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Effect of diet and physical exercise on weight, body composition, and resting metabolic rate in obese chilean adults

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ABSTRACT

Background*: Diet and exercise are the mainstay of weight reduction programs.* ***Aim****: To evaluate the effect of diet and exercise on body weight and composition and resting metabolic rate (RMR) in obese adults.* ***Material and Methods****: Twenty-eight obese adults aged 22 to 61 years (18 women) completed four months of diet and exercise. They attended monthly nutritional consultations, and two-three weekly exercise sessions. At baseline and the end of the intervention, anthropometry, body composition by bioimpedance and RMR by indirect calorimetry (IC) were measured. Metabolic adaptation, defined as a decrease in thermogenesis to an extent greater than predicted based on the change in body weight and composition, was calculated.* ***Results:*** *Significant reductions in body weight and fat mass were observed in both genders. Fat-free mass decreased in women and remained unchanged in men. RMR remained stable. Metabolic adaptation was observed in 11/27 participants. Fat mass change in participants with and without metabolic adaptation was 8 Kg and 4,4 kg, respectively (p = 0,018). In the linear regression analysis, male sex accounted for a higher RMR (247.80 Kcal, p = 0,006) than females. For each kg of fat and fat free mass, the RMR varies 7.25 Kcal, (p = 0.02) and 9.79 Kcal (p = 0,006), respectively.* ***Conclusions****: The intervention reduced body weight and fat mass and maintained RMR. Fat free mass decreased in women. Participants with metabolic adaptation showed greater changes in fat mass.*

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*(****Key words:*** *Basal Metabolism; Body Composition; Calorimetry, Indirect; Thermogenesis; Weight Loss)*

Efecto de la dieta y ejercicio sobre el peso, composición corporal y gasto calórico en reposo de obesos adultos chilenos

Antecedentes: *Para el tratamiento de la obesidad, la dieta y ejercicio físico (EF) contribuyen a reducir el peso corporal (PC), masa grasa (MG) y a mantener la masa libre de grasa (MLG) y tasa metabólica en reposo (TMR).* ***Objetivo****: Evaluar el efecto de la dieta y EF sobre el PC, composición corporal (CC), TMR y la presencia de adaptación metabólica.* ***Material y Métodos****: Veintiocho adultos obesos completaron cuatro meses de dieta y EF. Los adultos asistieron a consulta nutricional mensual y a 2-3 sesiones de EF semanal. En el período basal y después de la intervención se midió antropometría, CC por* *bioimpedanciometria y TMR por calorimetría indirecta. Se calculo la presencia de adaptación metabólica, definida como una disminución de la termogénesis mayor que la predicha por el cambio en peso y composición corporal.* ***Resultados:*** *Se observó una disminución significativa de PC y MG en hombres y mujeres. La MLG disminuyó en las mujeres y se mantuvo en los hombres. La TMR se mantuvo estable. Se observó adaptación metabólica en 11/27 participantes y una relación significativa con el cambio en MG (p = 0,018). En la regresión lineal, el sexo masculino da cuenta de una mayor TMR (247,80 Kcal, p = 0,006) que el sexo femenino. Por cada kg de MG y MLG la TMR varía 7,25 Kcal, (p = 0,02) y 9,79 Kcal, (p = 0,006) respectivamente.* ***Conclusiones****: La intervención redujo el PC y la MG, y mantuvo TMR. La MLG disminuyó en las mujeres. Los sujetos con adaptación metabólica mostraron mayores cambios de MG.*

Palabras clave: *Calorimetría Indirecta; Composición Corporal; Metabolismo Basal; Pérdida de Peso; Termogénesis; Composición Corporal.*

Obesity is a prevalent public health problem in 34.4% of the population over 15 years of age in Chile[1], and with an increasing trend worldwide[2]. This increases the risk of non-communicable chronic diseases, such as type 2 diabetes, atherosclerosis, arterial hypertension, non-alcoholic fatty liver, and different types of cancer, among others[3-5]. Therefore, the prevention and treatment of obesity are essential to reduce the incidence of these associated pathologies[6,7].

Among the multiple causes, an unhealthy diet, sedentary lifestyle, and physical inactivity would be correlated with the increase in incidence[1,8-10]. Therefore, the treatment of obesity focused on lifestyle interventions, seeks to reduce body weight and fat mass (FM), maintain fat-free mass (FFM) and avoid nutritional deficiencies through nutritional management and physical exercise[11-13].

