Coll. Antropol. **47** (2023) 1: 11–18
Original scientific paper
doi:10.5671/ca.47.1.2

Full-Body Circuit Training Improves Body Composition and Cardiorespiratory Fitness in Overweight Sedentary Adults – A Randomized Controlled Trial

Vincenzo Rago[1,2], Magni Mohr[3,4]

[1]Al Ain Sports and Cultural Club, Abu Dhabi, United Arab Emirates
[2]Faculty of Health and Sport Science, Universidade Europeia, Lisbon, Portugal
[3]Centre of Health Science, Faculty of Health Science, University of the Faroe Islands, Tórshavn, Faroe Islands
[4]Department of Sports Science and Clinical Biomechanics, SDU Sport and Health Sciences Cluster (SHSC), Faculty of Health Sciences, University of Southern Denmark, Odense, Denmark

ABSTRACT

Obesity and low cardiorespiratory fitness are major risk factors for numerous non-communicable diseases and mortality, and efficient treatment protocols to counteract these conditions are highly warranted. We evaluated the effect of high-intensity circuit training (CIT) on body composition and cardiorespiratory fitness of sedentary overweight individuals. Cardiorespiratory and body composition were assessed before and after a 8-week circuit training (CIT; four sessions of full-body CIT per week; age, 38 ± 9 years old; height, 174 ± 10 cm; body mass, 93.1 ± 22.2 kg; n = 32), and 8-week inactivity (CON; neither training nor lifestyle changes from week; 0–8 age, 39 ± 7 years old, height, 168 ± 8 cm, body mass, 89.5 ± 17.5 kg; n = 33). The two-way repeated-measures ANOVA revealed moderate to large reductions were observed in body mass, BMI, and fat percentage after CIT (d=0.43–0.81; P<0.05). In contrast, all body composition parameters remained stable after 8-week inactivity (P<0.05). A small to moderate group x moment interaction was found for body mass, BMI and % fat (d=0.10–0.60; P<0.05). Small improvements in VO_{2max} were observed after CIT (d=0.48 [0.11–0.85]; P=0.010), while small to moderate reductions were observed in VO_{2max} and PV were observed after inactivity (d=0.47 [0.11–0.83] and 0.64 [0.26–1.01], respectively; P<0.05). A small moment x group interaction was observed for VO_{2max} (d= 0.19 [0.13–0.26]; P<0.001). Our findings suggest that 8-week of full-body circuit training may improve cardiorespiratory fitness and body composition in sedentary overweight individuals.

Key words: *maximal oxygen consumption, high intensity training, body fat content, muscle mass, nutrition.*

Introduction

Poor cardio-respiratory fitness and obesity are worldwide concerning public health and predispose individuals to develop type 2 diabetes, dyslipidaemia, hypertension, pulmonary diseases, certain cancers, and cardiovascular disease[1]. Also, physical inactivity elevates the risk for premature death and the incidence of unhealthy conditions, which independently or in combination are well-established risk factors for various chronic diseases or conditions[2].

Extensive evidence showed that prolonged aerobic exercise training performed as running, brisk walking, or bicycling reduces the relative risk for developing several metabolic diseases[3–5]. In accordance, the World Health Organization (WHO) and the American College of Sports Medicine (ACSM) guidelines state that 150-to-250 min moderate intensity physical activity per week is sufficient and effective to prevent weight gain[6]. Moreover, national guidelines from public health institutions on physical activity, as well as the Committee on Exercise and Cardiac Rehabilitation of the American Heart Association have previously endorsed and supported these recommendations for healthy adults to improve and to maintain health[7].

A recent systematic review by Batrakoulis et al.[8] and network meta-analysis including 81 randomized controlled trials (RCT) encompassing five different exercise training types in relation to cardiometabolic health in obese individuals. The authors concluded that multicomponent or complex training methods appears to be superior in relation to cardiometabolic risk factors compared to conventional aerobic training, as well as resistance train-

Received for publication January 14, 2023

ing and high-intensity interval training alone, which may question the precision of current guidelines for physical activity for overweight and obese persons. These findings are supported by other meta-analyses evaluating the effect of other multicomponent or hybrid training protocols on cardiometabolic health parameters such as maximum oxygen uptake (VO_{2max}), body mass, fat percentage and muscle mass[9–11]. Thus, it is of interest to examine the effect of complex training modalities on cardiorespiratory fitness and body composition in sedentary obese population groups. For example, circuit training (CIT), which normally involves whole-body training with (or without) a large cardiovascular and metabolic loading, as well as high energy expenditure and strength elements, which are the main factors driving favourable adaptations in cardiorespiratory fitness and body composition. This is further supported by a recent systematic review and meta-analysis based on 45 trial, which demonstrates beneficial effects of circuit-based training on body composition and cardiorespiratory fitness[12].

