

## IMPACT OF AEROBIC EXERCISE PLUS CALORIE RESTRICTION INTERVENTION ON RESTING METABOLIC RATE, SUBSTRATE OXIDATION AND METABOLIC SYNDROME COMPONENTS IN OVERWEIGHT AND OBESE WOMEN

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### ABSTRACT

*Background.* Despite the existence of several studies investigating the role of combined different diet regimes and different exercise programs on weight loss and related health benefits, the effect of a 6-month program including 12.5% calorie restriction (CR) with weekly 150 minutes of moderate-intensity aerobic exercise remains unclear.

*The aim* of the study was to test the hypothesis that 6-month CR and aerobic exercise would increase resting metabolic rate (RMR) and fat oxidation, and improve anthropometric and metabolic parameters.

*Methods.* Twenty-six overweight and obese women aged  $44.2 \pm 7.2$  years were randomized to either control (CG) or experimental calorie restriction plus aerobic exercise group (EG) for six months. Changes in RMR, substrate oxidation, body mass index (BMI), waist circumference, blood pressure (BP), level of lipids and glucose were measured.

*Results.* RMR increased ( $P < 0.05$ ) in EG, whereas no changes in substrate oxidation were observed. Combined calorie restriction and exercise intervention decreased ( $P < 0.05$ ) BMI, waist circumference, systolic BP, triglycerides and glucose levels, and increased ( $P < 0.05$ ) high-density lipoprotein cholesterol level.

*Conclusions.* A 6-month combination of 12.5% calorie restriction and 150 weekly minutes of moderate-intensity aerobic exercise is associated with effective and healthy weight loss strategy, which can prevent metabolic syndrome and improve resting metabolic rate.

**Keywords:** obesity, female, diet, aerobic training, health.

### INTRODUCTION

The fast-growing prevalence of overweight and obesity is becoming a global burden. Well-established obesity development mechanism is that energy intake exceeds energy expenditure resulting in a positive energy balance (Hill et al., 2012), the excess energy being stored in the adipose tissue. Furthermore, obesity is the central feature in the pathogenesis of metabolic syndrome (MetS) (Zimmet et al., 2005).

It is claimed that anything that increases resting metabolic rate (RMR) facilitates weight loss and maintenance of weight loss (Connolly et al., 1999). There is

evidence that a combination of exercise and diet has beneficial effects on RMR (Lennon et al., 1985; Lopes et al., 2013).

It is well known that intervention that increases fat metabolism could reduce obesity (Achten, Jeukendrup, 2004). Nevertheless, we are not aware of any studies of combined diet and exercise effect on substrate oxidation, several studies have examined the role of exercise alone. These studies showed contradictory results, with aerobic exercise decreasing fat oxidation (van Aggel-Leijssen et al., 2001) or having no effect on fat oxidation (van Aggel-Leijssen et al., 2002).

Studies have shown that diet-induced weight loss in conjunction with exercise training effectively reverses MetS factors and improves physical function (Larson-Meyer et al., 2010; Weiss et al., 2017). Exercise training studies on overweight patients revealed that three to four months of exercise yields small reductions in body weight (~1–2%) and moderate improvements in MetS components (Dunkley et al., 2012). Adding calorie restriction (CR) to aerobic exercise can potentiate the benefits of exercise on the reduction of serum triglycerides (TG) (Kelley et al., 2012), total cholesterol, low-density lipoprotein cholesterol, BMI and body fat, and an increase of high-density lipoprotein cholesterol (HDL-C) (Normandin et al., 2017).

Despite the existence of several studies investigating the role of combined different diet regimes and different exercise programs on weight loss and related health benefits, the effect of the combination of widely used 12.5% CR (Anton et al., 2009; De Jonge et al., 2010; Lam et al., 2015; etc.) with the WHO (*World Health Organisation*, 2010) recommended at least 150 minutes of moderate-intensity aerobic physical activity throughout the week remains unclear. Thus, the aim of the present study was to test the hypothesis that 6-month CR and aerobic exercise would increase RMR and fat oxidation, and improve anthropometric and metabolic parameters (BMI, waist circumference, level of TG and HDL-C, blood pressure (BP), fasting glucose).

