulatory hormones inducing catabolism of lean mass. With the intake of a high protein diet, there is a less insulin release, which together with a delayed postprandial rate of disposal for amino acids appear to stabilize the glycemic environment and may conserve lean tissue. Also, amino acids as leucine and the branched-chain amino acids have a role in muscle protein synthesis[22]. Other studies report that high protein diets allow greater weight loss, provide greater satiety, produce more food thermogenesis, especially if the protein is of high biological value and help to preserve FFM[24].

Nevertheless a recent study shows that with a high carbohydrates-low fat, high protein diet, it is also possible to preserve muscle mass and produce anabolism. Bonfanti N et al, compared the effect of two hypocaloric diets (restriction of 40% of calories compared to the usual intake): Mediterranean diet (50% carbohydrates, 30% fat, 20-22% protein) and high carbohydrate-low fat diet (55-58% CHOS, 20% fat, 20-22% protein), with or without exercise, on GER and body composition. Thirty-six subjects obese, over 50 years of both sexes, were randomized to one of four intervention groups: low-calorie Mediterranean type diet, low-calorie, high carbohydrate-low fat diet, low-calorie mediterranean diet with exercise and low calorie, high carbohydrate-low-fat diet[25].

The main results of this study were: weight loss decreased significantly in all groups being higher in the groups that included exercise. Among these groups, the group hypocaloric, high carbohydrate-low fat diet had the largest decrease. Related to body composition, fat mass also decreased in all groups and it was higher in the groups that included exercise. Within these, also the hypocaloric, high carbohydrate-low fat diet had the largest decrease. Muscle mass had a significantly greater decrease in both Mediterranean diet groups. It also was greater in the exercise group compared with both groups of hypocaloric, high-carbohydrate, low fat diet[25].

The researchers attribute this result to the lower content of carbohydrates in Mediterranean diet. They say that carbohydrates are essential because it stimulates insulin secretion. Insulin is the main anaerobic hormone, essential for the recovery of muscle glycogen used in the exercise or for muscle protein synthesis[25].

Regarding GER, there was a significantly greater decrease in the exercise groups than without exercise ones. Additionally, the decrease was greater in the Mediterranean diet exercise group than in the hypocaloric, high-carbohydrate, low fat diet exercise group. It can be related with the loss of muscle mass[25].

So, the authors of this study suggest that the intervention with a hypocaloric, high carbohydrate, low fat and high protein diet mixed with a regular exercise program might be the best option because it produced greater weight loss, had less decrease of REE and FFM. However, the authors highlight the benefits of the Mediterranean diet on factors risk of metabolic syndrome. Nevertheless, this study has a small sample size does not allow to extrapolate the results[25].

Therefore, it seems to be relevant take into account not only the caloric restriction but also, the macronutrient distribution within a restricted diet in order to prevent loss of FFM.

Previous studies showing metabolic adaptation found correlations coefficients of REE or TEE with FFM ranging from $r = 0.77$ to 0.86[5-7,10]. In our study, the correlation between REE and FFM at baseline was significant but low ($r = 0.56$, $p<0.05$), which did not allow preforming a prediction of REE from FFM. However, Johansenn D et al and Goele K et al studies have shown that the decrease in REE/Kg FFM similar to the observed in our study is suggestive of metabolic adaptation[9,10]. In addition, the fact that the association between REE and FFM is lost at the end of study, may suggest the presence of metabolic adaptation because REE decreased despite the preservation of FFM.

The method used to assess body composition (DEXA) could also have influenced the lack of correlation between REE and FFM at the end of the study. DEXA, can lead to errors due to assuming a constant density of minerals, protein and water of FFM. Because of FFM measurement by DEXA is dependent on the state of hydration of the tissue, changes in body water could lead to inaccurate measurements[26,27]. However, fluctuations in body fluids occur only in the early stages of weight reduction[27]. In the case of our study, it is unlikely that after three months, there were still fluid fluctuations interfering with body composition assessment.

Unlike the reports by Weyer et al and Heilbronn L et al of a decreased TEE adjusted by FFM and FM after caloric restriction, we found as significant increase in this parameter in the compliant group[5,6]. This unexpected finding was probably due to an increase in physical activity according to actigraphy. The discrepancy may be due to methodological differences to assess TEE. The mentioned studies used a whole respiratory chamber where subjects are free to move within the place, eat and perform sedentary type activities, but cannot exercise as free living subjects. Measurements are made in a single day, which is not precise to assess the actual individual TEE[28]. The gold standard for measuring TEE is the doubly labeled water (DWL), allowing assess energy expenditure for several days without interfering with normal life. Its main limitation is its high cost. In the present study we determined TEE through Actiheart® accelerometers. Although they are not as accurate as DLW, there are reports of an acceptable level of agreement in children and adults[29-32].

The main strength of this study was that moderate caloric restriction with adequate nutrient balance and good acceptability had a significant level of adherence (54%), which is difficult to achieve especially in overweight and obese population[33]. Several reasons contribute to the loss of adherence to weight loss programs among which are the lack of motivation, accompanyng, and the pursuit of short-term results. Therefore, the medical team must use different strategies to achieve the objectives as implementing physical activity, educate about healthy eating habits or teach about weight self-monitoring[34].

Another strength is that through motivation in weekly follow-up appointments, it was possible for participants to increase their level of physical activity. This fact, together with the prescription of a high protein diet probably allowed to avoid the loss of FFM, one of undesired effects of weight loss induced by calorie restriction. Further studies should be carried out to study whether these metabolic changes are persist over time while the subject maintain weight.

These results should be seen in light of the limitations of the study, such as small sample size and the low correlation between baseline REE and FFM which did not allow to predict REE using changes in body composition, which is the most recommended way to evaluate the metabolic adaptation. Also, the study did not have a weight maintenance phase, therefore could not assess whether the energy expenditure remains low over time.

Conclusions

The findings of this study showed that women compliant with a short-term calorie diet had a significant reduction in both absolute and adjusted REE, which along with the loss of correlation between REE and FFM at the end of the intervention suggests a metabolic adaptation. However, we emphasize that although REE decreased, increased physical activity and a high protein content diet, could have contributed to preserve FFM, avoiding the decrease in TEE.

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