Thus, the objective of the present study was to test the hypothesis that 8-week of regular whole-body CIT and dietary advice generates clinically relevant beneficial adaptations in body composition and cardiorespiratory fitness in overweight adults.

Materials and Methods

Participants

Eighty sedentary overweight men (n=34) and women (n=46) were recruited for the study (Table 1). The participants were recruited via social media based a lifestyle, age, and body mass index (BMI). The possibility to participate was advertised on Facebook, and potential participants could sign up and come to an information meeting. The eighty participants were randomly and sex-specifically assigned to a CIT group and a control group (CON). The study was approved by the ethical committee of the Faroe Islands and conducted in accordance with the Declaration of Helsinki (1964). After being informed verbally and in writing of the experimental procedures and associated risks, all participants gave their written consent to take part in the study.

Experimental design

An RCT design was applied. After recruitment, 80 participants were enrolled in the present study based on selection criteria being a sedentary lifestyle for the last five years, an age range of 25–55 years, and a BMI >25. Participants with chronic diseases were excluded. The participants were first randomized gender-specifically into CIT (Mean ± standard deviation, age 38 ± 9 years old; height 174 ± 10 cm; body mass = 93.1 ± 22.2 kg; n = 40), and CON (age = 39 ± 7 years old, height 168 ± 8 cm, body mass = 89.5 ± 17.5 kg; n = 40). The training group took part in full-body high-intensity CIT with 2–4 training sessions per week for 8 weeks, while CON had no training or lifestyle changes in the same period. Fifteen dropouts were observed due to injuries (n = 4), low training attendance (n = 7), and lack of time (n = 4), which resulted in 32 and 33 participants in CIT (female aged 39 ± 5 years old; height 177 ± 5 cm; baseline body mass, 95.7 ± 18; male aged 39 ± 10 years old; height, 180 ± 7 cm; baseline body mass, 103.8 ± 16.9 kg) and CON (female aged 38 ± 8 years old; height, 163 ± 5; baseline body mass, 86.6 ± 16 kg; male aged 37 ± 8 years old; height 166 ± 7 cm; baseline body mass 88.5 ± 19.5 kg), respectively.

All subjects performed a VO_{2max}-test and body composition assessments at baseline, as well as after 8 weeks of intervention treatment. The post-fitness tests were conducted 48–72 hours after the last training session. The training was continued until the last measurement was obtained. The dietary intake was not controlled during the training period and the testing periods were not timed in relation to the menstrual cycle for women.

Training intervention and diet advice

The training was the "Burn-Classic" fitness concept being basic CIT involving a large muscle mass and aerobic training at high-intensity combined with recovery intervals with low intensity activity. All exercises were large muscle group exercises including jumps, pushing and pulling drills, high-intensity shuttle runs and core exercises. Exercise was conducted in an order, so the same muscle group was not used in consecutive exercises. Every session lasted 60 min (38–45 min of effective training) and consisted of 30–60 s full-body strength-based exercises interspersed by 15–20 s of passive recovery (changing exercise) after training principles previously described. In the first 4-week training, the participants completed 30-s work intervals, the following 4 weeks they completed 60-s work intervals. A trained and certified fitness coach was present during all training sessions in order to give technical advice and control the intensity and duration of the training and to secure a safe training environment.

To describe the exercise responses to CIT, participants' heart rate (HR) and rating of perceived exertion (RPE) were collected in one sample session in the fifth week. HR was measured continuously during the tests using a Polar Vantage NV chest belt monitor weighing ~100 g (Polar Electro Oy, Kempele, Finland). Exercise and peak HR were expressed as percentage of maximum HR obtained in the incremental test, as previously described[13]. Individual RPE using the Borg's category ratio scale (CR10) after training sessions. The participants' RPE was collected in isolation to avoid the potential effects of peer pressure 15–20 min after each training session since the timing of collection has previously been reported not to affect the RPE outcome[14]. This ensured that the perceived effort reflected the whole session and not the most recent exercise intensity[15]. The players answered the question "How intense was your today's session?" on a scale ranging from 0 (no effort at all) to 10 (maximal effort) arbitrary units [AU].

The CON did not change their lifestyle during the 8 weeks intervention (control period). Both CIT and CON received group-based dietary advice sessions led by a dietitian and provided with a standardised meal plan. CIT received the dietary advice at baseline. The meal plan aimed to lower body weight, but to maintain muscle mass. Thus, the meal plan was semi-low-caloric, providing 1,800 and 2,300 kcal per day for the women and men, respectively, which corresponds to protpcols delivered to patients with diabetes.