## METHODS

**Subjects.** Twenty-six healthy untrained overweight/obese females (BMI  $\geq$  25 kg/m<sup>2</sup>) aged 36–56 years were enrolled in this study. To be included, the participants had to be physically and mentally healthy, nonsmokers, non-alcoholic drinkers, not pregnant, not involved in regular physical activity, having stable body weight two months prior to the trial (permissible deviation was  $\pm$  2 kg). Informed consent was obtained from all individual participants included in the study, and the study was approved by the Kaunas Regional Biomedical Research Ethics Committee and was conducted in accordance with the Declaration of Helsinki.

**Protocol.** On the day of measurement, the participants arrived at the study room in the morning after 12-hour overnight fasting. Then anthropometric assessments, resting respiratory gas analysis, BP were evaluated and blood sampling was performed. Afterwards the individual meeting with a study dietitian was arranged for each participant. Questionnaires were given to the participants to fill in subjectively. Subjects were randomized into two groups, experimental (EG) and control (CG). Subsequently, EG underwent 6-month aerobic exercise plus CR intervention, while CG participants were instructed to maintain their usual dietary and exercise habits. After 6 months, the experimental measurements were repeated.

**Intervention.** *Exercise intervention.* Participants underwent 72 supervised aerobic exercise-training sessions on cycle ergometers, including three sessions of training per week. Training sessions consisted of 5 min of stretching exercise (warm-up) at low intensity (50–60% of maximum heart rate (HR)); 50 min of aerobic training (main part) at the intensity of between 60–70% of maximum HR; 5 min of stretching and breathing exercise (cool-down) of low intensity. HR during training was monitored with HR monitors (Polar, Finland).

*Calorie restriction (CR).* The intervention was designed to create a 12.5% energy deficit. Study dietitian advised the participants at the baseline to reduce energy intake by reducing portion size and by replacing energy-dense food with those of lower energy density. Individualized nutrition plans were prepared based on participants' nutrition habits described in four-day food diaries.

**Measurements.** *Anthropometric data.* Height (m) was measured to the nearest 0.5 cm using a wall-mounted stadiometer during the first visit. Body weight (kg) was measured with subjects wearing underwear. Values were reported to the nearest 0.1 kg using bioelectrical impedance analysis (TBF-300 body composition scale; Tanita, UK). BMI ( $\text{kg}/\text{m}^2$ ) was calculated as body weight divided by squared height.

Waist circumference (cm) was obtained with a flexible tape measure. Waist circumference was measured to the nearest 0.1 cm, in duplicate, at the level of the iliac crest at the end of the normal expiration.

*Resting metabolic rate and substrate oxidation.* A mobile spirometry system (Oxycon Mobile, Jaeger/VIASYS Healthcare, Germany) was used to measure pulmonary gas exchange. It measures oxygen consumption ( $\text{VO}_2$ ) and carbon dioxide production ( $\text{VCO}_2$ ) in l/min every five seconds on a breath-by-breath basis. Calibration was performed according to manufacturer's instructions. Resting  $\text{VO}_2$  and  $\text{VCO}_2$  were recorded for 15 min, but the data collected during the first 5 min was discarded for the calculation of RMR in 24 h kcal/min. The measure-

ments over the subsequent 10 min were calculated the equation of Weir (1949):  $\text{RMR (kcal/day)} = [3.9 \times \text{VO}_2 \text{ (ml/min)} + 1.1 \times \text{VCO}_2 \text{ (ml/min)}] \times 1.44$ .

Total carbohydrate (CHO) and fat oxidation (FO) rates were computed using the following non-protein stoichiometric equations (Péronnet, Massicotte, 1991):  $\text{CHO (g/min)} = 4.585 \times \text{VCO}_2 \text{ (l/min)} - 3.226 \times \text{VO}_2 \text{ (l/min)}$ , and  $\text{FO (g/min)} = 1.695 \times \text{VO}_2 \text{ (l/min)} - 1.701 \times \text{VCO}_2 \text{ (l/min)}$ . Respiratory exchange ratio ( $\text{RER} = \text{VCO}_2/\text{VO}_2$ ) was also used to determine substrate oxidation.

