EFFECTS OF INTERVENTION PROGRAMS ON CHANGES IN RESTING ENERGY EXPENDITURE

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The aim of the study was to assess the effects of two types of weight reducing programs on changes in resting energy expenditure (REE) in overweight middle aged women. We recruited 28 overweight or obese premenopausal women at the age of 40–50 years via poster advertisements, of which 6 of the women were withdrawn early. Participants were divided into 2 groups – D and DC. Women assigned to group D (n = 10) had only a diet regime prescribed, whereas group DC (n = 12) followed a combined diet and exercise intervention. The diet was identical for both groups and the daily energy restriction for each participant was approximately 2000 kJ. Group DC combined resistance training and aerobic exercise. Both programs ran for 6 weeks. At the beginning and end of the intervention REE values (measured by indirect calorimetry), REE/kg and selected anthropometric parameters: body weight, stature, BMI, waist, hips and thigh girth, and body fat percentage were monitored.

In the combined intervention program the REE decrease was smaller than in the group with only an energy restricted diet. However, the REE and REE/kg changes detected at the end of the monitored period were not statistically significant, and there was no significant statistical difference between the applied intervention programs. Apart from the thigh circumference, the two intervention programs did not show different effects of any statistical significance on the change of monitored anthropometric indices. However, for all the parameters monitored (REE as well as the anthropometric ones) we can see that energy restricted diet combined with exercise is more effective than diet alone.

To affect the REE more markedly, prescription of physical exercise of longer duration, and of greater intensity and frequency would be necessary.

Keywords: Obesity, resting energy expenditure, exercise, weight reduction.

INTRODUCTION

The occurrence of obesity in developed countries has recently reached epidemic dimensions. This is also the reason for the growing number of research work and studies focusing on finding the most convenient obesity therapy. In most cases programs focusing on weight reduction include dieting and training regime intervention, as these are the most effective tools for weight management. Therefore, with respect to the long term effectiveness of weight loss programmes, the loss of fat mass while maintaining fat free mass and resting energy expenditure seems desirable.

Resting energy expenditure (REE) represents 60–70% of one's total daily expenditure and thus plays a substantial role in body weight modulation (Poehlman, 1989). Results of research dealing with changes in REE during the keeping of a reducing diet is not clear. Luscombe et al. (2002), Stiegler and Cunliffe (2006) or Wadden et al. (1996) have shown that a reducing diet results in REE decrease; others, however, do not confirm this (Brehm et al., 2005; Rumpler et al., 1991).

A uniform opinion of researchers prevails concerning the effects of increased physical activity on increasing the resting energy expenditure (Gilliat-Wimberly et al., 2001; Goran et al., 1994; Poehlman, Melby, & Goran, 1991; Stiegler & Cunliffe, 2006). According to Poehlman, Melby and Goran (1991) exercise may influence REE in two ways: 1) a prolonged increase in post exercise metabolic rate from an acute exercise challenge; and 2) a chronic increase in resting metabolic rate associated with exercise training. At the same time, however, the authors say that an exercise prescription for the general population that consists of exercise of low (less than 50% VO_2max) or moderate (50–75% VO_2max) intensity does not appear to produce a prolonged elevation of post exercise metabolic rate that would influence REE. Van Zant (1992) has shown that the REE value increases only via endurance exercise at > 70% VO_2max increases REE. However, such a level of strain intensity cannot be applied to untrained obese individuals.

The trouble with programs focusing on weight reduction is that they may lead to a decrease in the resting energy expenditure, since the exercise intensity is far too

low for effective adjustment of REE reduced by the diet restriction. This REE decrease is often the main cause of weight gain after the reducing program is ended.

This study aims to assess the effects of an energy restricted diet and of an energy restricted diet combined with physical activity on REE changes in a group of overweight or obese middle aged women. This research sets to determine such a program that would result in weight loss, but not in REE decrease. In the study we have used exercise at 50–60% of maximum heart rate reserve and a diet with slight reduction of energy intake (by 2000 kJ per day), which should significantly decrease REE.