Previous studies of group-based diabetes education have reported HbA1C decreases of 0.5–2.0% in T2DM patients[16]. The main principles of the meal plan were substituting high-starch and high-sucrose foods with low-glycaemic natural fibre-rich plant foods[17]. In accordance with the official Danish dietary recommendatins, the recommended vegetable intake was 300 g per day and fruit consumption was limited to two to three pieces per day in order to limit fructose intake[17–18]. The participants were instructed to minimise consumption of sucrose-containing foods, especially sugar-sweetened beverages, and to substitute starchy foods with wholemeal foods such as wholemeal bread, pasta and rice[19]. The recommended intake of saturated fat, dietary cholesterol and trans fat is the same for diabetic subjects as for the healthy population[16,19]. However, based on Danish dietary surveys, the participants were advised to increase consumption of foods containing long-chain n-3 fatty acids (EPA and DHA) from fatty fish[19].

Testing

Maximal oxygen uptake testing

Participants reported to the laboratory after being instructed to refrain from vigorous exercise 24 hours prior to the tests and to avoid alcohol, tobacco, and caffeine on the day of testing. To determine VO_{2max} and peak pulmonary ventilation (PV) participants completed an incremental cycling test to exhaustion on an electronically braked cycle ergometer (Excalibur Sport, Lode, Groningen, Netherlands) with continuous measurements of VO_2 and V_E using an online gas collection system (model Cosmed, Quark b2, Milano, Italy). Heart rate was monitored (HRM-Dual, Garmin, Olathe, Kansas, USA) throughout the test. Gas analyzers and the flow of the applied spirometer were frequently calibrated. The exercise protocol started with a 6 min warm-up period; 3 min at 30 or 50 W followed by 3 min at 50 or 70 W for women and men, respectively, after which the workload was increased 15 or 20 W/min for women and men until the point of exhaustion or a cadence <60 rpm. Participants were verbally encouraged and motivated throughout the test. Participants were blinded to pulmonary measurements, power output and time elapsed. Breath-by-breath VO_2 values were averaged over 30 s, and the VO_{2max} was defined as the highest 30s value. The highest HR averaged over 15 s in the three different tests was retained as maximum HR. Participants were tested at the same time of the day for all three tests and were familiarized to the testing procedure prior to baseline testing.

Body composition

Body composition was assessed using bioelectrical impedance analysis (InBody 270, Biospace, California, USA prior to the cardiorespiratory testing. Total body mass, whole-body fat percentage and lean body mass were evaluated. Additionally, body mass index (BMI) was calculated.

Statistics

Shapiro-Wilks test revealed that all variables were normally distributed within each group and evaluation moment ($P>0.05$). A multiple one-way analysis of variance (ANOVA) was used to assess possible between groups differences at baseline. A two-way repeated-measures ANOVA was used to test for differences in body composition and cardiorespiratory fitness. The independent variables included one between-subjects factor (training intervention) with two levels (CIT and CON), and one within-subject factor (time) with two levels (pre- and post-intervention). To examine the influence of training intervention on the development of our dependent variables, we used these ANOVAs to test the null hypothesis of no different change over time between groups (training intervention × time interaction). To qualitatively interpret the magnitude of differences, effect sizes (d) and associated 95% confidence intervals (95% CI) were classified as small (0.2–0.5), moderate (0.5–0.8) and large (>0.8).

Relative changes in body composition and cardiorespiratory were calculated using delta (Δ) values. Paired sample correlations were computed to analyse the associations between acute exercises responses to CIT and percentages of changes (Δ) in body composition and cardiorespiratory variables, as well as between Δ values among our dependent variables. To interpret either the magnitudes of correlation, the following criteria were adopted: trivial ($r \leq 0.1$), small ($r=0.1–0.3$), moderate ($r=0.3–0.5$), large ($r=0.5–0.7$), very large ($r=0.7–0.9$) and almost perfect ($r \geq 0.9$). The associated 95% confidence intervals (95%CI) were also calculated.

Data were reported as mean (SD) for all variables. The level of statistical significance was set at $P \leq 0.05$. Data analyses were performed using Statistical Package for Social Science software (IBM SPSS, Version 25.0. Armonk, NY).

Results

Acute exercise responses to circuit training

The CIT group completed in total 22 ± 3 training sessions over the 8-wk intervention period corresponding to a training frequency 2.7 ± 0.4 sessions per week. During CIT, HR during exercise averaged 84 ± 3 % HR_{max} and peaked 94 ± 4 % HR_{max}. After CIT, the participants perceive the intensity as 7 ± 1 au. No significant correlations were observed between exercise responses to CIT and training adaptations (*P*<0.05).