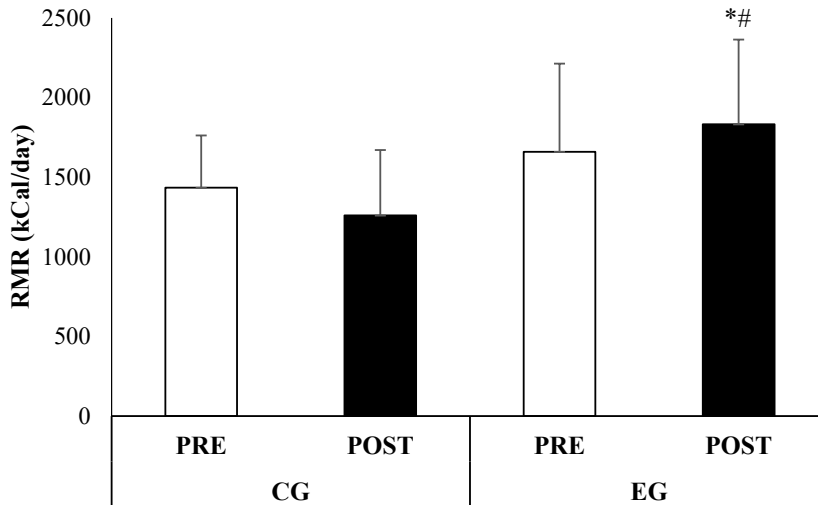
**Blood pressure.** Resting BP (systolic and diastolic) was measured using a digital electronic BP monitor (Microlife BP A100, Switzerland). The measures were taken in a sitting position with the legs uncrossed and the back and arms supported.

**Blood glucose and lipid concentration.** The level of fasting blood glucose (mmol/L) was determined using a glucose analyzer Glucocard X-mini plus meter (Arkray, Japan). The level of HDL-C (mmol/L) and TG (mmol/L) was determined using a CardioCheck PA analyzer (Polymer Technology Systems Inc, USA).

**Statistical analysis.** All statistical analyses were performed using SPSS (version 25.0; IBM Corp., USA). Data are reported as means  $\pm$  standard deviations. The data were tested for normal distribution using the Shapiro-Wilk test. The results *before and after the intervention* were analyzed using a paired Student's *t*-test if the values were normally distributed or a Wilcoxon rank sum test if the data were not normally distributed. The results between two groups were compared using independent Student's *t*-test if the values were normally distributed or a Mann-Whitney test if the data were not normally distributed. The level of significance was set at  $P < 0.05$ .

## RESEARCH RESULTS

**Resting metabolic rate.** The RMR is presented in Figure 1. RMR increased ( $P = 0.046$ ) in EG, but no changes were observed in CG. Greater RMR ( $P = 0.002$ ) was observed after the 6-month aerobic exercise plus CR intervention compared with a usual-diet CG.



**Note.** Data are presented as mean  $\pm$  standard deviation. \* $P < 0.05$ , compared with values before; # $P < 0.05$ , compared with control group. CG, control group; EG, experimental group; RMR, resting metabolic rate.

**Figure 1. Changes in resting metabolic rate induced by aerobic exercise plus calorie restriction intervention**

*Substrate oxidation.* The substrate oxidation is presented in Table 1.  $VO_2$  ( $P = 0.005$ ) and  $VCO_2$  ( $P = 0.011$ ) increased, whereas substrate oxidation remained unchanged in EG. No changes were observed in CG. Greater  $VO_2$  ( $P = 0.016$ ) and  $VCO_2$  ( $P = 0.017$ ) were observed after the 6-month aerobic exercise plus CR intervention compared with a usual-diet CG.