METHODS

The research was carried out on women recruited via poster advertisements. There were several criteria for subject inclusion: BMI > 25 kg/m^2, an age of 40–50 years and regular menstruation. Exclusion criteria were: thyroid disease, diabetes mellitus, hypertension or hyperlipidemia, the fact of having undergone surgical or medication obesity therapy, drug addicts and alcoholics, and also weight loss of > 3 kg during the last 3 months. All subjects were non smokers and before the study was started had not exercised regularly.

The study was approved by an ethics committee and each subject was informed of the entire course of the examination verbally and in writing, and by her signature confirmed her voluntary participation in the study.

There were 28 asymptomatic obese or overweight women at the age of 40–50 years who were included in the study. Six of them were withdrawn early; the final group thus consisted of 22 women of a mean BMI value of 29.2 ± 4.3 kg/m^2 and aged 45.8 ± 7.4 years.

The women were randomized into subgroups D (n = 10) and DE (n = 12). Women assigned to group D had only diet program prescribed, whereas group DE followed a combined diet and training intervention program. Both programs ran for 6 weeks.

At the beginning and after the 6 week intervention REE values and anthropometric parameters were taken. The subjects were tested always after fasting for at least 12 hours in the physiology lab of the Faculty of Physical Culture in Olomouc.

Diet intervention

At the beginning of the program each woman completed a questionnaire analysing her eating habits and appetite preferences. Based on the results of the anthropometric values and eating habits questionnaire, a detailed eating plan was drawn up for the subjects. Daily energy restriction for each subject was approximately 2000 kJ. Basic nutrients in the food were represented in accordance with standard recommendation – fats 20–30%, saccharides 55–60% and proteins 15% of the total energy intake. The diet was divided into five meals during the day (three main meals and two snacks), and their energy value was determined following a model, in that the breakfast represented 30% of daily energy intake, lunch 30%, dinner 20% and morning and afternoon snacks 10% each. The individual portions were composed so that their energy density reached at most 500 kJ/100g of food. To achieve an optimum liquid intake it was recommended to drink 2.5–3.0 l of unsweetened liquids per day. The prescribed reducing diet was identical for both groups.

Exercise intervention

A combination of resistance training practised by a method of very slow repeating (Westcott et al., 2001) and aerobic exercise was designed for women assigned to group DE. The subjects had an individual program designed for each training unit, changing according to the principles of gradually increasing exercise of intensity and durance. After a short warm up and stretching, the resistance training program involving all major muscle groups (muscles of the chest, shoulder, abdomen and limbs) followed; the positive (concentric) stage lasting 5 seconds and the negative (eccentric) stage 7 seconds and was repeated in one sequence 5 to 7 times. During the first two weeks of the program 1–2 sets per exercise were applied (depending on the subject's abilities), and from the third week on 2 sequences were always used. In the first week of training the following aerobic part on a bicycle ergometer or stair stepper had a 60% intensity of maximum pulse reserve and lasted 20 minutes; every week one minute was added. A telemetric heart rate monitor (Polar) was available to all subjects to accurately determine exercise intensity. Training with a fitness specialist was scheduled twice a week in about 90 minute lessons.

Resting energy expenditure

Measurements were taken always in the afternoon after at least 12 hours of fasting. Indirect calorimetry together with a ventilation mask and ZAN 600 Ergo USB device (ZAN Messgeraee GmbH, Oberthulba, Germany) was used. Calibration was performed before each measurement. While being measured the subjects were lying on a bed in a quiet room with a comfortable temperature of 23°C. Following half an hour of measuring, the ventilation mask was applied and oxygen consumption and carbon dioxide production were recorded for 30 minutes. Mean values of ventilation gases necessary for REE calculation by Weir's formula (Weir, 1949) were calculated based on the results of the last 20 minutes of measuring (the first 10 minutes of data were discarded to ensure all subjects had reached equilibrium).