Body composition

A detailed description of changes in body composition parameters through 8-week CIT compared to CON is reported in Table 1.

Women undergoing CIT experienced large reductions in body mass, BMI and fat percentage (*d*= 0.98 to 0.81; *P*<0.001), with no changes in muscle mass percentages (*P*=0.020). On the other hand, women experienced moderate increases in only muscle mass after 8-week inactivity (*d* [95% CIs] = –0.57 [–1.02; –0.10]; P= 0.018). A small to moderate group x moment interaction was found in women in all body composition parameters (*d*= 0.15 to 0.62; P<0.05).

Men experienced large reductions in body mass and BMI after 8-week CIT (*d*= 1.79 [0.98; 2.58] and 1.82 [1.00; 2.61), respectively). No changes in body composition parameters were observed in men after inactivity (*P*<0.05). A small to moderate interaction was found in men for body mass and BMI (*d*= 0.58 [0.29; 0.88] and 0.42 [0.21; 0.64], respectively; *P*< 0.001).

When pooling women and men, moderate lo large reductions were observed in body mass, BMI and % fat after CIT (*d*= 0.43 to 0.81; *P*<0.05). On the other hand, all body composition parameters remained unchanged in CON after 8-week inactivity (*P*<0.05). A small to moderate group x moment interaction was found for body mass, BMI and % fat (d= 0.10 to 0.60; *P* < 0.05).

Cardiorespiratory parameters

A detailed description of changes in cardiorespiratory parameters through 8-week CIT compared to CON is reported in Table 2.

Women undergoing CIT experienced moderate increases in VO_{2max} and reductions PV (*d*= –0.58 [–1.1; –0.04] and 0.72 [0.16; 1.26], respectively; *P*<0.05). On the other hand, inactive women did not observed any changes in VO_{2max} (P= 0.107) but observed moderate reductions in PV after 8-week inactivity (*d* [95% CIs] = 0.67 [0.19; 1.14]; P= 0.006). A small to moderate group x moment interaction was found in women for VO_{2max} (d=0.17 [0.04; 0.29]; P=0.013)

No changes in physiological parameters were observed in men after either 8-week CIT or inactivity (*P*<0.05). However, a small interaction was observed in men for VO_{2max} after 8-week CIT (*d*= 0.23 [0.07; 0.39]; *P*= 0.010).

When pooling men and women, small improvements in VO_{2max} were observed after CIT (d= –0.48 (–0.85; –0.11); *P* = 0.010). On the other hand, small to moderate reductions were observed in VO_{2max} and PV were observed in CON after inactivity (d= 0.47 [0.11; 0.83] and 0.64 [0.26; 1.01]; P< 0.05). A small moment x group interaction was observed for VO_{2max} (d= 0.19 [0.13; 0.26]; *P* < 0.001).