It has been shown that a lifestyle program reduces weight, improves body composition, physical condition and quality of life in these patients[14-16]. But sadly, not all participants have the same results, and most of these people regain the weight lost within the next two to five years[17]. This is possibly partly due to compensatory mechanisms related to FM reduction, FFM[18,19].

While the amount of weight lost depends on adherence, physiological adaptations work against losing bodyweight. Within these adaptations, a disproportionate reduction in energy expenditure at rest and due to physical activity (i.e., metabolic adaptation)[20] and an increase in hunger and energy intake have been described.

Although these compensatory mechanisms have been related to the reduction of FM, FFM during weight loss[18,19], there is still controversy regarding the actual existence of metabolic adaptation and its possible effects on weight loss and body composition[21-23]. Therefore, in need of more studies in this regard.

According to the above, the study's primary aim was to evaluate the effect of a nutritional intervention program and physical exercise on body weight, body composition, and resting metabolic rate (RMR) in adults with obesity. Furthermore, as a secondary objective, evaluating the presence of metabolic adaptation by a predictive model for RMR.

Materials and Methods

This prospective experimental study was reviewed and approved by the Ethics Committee of Santa María Clinic.

Participants

During a year in the Endocrine Medical Center, 44 adult volunteers (24 women and 20 men), after signing informed consent, were recruited from the Comprehensive Program for Overweight and Obesity, in accordance with the Declaration of Helsinki. They had to meet the inclusion criteria of BMI > 30 Kg/m^2, sedentarism, and not be using weight loss drugs. As exclusion criteria, morbid obesity BMI > 39.9Kg/m^2 and a history of previous bariatric surgery were considered.

Nutrition and physical exercise

During four months, participants followed a personalised hypocaloric diet (caloric restriction of 500-1000 Kcal/day). The protein content was 1.0 gram per kg of body weight, and low-glycaemic-index carbohydrates and unsaturated fats were included. Participants attended an initial nutritional assessment and follow-ups at 4, 8, 12, and 16 weeks. A nutritional evaluation, food registers, and diet adjustments were carried out at each session.

The exercise intervention consisted of 36 supervised training sessions, 2-3 times per week. 45 minutes of endurance training at 60-85% of the estimated VO2 maximum and five muscle groups strength exercises (3-4 sets, 12-15 repetitions, 50-75% 1-RM) were performed. The workloads were adjusted every month (Figure 1).

RMR measurements

The RMR measurement was carried out by indirect calorimetry (IC) –Sensor Medics Vmax Encore 29 equipment with a canopy facemask. Oxygen consumption and CO_2 production were measured for approximately 30 minutes, discarding the first 10 minutes to obtain the RMR when the equipment showed a steady state. Measurements were completed in a supine position under thermoneutral environmental conditions. Participants fasted for 8 to 10 hours, abstained from ingesting coffee and alcohol, and did not perform physical exercise 24 hours before the examination; in women, evaluations were performed when they were not menstruating.

Body composition

FM and FFM deposits were estimated by bioelectrical impedance (InBodyS10). Participants were fasting for 8 to 10 hours, without consuming coffee, alcohol, or doing physical exercise 24 hours before the examination; women were evaluated while they were not menstruating. The measurement was made in the supine position and under thermoneutral environmental conditions. Other anthropometric measurements –body weight, height and abdominal circumference– were made in the nutritional consultation.

The effect of diet and exercise was evaluated in subjects who adhered to the intervention, defined as compliance with of four months with the diet, Ex sessions and attending nutritional consultations.

Regarding the sample size calculation, we worked with convenience sampling, that is, with an n that was satisfied with the subjects who adhered to the intervention.

Professional	Intervention	Instrument	Schedule
Dietician . Nutritional therapy	Nutritional assessment	Weight and height on a SECA scale with built-in height rod Abdominal circumference with a tape measure	Monthly
	Alimentary anamnesis	24-hour food recal	Monthly
	Diet therapy	Calculation of requirements and prescription of a personalised hypocaloric diet.	First month
	Follow-up	Reinforce behavioural changes and plan consensus feeding	Monthly
Physiotherapist Exercise training	Assessment of physical fitness	Submaximal and indirect tests to estimate cardiorespiratory capacity by extrapolation of heart rate (Polar Electro, Inc., Oulu, Finland) and intensity of multiple treadmill steps. Indirect evaluation of 10 maximum repetitions of leg press, chest press, back row, using the protocol of the National Strength and Conditioning Association, USA, and using the Epley-Welday equation.	Pre and post intervention
	45-minute session of exercise	Supervised exercise sessions (researcher I.P), monitoring subjective perception of effort and target heart rate.	2-3/week

Figure 1.