Anthropometric measuring

The following parameters were statistically evaluated: weight, waist, hips and thigh circumference, and body fat percentage. BMI was calculated by dividing weight (kg) by square of height (m^2). The body weight and stature were measured by a medical digital scale with precision to 0.1 kg and 0.1 cm. The waist circumference was measured with a metal tape measure with precision to 0.1 cm in the midpoint between the lower part of the rib cage and the illiac crest in the horizontal plane; hip circumference was measured at the widest part of the hip region in the horizontal plane. The body fat percentage was determined with callipers by measuring performed on 10 skin folds following Pařízková (1973).

Statistical data processing

For each monitored quantity, basic statistical quantities were calculated (the arithmetic mean and standard deviation). Due to the character of data measured we applied non parametric tests. The significance of the changes of the monitored parameters at the end of the intervention program was tested by a sign test and the difference between groups D and DE was verified by the Mann-Whitney U test. The α significance level was set to 0.05. The statistical processing of results was carried out by computer software Statistica 6.

TABLE 1
Changes of the measured data after a 10 week weight reduction programme

Parameter	Group D (n = 10)	Group DE (n = 12)	D vs DE
	M SD	M SD	
Age (years)	48.70 3.80	43.83 8.82	NS
Stature (cm)	167.60 5.04	167.25 6.27	NS
Weight 1 (kg)	81.34 12.54	81.25 14.14	NS
Weight 2 (kg)	78.72 * 14.06	77.84 * 13.62	NS
R_weight (kg)	2.62 2.99	3.41 2.41	NS
BMI 1 (kg/m^2)	28.88 3.58	29.07 5.01	NS
BMI 2 (kg/m^2)	27.93 * 4.16	27.80 * 4.90	NS
R_BMI (kg/m^2)	0.95 1.08	1.20 0.85	NS
Waist circumference 1 (cm)	99.30 9.03	91.83 11.08	NS
Waist circumference 2 (cm)	95.60 * 9.98	87.58 * 9.85	NS
R_waist circumference (cm)	3.70 3.68	4.25 3.77	NS
Hip circumference 1 (cm)	109.70 7.20	111.17 7.88	NS
Hip circumference 2 (cm)	107.50 * 7.56	108.75 * 6.36	NS
R_hip circumference (cm)	2.20 1.81	2.42 2.54	NS
Thigh circumference 1 (cm)	64.25 4.26	60.29 7.58	NS
Thigh circumference 2 (cm)	62.00 * 4.80	57.58 * 5.20	+
R_thigh circumference (cm)	2.25 1.93	2.71 3.78	NS
Body fat 1 (%)	32.85 4.20	29.66 5.47	NS
Body fat 2 (%)	30.80 * 4.94	26.19 * 6.20	NS
R_body fat (%)	2.05 1.89	3.47 2.71	NS
REE 1 (kcal)	1750.11 299.84	1778.96 276.50	NS
REE 2 (kcal)	1538.78 ns 487.64	1700.35 ns 276.58	NS
R_REE (kcal)	211.33 385.46	78.60 258.54	NS
REE/kg 1 (kcal/kg)	21.36 3.17	22.23 3.41	NS
REE/kg 2 (kcal/kg)	19.89 ns 7.31	22.40 ns 5.01	NS
R_REE/kg (kcal/kg)	1.40 5.50	−0.17 3.49	NS

Legend
D – group with diet restriction
DE – group with combined diet and exercise intervention
M – arithmetic mean
SD – standard deviation
R_... – difference in measured parameters
Statistically significant difference:
a sign test
* $p < 0.05$ changes from baseline
ns – no significant from baseline
Mann-Whitney U test
+ $p < 0.05$ D vs DE
NS – no significant D vs DC

RESULTS

Results of the data measured are presented in TABLE 1. REE and REE/kg input values for groups D and DC did not show any statistically significant differences.