TABLE 1

CHANGES IN BODY COMPOSITION PARAMETERS THROUGH 8-WEEK CIRCUIT TRAINING COMPARED TO CONTROL GROUP

	Control group				Circuit training group				Group x moment interaction	
	Before	8 weeks	P	d (95% CIs)	Before	8 weeks	P	d (95% CIs)	P	d (95% CIs)
Women (n=21 and 16)										
Body mass (kg)	86.6 ± 16.7	86.8 ± 16.3	0.605	-0.12 (-0.54; 0.32)	88.6 ± 19.6	83 ± 17.5	<0.001	1.80 (0.98; 2.59)	<0.001	0.62 (0.36; 0.87)
BMI (kg · m-2)	32 ± 5.2	32.1 ± 5.1	0.562	-0.13 (-0.56; 0.30)	31.8 ± 6.3	29.8 ± 5.6	<0.001	1.81 (0.99; 2.6)	<0.001	0.61 (0.36; 0.87)
Fat (%)	41.5 ± 5.9	41.7 ± 6.3	0.365	-0.20 (-0.63; 0.23)	37.4 ± 7.7	35.8 ± 7.4	<0.001	0.98 (0.37; 1.57)	<0.001	0.34 (0.2; 0.47)
Muscle mass (%)	27.7 ± 3.9	28.1 ± 4.2	0.018	-0.57 (-1.02; -0.10)	28.9 ± 4.9	28.8 ± 4.8	0.380	0.23 (-0.27; 0.72)	0.020	0.15 (0.03; 0.27)
Men (n= 16 and 16)										
Body mass (kg)	95.7 ± 18.0	96.3 ± 17.6	0.338	-0.29 (-0.86; 0.3)	103.8 ± 16.9	97.5 ± 15.1	<0.001	1.79 (0.98; 2.58)	<0.001	0.58 (0.29; 0.88)
BMI (kg · m-2)	30.6 ± 5.1	30.5 ± 4.2	0.888	0.04 (-0.53; 0.61)	31.9 ± 4.9	30.0 ± 4.4	<0.001	1.82 (1.00; 2.61)	<0.001	0.42 (0.21; 0.64
Fat (%)	30.9 ± 5.6	31.1 ± 6.2	0.670	-0.13 (-0.69; 0.45)	26.7 ± 8.5	26 ± 8.9	0.412	0.21 (-0.29; 0.7)	0.391	0.03 (-0.04; 0.1)
Muscle mass (%)	37.3 ± 7	37.2 ± 7.0	0.744	0.10 (-0.47; 0.66)	41.2 ± 5.2	40.6 ± 4.9	0.345	0.24 (-0.26; 0.74)	0.508	0.02 (-0.04; 0.07)
All pooled (n= 37 and 32)										
Body mass (kg)	89.9 ± 17.5	90.3 ± 17.1	0.277	-0.19 (-0.54; 0.15)	96.2 ± 19.6	90.3 ± 17.7	<0.001	1.81 (1.24; 2.37)	<0.001	0.60 (0.40; 0.80)
BMI (kg · m-2)	31.5 ± 5.1	31.5 ± 4.8	0.852	-0.03 (-0.37; 0.31)	31.8 ± 5.6	29.9 ± 5.0	<0.001	1.84 (1.26; 2.4)	<0.001	0.53 (0.35; 0.71)
Fat (%)	37.6 ± 7.7	37.8 ± 8	0.378	-0.16 (-0.50; 0.19)	32.0 ± 9.7	30.9 ± 9.5	0.022	0.43 (0.06; 0.79)	0.012	0.10 (0.02; 0.17)
Muscle mass (%)	31.1 ± 6.9	31.4 ± 6.9	0.097	-0.30 (-0.64; 0.05)	35.1 ± 8.0	34.7 ± 7.7	0.241	0.21 (-0.14; 0.56)	0.067	0.05 (0.00; 0.11)

BMI= body mass index

TABLE 2

CHANGES IN CARDIORESPIRATORY PARAMETERS THROUGH 16-WEEK CIRCUIT TRAINING COMPARED TO CONTROL GROUP

	Control group				Circuit training group				Group x moment interaction	
	Before	8 weeks	P	d (95% CIs)	Before	8 weeks	P	d (95% CIs)	P	d (95% CIs)
Women (n=21 and 16)										
VO2max (ml·kg-1·min-1)	22.1 ± 3.2	21.0 ± 3.0	0.107	0.37 (-0.08; 0.81)	22 ± 2.6	23.2 ± 3.5	0.035	-0.58 (-1.1; -0.04)	0.013	0.17 (0.04; 0.29)
PV (L·min-1)	85.5 ± 14.2	80.1 ± 15.5	0.006	0.67 (0.19; 1.14)	97.5 ± 13.3	89.1 ± 16.1	0.012	0.72 (0.16; 1.26)	0.383	0.02 (-0.03; 0.0)
Men (n= 16 and 16)										
VO2max (ml·kg-1·min-1)	27.6 ± 6.1	25.4 ± 5.9	0.051	0.64 (0.00; 1.25)	26.4 ± 6.3	28.3 ± 6.2	0.084	-0.46 (-0.97; 0.06)	0.010	0.23 (0.07; 0.39)
PV (L·min-1)	117.3 ± 19.4	109.3 ± 26.4	0.054	0.62 (-0.01; 1.23)	125.5 ± 20.7	127.2 ± 28.7	0.712	-0.09 (-0.58; 0.4)	0.123	0.09 (-0.03; 0.2)
All pooled (n= 37 and 32)										
VO2max (ml·kg-1·min-1)	24.1 ± 5.1	22.6 ± 4.7	0.010	0.47 (0.11; 0.83)	24.2 ± 5.2	25.7 ± 5.6	0.010	-0.48 (-0.85; -0.11)	<0.001	0.19 (0.13; 0.26)
PV (L·min-1)	97.1 ± 22.3	90.7 ± 24.4	0.001	0.64 (0.26; 1.01)	111.5 ± 22.3	108.2 ± 30	0.238	0.21 (-0.14; 0.56)	0.350	0.01 (-0.02; 0.0)

PV, peak ventilation; VO2max, maximal oxygen uptake

Correlations between body composition and physiological parameters after circuit training

A detailed description of correlations among changes body composition and physiological parameters after circuit training is reported in Table 3.