Statistical analysis

The Wilcoxon-Mann-Whitney test or Fisher's Exact Test was used to evaluate differences according to adherence to the program. The anthropometric variables, body composition and RMR in men and women were analysed at baseline and post-intervention by the Wilcoxon rank test with signs.

Spearman correlation was obtained between indirect calorimetry and bioimpedance RMR measurements with their respective p-value, and a Bland Altman analysis was performed to evaluate the agreement between the two measurements. A multiple linear regression was adjusted to predict the post-intervention RMR (IC) from the pre-intervention variables: sex, age, FM (kg), FFM (kg) and respiratory quotient (RQ.) The metabolic adaptation degree was evaluated according to the method of Galgani and Santos[24]: the predicted value of resting metabolic rate (pre-and post-intervention) was obtained according to the adjusted model, and the residuals were calculated for each prediction and classified as metabolic in those patients whose difference between residuals was positive. The association between metabolic adaptation and sex, change in weight, change in FM and FFM, height and age were evaluated using Fisher's exact and Wilcoxon-Mann-Whitney tests.

The quantitative variables were expressed in median and range, qualitative variables in absolute frequency and percentage. Interquartile range was used to compare the variables according to metabolic adaptation. A significance level of 0.05 was considered. All the procedures were completed using Stata 13 software.

Results

1. The baseline characteristics according to program's adherence (Table 1)

Table I shows the comparison of participants' baseline characteristics according to intervention's adherence. Out of the total participants who entered the study (44), 28 completed it (i.e., 63.6%). Baseline characteristics such as age, weight, BMI, waist circumference and FM were similar between participants who adhered to the intervention and those who did not. The only significant difference in people who completed the intervention was that they had significantly lower FFM ($p = 0.027$) than those who did not finish the intervention.

2. Effect of nutritional intervention and physical exercise on anthropometry, body composition, RMR and respiratory quotient according to sex (Table 2)

At the end of the intervention, there was a significant decrease in the median body weight and FM for both sexes. This decrease in women was approximately 8.2 kilograms of body weight ($p < 0.001$) and 5.4 kilograms of fat mass ($p < 0.001$), and in men it was 11.5 kilograms ($p = 0.005$) and 9.6 kilograms ($p = 0.005$), respec-

Table 1. The baseline characteristics according to program's adherence

Parameter	Completed the intervention n = 28		Did not complete the intervention n = 16		P-value
	Median/ n	(Range/ %)	Median/ n	(Range/ %)	
Women	18	(64.3%)	6	(37.5%)	0.080
Age (years)	33.0	(22.0-61.0)	41.0	(24.0-58.0)	0.172
Body weight (kg)	86.1	(73.3-102.1)	98.8	(76.4-111.2)	0.188
BMI (Kg/mt^2)	33.3	(30.0-40.1)	33.5	(30.3-37.5)	0.450
Waist circumference (cm)	108.5	(94.0-134.0)	111.5	(94.0-122.0)	0.222
Fat-mass (kg)	37.7	(22.8-59.2)	34.2	(27.7-42.2)	0.078
Fat-free mass (kg)	51.0	(36.6-76.7)	66.3	(39.0-80.6)	0.027

Quantitative variables expressed in median and range (minimum-maximum) and qualitative variables in absolute frequency and percentage. Wilcoxon-Mann-Whitney test or Fisher's exact test was used to evaluating differences according to adherence to the program. FFM: Fat-free mass.