At the end of the monitored period REE decreased by 12.1% vs. 4.4% as compared to the initial values (D vs. DE). REE/kg in group D decreased by 7% and in group DE increased by 0.8% as compared to the initial values. The changes in REE and REE/kg were not statistically significant and there were also no differences between groups D and DE. At the beginning of the intervention there were no statistically significant differences in the monitored anthropometric parameters between groups D and DE. At the end of the six week intervention, weight decreased by 2.62 ± 2.99 kg vs. 3.41 ± 2.41 kg, BMI by 0.95 ± 1.08 kg/m^2 vs. 1.20 ± 0.85 kg/m^2, waist circumference by 3.70 ± 3.68 cm vs. 4.25 ± 3.77 cm, hip circumference by 2.20 ± 1.81 cm vs. 2.42 ± 2.54 cm, thigh circumference by 2.25 ± 1.93 cm vs. 2.71 ± 3.78 cm and body fat by 2.05 ± 1.89% vs. 3.47 ± 2.71% (D vs. DE). The weight change oscillated around the generally recommended value of 0.5 kg/week, on average it was 0.4 kg/week in group D and 0.6 kg/week in group DE. In both groups a statistically significant decrease in all anthropometric values occurred. In two women (each in a different group) weight, body fat as well as other anthropometric parameters increased. In an interview it was elicited that the woman from group D adhered to the prescribed diet program rather loosely, and the subject from group DE, although attending the training regularly, often contravened the dieting regime. The only statistically significant difference in the monitored anthropometric parameters between group D and group DE was the thigh circumference shortage.

DISCUSSION

This study has confirmed that when energy intake decreases, so does the energy expenditure. This is a very important fact that needs to be taken into account in obesity therapies. In a recent study Brehm et al. (2005) describe a 7% REE decrease and 1% REE/kg decrease in 50 obese women undergoing a two month reducing diet. The women had a prescribed daily restriction of 3500 kJ and decreased their weight by 5.8 kg. Similarly Miles et al. (1993) have found a REE decrease in obese women by 8.8% while their weight was reduced by 7.3 kg. In this study we applied less strict dietary restrictions (2000 kJ/day), with weight in group D decreasing on average by 2.62 kg. We could therefore also assume a more moderate REE decrease, as the diet induced REE decrease depends on the amount of weight loss (Froidevaux et al., 1993). In fact, however, the REE values in group D decreased by 12% and REE/kg by 7%. Detected values showing significant REE decrease can be explained by the short duration of the intervention, since during the first weeks of the reducing regime the REE decrease is probably more marked and only later subsides. A continuation of the above study by Brehm et al. (2005) might suggest so, as after the next two months of the reducing diet the REE values decreased only by 6% as compared to the initial values and REE/kg values even increased by 5%. For this reason a study that is to be a continuation of the present one will prolong the intervention to 6 months.

REE and REE/kg values in group D obtained during the initial measuring were highly diffuse as compared to group DE (great SD). In single subjects a great variability of reaction to the intervention programs used was detected. Causes can be seen in individually differing reactions to the training stimulation conditioned by genetic dispositions (Joosen et al., 2005). In addition, the amount of habitual physical exercise not monitored within the study also differed.

The REE increase caused by regular exercise has been described in a number of works (Gilliat-Wimberly et al., 2001; Goran et al., 1994; Poehlman, Melby, & Goran, 1991; Stiegler & Cunliffe, 2006; and others). Nevertheless, the sole increase of physical activity for weight reduction in obese women without also modifying their diet is not too happy a solution, since women, more so than men, tend to increase their energy intake in proportion to the increased energy expenditure (Westerterp et al., 1992).