Changes in body mass were almost perfectly correlated to changes in BMI (r=0.99 [0.99; 1.00]; P<0.001). Changes in muscle mass were moderately related to changes in BMI (r=0.38 [0.04; 0.65] and negatively related to changes in body fat (r=–0.87 [–0.93; –0.74]; P<0.001). Changes in VO_{2max} were largely related to changes in PV (r= 0.58 [0.29; 0.77]; P <0.001).

Discussion and conclusions

The main findings of our study were that 8 weeks of full-body high intensity CIT combined with dietary advice improved cardiorespiratory fitness, as well as induces marked reductions in body mass and body fat content in obese sedentary individuals with some minor sex-specific differences.

There was a 19% dropout rate with main reasons being exclusion because of too low attendance, injures and lack of time to commit to training. Thus, compared to other types of training interventions[20–21], the intervention can be considered feasible despite having a very high intensity and being perceived as physically demanding with an average RPE of 7. There was a relatively high training attendance with nearly three weekly session which falls within the WHO guidelines for physical activity [1], but with a markedly higher exercise intensity. Indeed, mean heart rate during training was ~85% HR_{max} with near maximum levels attained, which can be classified as vigorous or high intensity interval training[22,23] with a high energy expenditure[24]. Thus, the applied "Burn-Classic" fitness concept with full-body circuit training elicits a powerful stimulation of the cardiovascular system and a high energy expenditure of a level comparable to a small-sided game training session in football[25], which has been shown highly efficient in relation to upregulating cardiorespiratory fitness and body composition[10,11].

The intervention was highly efficient in relation to inducing weight loss. The CIT-group displayed a weight loss

TABLE 3

CORRELATIONS AMONG CHANGES BODY COMPOSITION AND PHYSIOLOGICAL PARAMETERS AFTER CIRCUIT TRAINING

	BMI		Body fat		Muscle mass	
	P	r (95% CIs)	P	r (95% CIs)	P	r (95% CIs)
Body mass	<0.001	0.99 (0.99; 1.00)	0.641	-0.09 (-0.42; 0.27)	0.025	0.40 (0.05; 0.65)
BMI	-		0.724	-0.07 (-0.40; 0.29)	0.030	0.38 (0.04; 0.65)
Body fat	-		-		<0.001	-0.87 (-0.93; -0.74)
Muscle mass	-		-			
VO2max	-		-			

BMI, body mass index; VO2max, maximal oxygen uptake of ~6 kg, which is more than observed after comparable short-term exercise training interventions[11, 26–28], which may be a combination between the high energy expenditure in training and the inclusion of dietary guidance towards a calorie restricted diet. This notion is supported by other studies combining dietary advice and high intensity training and inducing a comparable weight loss[29,30]. The weight loss in the present study, was partly caused by fat loss, which is supported by a significant correlation between the change score in body mass and fat percentage. Indeed, for the entire sample body fat content declined from 32.0 to 30.9% corresponding to ~3 kg fat, which is a large absolute effect). These findings are also supported by a recent meta-analysis by Ramos-Campo et al.[12] showing a 4.3% decrease in fat mass after circuit-based resistance training. No change was observed in muscle mass in our study, which is on contrast to the above-mentioned meta-analysis showing an average ~2% increase. Thus, the remaining weight loss in our trial is likely to associate with fluid loss in relation to expected depletion of the muscle glycogen stores due to the high intensity training[31] and altered diet[32]. The intervention-induced lowered body mass reduced the body mass index from around 32 to below 30 $kg{\cdot}m^2$, which is the threshold between obesity and overweight, which has clinically relevance[33]. While both men and women displayed a similar weight loss, only the women-group reached statistical significance in lowered body fat content, which may be associated with the fact that women may be more prone to adhere to dietary advice, compared to men. For example, has it been shown that women manifest a more pronounced adherence to health foods and greater engagement in controlling body weight[33]. It cannot be ruled out that the lack of significance in the male group can be associated with a statistical type 2 error due to lowered sample size. Collectively, our results indicate that full-body high intensity CIT combined with dietary advice is an efficient method to induce short-term weight loss without compromising muscle mass in obese and sedentary men and women.