Table 2. Comparison of baseline and post-intervention values in women and men

Parameter	Pre		Post		P value
Women (n=18)					
Body weight (kg)	80.4	(73.3-100.2)	72.2	(65.3-95.1)	<0.001
BMI (Kg/mt²)	31.8	(30.0-38.7)	29.2	(26.4-36.7)	<0.001
Waist circumference (cm)	106.5	(94-114)	98.5	(80-114)	<0.001
Fat-mass (kg)	36.9	(31.1-45.9)	31.5	(22.9-41.5)	<0.001
Fat-free mass (kg)	45.6	(36.6-54.4)	41.9	(37.2-55.0)	0.028
RMR IC	1451.5	(1150-1767)	1445	(1148-1648)	0.192
BIA	1330.5	(1161-1548)	1324	(1173-1557)	0.868
RQ	0.84	(0.72-1.05)	0.90	(0.78-0.98)	0.005
Men (n=10)					
Body weight (kg)	108.2	(86.6-120.1)	96.7	(74.0-116.0)	0.005
BMI (Kg/mt²)	34.1	(30.7-40.1)	31.7	(26.2-38.8)	0.005
Waist circumference (cm)	115	(108-134)	106.8	(97-131)	0.005
Fat-mass (kg)	40.2	(22.8-59.2)	30.6	(16.0-55.4)	0.006
Fat-free mass(kg)	64.6	(55.6-76.7)	64.3	(52.4-74.9)	0.114
RMR IC	1898.5	(1643-2216)	1818.5	(1642-2032)	0.358
BIA	1760	(1548-2075)	1760.5	(1522-2051)	0.683
RQ	0.88	(0.80-0.98)	0.91	(0.81-1.13)	0.305

Data expressed in median and range (minimum-maximum) according to sex. Wilcoxon-Mann-Whitney test or Fisher's exact test was used to evaluate the change between baseline values v. post-intervention. FFM: Fat-free mass; RMR: Resting metabolic rate; BIA: bio electrical impedance; RQ: Respiratory quotient.

tively. However, only women reached a median BMI lower than 30. Waist circumference showed a significant decrease ($p < 0.001$) in both women and men (8 cm and 8.2 respectively). Regarding the FFM, only women had a significant decrease (-3.7 Kg; $p = 0.028$), while FFM in men did not change ($p = 0.114$).

RMR –obtained by IC and BIA– remained stable in both groups. The correlation and agreement with indirect calorimetry measurements were assessed to validate bioelectrical impedance for estimating resting metabolic rate. A high positive correlation, both for pre-and post-intervention measurements (Spearman's correlation: 0.849 and 0.821, respectively), and a moderate to high concordance were obtained (percentage of observations outside agreement limit of 7.3% and 3.7% respectively).

RQ in women showed a significant increase in the median of 0.06 units ($p = 0.005$), demonstrating a variation in the use of energy substrates. In contrast, RQ in men did not change ($p = 0.305$).

3. Multiple linear regression to predict RMR (calorimetry) from the independent variables (Table 3)

A linear regression model was adjusted to predict the pre-intervention RMR, and the variables that were significantly associated with RMR were kept in the model: sex, FM and FFM. The results show that men present an average RMR of 247.80 units (Kcal) higher than women; and the RMR increases 7.25 units (Kcal) on average for each kilogram of FM and it increases 9.79 units (Kcal) on average for each kilogram of FFM. Age and RQ did not have a significant effect on RMR.

The coefficient of determination (R^2) obtained was 77.8%, indicating that the variables present in the model explain the high RMR value. Predictive models for men and women are as follows:

Men: RMR = 994.49 (Kcal) + 7.25*FM (Kg) + 9.79* FFM (Kg)

Women: RMR = 746.69 (Kcal) + 7.25*FM (Kg) + 9.79* FFM (Kg)

Table 3. Multiple linear regression to predict pre-intervention RMR (indirect calorimetry) from independent variables

Variable	Coefficient	(IC 95%)		P value
Masculine sex*	247.80	76.44	419.17	0.006
Fat-mass (kg)	7.25	1.00	13.50	0.024
Fat-free mass (kg)	9.79	2.99	16.59	0.006
Intercept	746.69	322.47	1170.91	0.001

For the sex variable, women were used as the reference category.

Table 4. Comparison of variables between participants with and without metabolic adaptation

Variable	Without metabolic adaptation (n=16)		With metabolic adaptation (n=11)		P-value*
	Median	(IQR)	Median	(IQR)	
Changes in body weight	7.4	(4.9-8.3)	6.6	(4.7-10.7)	0.570
Changes in fat-mass	4.4	(2.2-7.0)	8.0	(5.5-10.0)	0.018
Changes in fat-free mass	2.8	(0.6-4.2)	0.7	(-1.5-2.1)	0.089
Height	1.62	(1.57-1.70)	1.67	(1.58-1.76)	0.335
Age	34	(31-43.5)	33	(29-41)	0.621

*Test de Wilcoxon-Mann-Whitney. Variables expressed in median and interquartile range. To make the comparison of the variables, the Wilcoxon-Mann-Whitney test was used. IQR: interquartile range.