For REE maintenance the regular exercise model applied combining slow resistance training and endurance training with the intensity of 60–70% of maximum heart rate reserve was sufficient. This result does not correspond to the outcomes of Van Zant's (1992) or Poehlman, Melby and Goran's (1991) works, who state that in this respect effective exercise must have higher intensity. It should be realised that obese untrained subjects would not be even able to perform regular exercise under higher intensity. Higher exercise frequency and longer duration of the intervention program could affect the metabolism more significantly, as suggested by the first results of a new continuation study with the intervention period prolonged to six months.

CONCLUSION

In the group with a combined intervention program, the REE decrease was smaller than in the group with only dieting restrictions. REE and REE/kg changes at the end of the monitored period were, however, not statistically significant and there was not a statistically significant difference detected between the two intervention programs applied. The two intervention programs also did not show a statistically significant difference in the change of the monitored anthropometric parameters, with the exception of thigh circumference. Nevertheless, both reducing programs resulted in marked changes

in all the monitored anthropometric parameters. For all monitored parameters (REE and anthropometric) a reducing diet combined with exercise tends to be more effective than dieting alone.

The often described "yo-yo" effect is linked to the REE decrease as a result of the reducing diet carried over even after the energy restrictions are ended. If maintaining or even increasing REE is successful, the reduced weight is also easier to maintain. In this experiment the selected exercise program succeeded in maintaining or even slightly increasing the REE reduced by the diet. In the case of the REE/kg value it is apparent that the diet intervention used decreases its value, whereas the combined intervention slightly increases it.

To affect the REE more markedly, prescription of physical exercise of longer duration, and of greater intensity and frequency would be necessary.

The presented results suggest that to reduce weight in obese women, it is more effective to apply a complex program comprising dieting restrictions and higher physical activity.

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VLIV INTERVENČNÍCH PROGRAMŮ NA ZMĚNY KLIDOVÉHO ENERGETICKÉHO VÝDEJE

(Souhrn anglického textu)

Cílem naší studie bylo posoudit vliv dvou typů redukčních programů na změny klidového energetického výdeje (REE) u skupiny žen středního věku s nadměrnou hmotností. Intervenčních programů se zúčastnilo 28 asymptomatických žen ve věku 40–50 let s nadváhou či obezitou, 6 žen studii nedokončilo. Soubor byl rozdělen na 2 skupiny – D a DE. Ženy zařazené do skupiny D (n = 10) měly předepsanou pouze dietní intervenci a ve skupině DE (n = 12) kombinovaný program dietní a pohybové intervence. Dietní program byl v obou skupinách stejný a denní energetická restrikce činila pro každého jedince přibližně 2000 kJ. Ve skupině s pohybovou intervencí byla zvolená kombinace silového a aerobního tréninku. Oba programy trvaly 6 týdnů. Na počátku a konci intervence jsme sledovali hodnoty REE (nepřímou kalorimetrií), REE/kg a vybrané antropometrické parametry: tělesnou hmotnost, výšku, BMI, obvod pasu, boků a stehna a procento tělesného tuku.

Ve skupině s kombinovaným intervenčním programem byl pokles REE menší než ve skupině s pouhou dietní restrikcí. Změny REE a REE/kg na konci sledovaného období však nebyly statisticky významné a nebyl zjištěn statisticky významný rozdíl ani mezi použitými intervenčními programy. Rozdílné intervenční programy rovněž neměly, kromě obvodu stehna, statisticky významně rozdílný vliv na změnu sledovaných antropometrických ukazatelů. Ve všech sledovaných parametrech (REE i antropometrických) můžeme však pozorovat tendenci efektivnějšího působení kombinace redukční diety a cvičení než samotné diety.

Pro výraznější ovlivnění REE by bylo patrně zapotřebí použití předpisu pohybové aktivity s delším trváním, vyšší intenzitou a frekvencí cvičení.

Klíčová slova: obezita, klidový energetický výdej, cvičení, redukce hmotnosti.

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