The CIT intervention resulted in a between-group difference in VO_{2max}. The entire sample displayed an increase of 1.5 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ corresponding to 6%, which is in accordance with an average increase of 6.3% at meta-analysis level[12]. This is generally is less than observed after other high intensity multicomponent training protocols such as football training[10], interval running[26], cycling[34] and rowing[13]. The relatively small change induced a group x time interaction, since the control group displayed a significant decrease in VO_{2max} of around the same magnitude (6%) as the increase in CIT (see Table 2). Moreover, similar post-intervention improvements were observed in both men and women, with the males demonstrating a numeric, but non-significant change (despite a strong tendency), but a group x time interaction was present due to a numeric decrease in the controls. Thus, CIT may also upregulate the weight-adjusted VO_{2max} in obese sedentary controls over an 8-week period, which mainly is caused by a large decline in body mass. It is surprising that the increase in VO_{2max} was limited to a 6% increase considering the low baseline values of the sample, a 6 kg decline in body mass and the high cardiorespiratory loading observed during CIT. For example, other studies showed an increase in VO_{2max} of 2.5–4–5 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ after 12-week low volume high-intensity interval training in frail patients with coronary artery disease with a similar baseline level[20–35], despite that the training frequency was lower than in the present study. Also, a previous meta-analysis showed an increase of 3.5 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ after short-term (12–16 weeks) recreational football training interventions, which elicits a similar heart rate response the circuit training protocol in this study. It is possible that the intervention was too short, but it should be mentioned that the CIT-group continued training for 8 additional weeks, which did not cause marked additional changes in VO_{2max} (unpublished data). Both men and women displayed a similar improvement in VO_{2max}, which is in line with other high intensity group-based training interventions[10, 29]. Thus, full-body circuit training can be applied to both sexes to cause small improvements in cardiorespiratory fitness. The PV did not change in the intervention group, while a decline was observed in the control group, which indicate that 8 weeks was insufficient to improve the capacity of the respiratory muscles.

One of the strengths of this was that a randomized controlled design was applied, and relatively homogenous sample consisting of obese and overweight sedentary individual representing both sexes was recruited. The initial sample size was high and despite a ~20% dropout, the statistical power was still sufficient with 32 and 33 subjects in each group. However, the testing for sex-specific changes there is a risk of a statistical type 2 error due to small sub-groups. The training attendance was high, and all sessions were supervised, which is a strength.

It is also important to denote some limitations. The dietary advice and meal plan were provided, but the nutritional intake was not registered during the intervention. Except for VO_{2max}, we did not measure any other fitness parameters which may have significantly affected outcome of training protocol, such as strength and power level of the participants. Additionally, although we classified our participants as adults, the age span was wide (25–54 years old). In this context, the chronological may have interfered with specific training adaptation on any training system, with younger adults expected to adapt sooner than their older counterparts.

In conclusion, short-tern full-body high intensity circuit training combined with dietary advice caused marked and clinically relevant improvements in body composition, as well as augmented maximum oxygen uptake in obese and sedentary individuals. Thus, fitness concepts such as the circuit training applied with concomitant dietary advice can be suggested as efficient short-term treatment of obesity and physical inactivity.

Acknowledgement

We would like to acknowledge the committed effort demonstrated by the participants. Moreover, the technical assistance from Andras Vágsheyg, Tórur Sjúðrarson, as well as Janus Vang at iNOVA Human Performance Laboratory and Jákup Suni Berg at Burn Fitness is valued.