4. Metabolic adaptation (Table 4)

Using the method of Galgani and Santos (24), metabolic adaptation was detected in 11 of the 27 participants (40.7%), which corresponds to 60.0% of men (6) and 29.4% of women (5). No significant relationship was found between metabolic adaptation and sex (p = 0.124), as with changes in body weight and FFM, height and age (table VI). However, a significant relationship between metabolic adaptation and FM change was observed, with a median of 4.4 kilograms in participants without metabolic adaptation and 8.0 kilograms in participants with metabolic adaptation (p = 0.018).

Discussion

In obese adults, the first treatment for body weight loss is lifestyle modification through diet and physical exercise[25-27]. In general, the goal is to reduce 5 to 10% of the actual weight[28]. Weight loss has been observed increases quality of life[29]. Although losing 10% of body weight is usually not enough to reach a BMI under 25 Kg/m^2, this effectively reduces FM and modifies metabolic parameters[30]. The results reported in this study regarding the change in body weight and composition are similar to those described in other diet and exercise interventions[29-31].

Adherence to the intervention is essential to obtain successful results. Usually, a percentage of subjects do not comply with the treatment (diet and exercise) and drop out before finishing the intervention. Of the total number of participants who entered the study, 63.6% showed adherence to the intervention. The reasons for abandoning the intervention were not feeling satisfied with the results regarding the loss of body weight and lack of time to attend the sessions with health professionals. Unfortunately, subjects living with obesity who are in lifestyle treatment frequently focus only on body weight and do not tend to consider other parameters such as body composition.

When comparing the baseline characteristics: age, weight, BMI, waist circumference and fat mass, these were similar between the subjects who adhered versus those who did not complete the intervention.

According to the results, a significant decrease in body weight was observed in adults with type 1 obesity who adhere to the intervention [women 10% (8.2 kilograms) and men 10.6% (11.5 kilograms)], in addition to the maintenance of RMR for both groups; but only women reached a median BMI lower than 30 Kg/m^2.

Regarding body composition, FM decreased in both groups, women 5.4 kilograms ($p < 0.001$) and men 9.6 kilograms ($p < 0.005$), representing 65.85% and 83.47% of the total weight loss, respectively. Furthermore, only women showed a significant decrease in FFM (3.7 kilograms; $p = 0.028$). These results are in line with other reports[33]. The low FFM reductions may be related to the fact that most of the participants were previously physically inactive[34] and consumed a poor diet.

In the present study, RMR did not vary significantly at a group level despite reductions in body weight and FM for both groups and FFM in women. The maintenance of RMR could be due to increased levels of physical activity[35]. Nevertheless, neither can the consumption of coffee, alcohol, nicotine and strenuous physical activity be ruled out before the RMR assessment, despite the indications received[36,37].

To analyse individual changes in RMR, a linear regression model was fitted with the data obtained by pre-intervention IC to predict post-intervention RMR. The model obtained included the variables sex, FM and FFM. The results show that men present an average RMR of 247.80 units (Kcal) higher than women, and RMR increases 7.25 units on average (Kcal), for each kilogram of FM, and for each kilogram of FFM it increases 9.79 units (Kcal) on average. Based on this model and according to the IC, we sought to determine the presence of metabolic adaptation at the end of the intervention. According to the results, 40% of the participants presented a RMR reduction above the estimated (metabolic adaptation). These participants were the ones who reduced FM the most, as reported in other studies[20,26,38].

Regarding the RQ, it increased significantly ($p = 0.005$) in women after the intervention, reflecting an increase in the contribution of carbohydrates at rest[39,40]. The results differ from what was expected[41] since, after a period of energy deficit, the metabolism of fatty acids at rest would be favoured[42-44]. Our results could be related to a significant reduction in body weight and adherence to a balanced diet.

Finally, as for weaknesses of the study, we can point out the lack of laboratory tests for all participants, explaining why they were not finally included in the analyses; the analysed sample size, of the total participants just 63.6% completed it; and the lack of strict control over compliance with the standard measures for the measurement of the RMR by IC.

Conclusion

Our intervention effectively reduced body weight, FM, maintaining RMR in obese type 1 adults. However, when analysed individually, 40% of the participants presented metabolic adaptation, which was significantly correlated with the FM loss. The average estimated RMR by post-intervention linear regression did not show significant differences with the values from IC.

The adherence is not perfect, thus further research must care about how to keep people involved. Finally, it is necessary to continue investigating this type of intervention but considering the inter-individual variability to improve the response to this type of treatment.

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