**Table 1. Changes in substrate oxidation induced by aerobic exercise plus calorie restriction intervention**

Parameter	CG (n = 13)		EG (n = 13)	
	PRE	POST	PRE	POST
$VO_2$ (l/min)	$0.20 \pm 0.03$	$0.20 \pm 0.05$	$0.21 \pm 0.03$	$0.26 \pm 0.07^{*}\#$
$VCO_2$ (l/min)	$0.16 \pm 0.05$	$0.17 \pm 0.04$	$0.18 \pm 0.05$	$0.22 \pm 0.07^{*}\#$
RER	$0.84 \pm 0.06$	$0.81 \pm 0.07$	$0.86 \pm 0.06$	$0.82 \pm 0.08$
CHO (g/min)	$0.05 \pm 0.02$	$0.15 \pm 0.03$	$0.18 \pm 0.11$	$0.21 \pm 0.10$
FO (g/min)	$0.18 \pm 0.07$	$0.05 \pm 0.02$	$0.05 \pm 0.02$	$0.07 \pm 0.03$

**Note.** Data are presented as mean  $\pm$  standard deviation. \* $P < 0.05$ , compared with values before; # $P < 0.05$ , compared with control group. CG – control group; EG – experimental group;  $VO_2$  – oxygen uptake;  $VCO_2$  – carbon dioxide production; RER – respiratory exchange ratio; CHO – carbohydrate oxidation; FO – fat oxidation.

*Metabolic syndrome parameters.* The MetS parameters are presented in Table 2. BMI ( $P < 0.001$ ), waist circumference ( $P = 0.019$ ), systolic BP ( $P < 0.001$ ), triglycerides ( $P = 0.013$ ) and glucose ( $P = 0.027$ ) levels decreased, and HDL-C level ( $P = 0.032$ ) increased in the EG, whereas waist circumference ( $P = 0.044$ ) and diastolic BP ( $P = 0.048$ ) significantly increased in the CG. Lower glucose level ( $P = 0.046$ ) and systolic BP ( $P = 0.022$ ) were observed after the 6-month aerobic exercise plus CR intervention compared with a usual-diet CG.

Table 2. **Changes in metabolic syndrome parameters induced by aerobic exercise plus calorie restriction intervention**

Parameter	CG (n = 13)		EG (n = 13)	
	PRE	POST	PRE	POST
BMI (kg/m <sup>2</sup> )	32.5 ± 3.6	32.8 ± 3.1	31.9 ± 3.4	30.5 ± 3.6*
Waist circumference (cm)	96.7 ± 5.1	97.6 ± 5.6*	96.6 ± 10.0	93.8 ± 9.0*
TG (mmol/L)	1.31 ± 0.42	1.79 ± 1.27	1.84 ± 0.80#	1.49 ± 0.46*
HDL-C (mmol/L)	1.50 ± 0.48	1.41 ± 0.38	1.40 ± 0.28	1.55 ± 0.33*
Glucose (mmol/L)	5.75 ± 0.69	5.91 ± 0.75	6.09 ± 1.05	5.38 ± 0.49*#
Systolic BP (mmHg)	132.8 ± 11.9	131.2 ± 11.6	135.2 ± 7.1	127.7 ± 7.8*#
Diastolic BP, mmHg	80.0 ± 6.2	85.4 ± 9.7*	87.3 ± 6.1#	85.2 ± 6.7

**Note.** Data are presented as mean ± standard deviation. \* $P < 0.05$ , compared with values before; # $P < 0.05$ , compared with control group. CG – control group; EG – experimental group; BMI – body mass index; TG – triglycerides; HDL-C – high-density lipoprotein cholesterol; BP – blood pressure.

## DISCUSSION

In the present study, we found that RMR, anthropometric and metabolic parameters improved after CR and aerobic exercise intervention, whereas substrate oxidation remained unchanged.

In accordance with previous studies (Lennon et al., 1985; Lopes et al., 2013) we have observed increased RMR by  $13 \pm 21\%$ , which may be related to the increase of fat free mass in this group (Connolly et al., 1999; Lopes et al., 2013). However, in contrast to our expectations, fat metabolism remained unchanged after a 6-month combined diet and exercise intervention. Differences between study results might be associated with different exercise intervention duration. It seems that only a short-term intervention (ten weeks) is associated with decreased fat oxidation (van Aggel-Leijssen et al., 2001), whereas a long-term intervention (40 weeks) has no effect on substrate oxidation (van Aggel-Leijssen et al., 2002).

Although only nearly 15% of participants in the EG met the criteria for MetS, we observed improvement in MetS components for all participants, such as de-

creased BMI by  $4 \pm 4\%$ , waist circumference – by  $3 \pm 4\%$ , systolic BP – by  $6 \pm 3\%$ , TGs – by  $13 \pm 22\%$  and fasting glucose levels – by  $10 \pm 14\%$ , and increased HDL-C by  $12 \pm 18\%$ . These improvements are in accordance with the previous studies combining exercise and CR intervention (Kelley et al., 2012; Normandin et al., 2017).

It is suggested that MetS risk factor improvements are primarily the result of weight loss (Normandin et al., 2017). The reductions found for MetS components might be associated with reduced risk of all-cause and cardiovascular disease mortality (Katzmarzyk et al., 2005) in overweight and obese adults.

The current study has limitations. Firstly, we enrolled healthy physically inactive overweight and obese middle-age women, this limits the generalizability of the findings, and whether the results found here refer to different population has yet to be studied. Secondly, the differences in anthropometric and substrate oxidation outcomes between groups may have been non-significant because of an insufficient sample size. Lastly, there was no follow-up measurements conducted in this study.

## CONCLUSION

In conclusion, a 6-months combination of 12.5% CR and 150 weekly minutes of moderate-intensity aerobic exercise is associated with effective and healthy weight loss strategy, which can prevent the metabolic syndrome and improve resting metabolic rate. Future studies should examine the most effective weight loss strategy including different exercise and CR regimes to promote health. In addition, considerable knowledge gaps remain regarding the residual effects of these interventions.

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## AEROBINIŲ PRATIMŲ IR KALORIJŲ APRIBOJIMO POVEIKIS NUTUKUSIŲ IR ANTSVORĮ TURINČIŲ MOTERŲ RAMYBĖS MEDŽIAGŲ APYKAITAI, SUBSTRATŲ OKSIDACIJAI IR METABOLINIO SINDROMO RODIKLIAMS

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### SANTRAUKA

*Tyrimo pagrindimas.* Nors yra keletas tyrimų, nagrinėjančių skirtingų mitybos režimų ir fizinių pratimų programų kombinacijų įtaką svorio mažinimui ir su tuo susijusiam poveikiui sveikatai, vis dar neaišku, kaip šiuos rodiklius veikia šešių mėnesių 12,5% kalorijų apribojimo ir 150 minučių vidutinio intensyvumo aerobinių pratimų per savaitę programa.

*Tyrimo tikslas* buvo patikrinti hipotezę, kad šešių mėnesių kalorijų apribojimo ir aerobinių pratimų intervencija padidins medžiagų apykaitą ramybėje ir riebalų oksidaciją, pagerins antropometrinius ir metabolinius rodiklius.

*Metodai.* Nutukusios ir antsvorį turinčios tiriamosios (amžius  $44,2 \pm 7,2$  m.) buvo atsitiktinai suskirstytos į kontrolinę ( $n = 13$ ) ir eksperimentinę (pastarajai buvo taikyta kalorijų apribojimo ir aerobinių pratimų intervencija, trukusi 6 mėnesius) grupes ( $n = 13$ ). Buvo išmatuoti ramybės medžiagų apykaitos, substratų oksidacijos, kūno masės indekso, liemens apimtys, kraujo spaudimo, lipidų ir gliukozės pokyčiai.

*Rezultatai.* Ramybės medžiagų apykaita padidėjo ( $p < 0,05$ ) eksperimentinėje grupėje, o substratų oksidacijos pokyčių nenustatyta. Po kombinuotos kalorijų apribojimo ir pratimų intervencijos sumažėjo ( $p < 0,05$ ) kūno masės indeksas, liemens apimtis, sistolinis kraujo spaudimas, trigliceridų ir gliukozės koncentracija, padidėjo ( $p < 0,05$ ) didelio tankio lipoproteinų cholesterolio koncentracija.

*Išvados.* Šešių mėnesių taikoma kalorijų apribojimo 12,5% ir 150 minučių vidutinio intensyvumo aerobinių pratimų per savaitę programa yra susijusi su veiksminga ir sveika svorio mažinimo strategija, kuri gali apsaugoti moteris nuo metabolinio sindromo ir pagerinti ramybės medžiagų apykaitą.

**Raktažodžiai:** nutukimas, moterys, aerobinė treniruotė, sveikata.

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