REFERENCES

1. WHO, Guidelines on physical activity and sedentary behaviour: web annex: evidence profiles (WHO, GENEVA, 2020). – 2. LEE IM, SESSO HD, PAFFENBARGER RS, JR, International journal of epidemiology, 28 (1999) 620. doi: 10.1093/ije/28.4.620. – 3. BLAIR SN, CONNELLY JC, Research quarterly for exercise and sport, 67 (1996) 193. doi: 10.1080/02701367.1996.10607943. – 4. PEDERSEN BK, SALTIN B, Scandinavian Journal of Medicine & Science in Sports, 25 (2015) 1. doi: 10.1111/sms.12581. – 5. BOOTH FW, ROBERTS CK, LAYE M. J Compr Physiol, 2 (2012) 1143. doi: 10.1002/cphy.c110025. – 6. DONNELLY JE, BLAIR S N, JAKICIC JM, MANORE MM, RANKIN JW, SMITH BK, Medicine and science in sports and exercise, 41 (2009) 459. doi: 10.1249/MSS.0B013E3181949333. – 7. HASKELL WL, LEE IM, PATE RR, POWELL KE, BLAIR SN, FRANKLIN BA, MACERA CA, HEATH GW, THOMPSON PD, BAUMAN A, Medicine and science in sports and exercise, 39 (2007) 1423. doi: 10.1249/MSS.0B013E3180616B27. – 8. BATRAKOULIS A, JAMURTAS AZ, METSIOS GS, PERIVOLIOTIS K, LIGUORI G, FEITO Y, RIEBE D, THOMPSON WR, ANGELOPOULOS TJ, KRUSTRUP P, MOHR M, DRAGANIDIS D, POULIOS A, FATOUROS IG, Circ Cardiovasc Qual Outcomes, 15 (2022) E008243. doi: 10.1161/CIRCOUTCOMES.121.008243. – 9. OJA P, TITZE S, KOKKO S, KUJALA UM, HEINONEN A, KELLY P, KOSKI P, FOSTER C, British Journal of Sports Medicine 49 (2015) 434. doi: 10.1136/BJSPORTS-2014-093885. – 10. MILANOVIĆ Z, SPORIŠ G, WESTON M, Sports Med, 45 (2015) 1469. doi: 10.1007/S40279-015-0365-0. – 11. MILANOVIĆ Z, PANTELIĆ S, ČOVIĆ N, SPORIŠ G, MOHR M, KRUSTRUP P, British Journal of Sports Medicine, 53 (2019) 926. doi: 10.1136/BJSPORTS-2017-097885. – 12. RAMOS-CAMPO DJ, ANDREU CARAVACA L, MARTÍNEZ-RODRÍGUEZ A, RUBIO-ARIAS J, Biology (Basel), 10 (2021) 377. doi: 10.3390/biology10050377. – 13. SJÚRÐARSON T, BEJDER J, BREENFELDT ANDERSEN A, BONNE T, KYHL K, RÓIN T, PATURSSON P, ODDMARSDÓTTIR GREGERSEN N, SKORADAL MB, SCHLIEMANN M, LINDEGAARD M, WEIHE P, MOHR M, NORDSBORG NB, Physiol Rep, 10 (2022) E15382. doi: 10.14814/PHY2.15382. – 14. CASTAGNA C, BIZZINI M, PÓVOAS SCA, D'OTTAVIO S, Int J Sports Physiol Perform, 12 (2017) 1157. doi: 10.1123/ijspp.2016-0626. – 15. IMPELLIZZERI FM, RAMPININI E, COUTTS A, SASSI A, MARCORA SM, Medicine & Science in Sports & Exercise, 36 (2004) 1042. doi: 10.1249/01.mss.0000128199.23901.2f. – 16. MARATHE PH, GAO HX, CLOSE KL, J Diabetes, 9 (2017) 320. doi: 10.1111/1753-0407.12524. – 17. WHEELER ML, DUNBAR SA, JAACKS LM, KARMALLY W, MAYER-DAVIS E J, WYLIE-ROSETT J, YANCY WS, Jr Diabetes Care, 35 (2012) 434. doi: 10.2337/dc11-2216. – 18. MINISTRY OF FOOD, AGRICULTURE AND FISHERIES, De officielle kostråd [The official dietary advice] (Ministeriet for Fødevarer, Landbrug og Fiskeri - Fødevarestyrelsen, Glostrup, 2013). – 19. NORDIC COUNCIL OF MINISTERS, Nordic Nutrition Recommendations 2012: Integrating nutrition and physical activity (Nordic Council of Ministers, Copenhagen, 2014). doi. 10.6027/NORD2014-002. – 20. KRISTIANSEN J, SJÚRÐARSON T, GROVE EL, RASMUSSEN J, KRISTENSEN SD, HVAS AM, MOHR M, Scientific Reports, 12 (2022) 17295. doi: 10.1038/s41598-022-21655-w. - 21. FLØTUM LA, OTTESEN LS, KRUSTRUP P, MOHR M, BioMed Research International, 6 (2016) 7231545. doi: 10.1155/2016/7231545. – 22. GIBALA MJ, LITTLE JP, MACDONALD MJ, HAWLEY JA, The Journal of Physiology, 590 (2012) 1077. doi: 10.1113/jphysiol.2011.224725. – 23. HAMMAMI A, HARRABI B, MOHR M, KRUSTRUP P, Managing Sport and Leisure, 27 (2022) 26. doi: 10.1080/23750472.2020.1757494. – 24. IAIA FM, HELLSTEN Y, NIELSEN JJ, FERNSTRÖM M, SAHLIN K, BANGSBO J, Journal of Applied Physiology, 106 (2009) 73. doi: 10.1152/japplphysiol.90676.2008. – 25. RANDERS MB, NYBO L, PETERSEN J, NIELSEN JJ, CHRISTIANSEN L, BENDIKSEN M, BRITO J, BANGSBO J, KRUSTRUP P, Scandinavian Journal of Medicine & Science in Sports, 20 (2010) 14. doi: 10.1111/j.1600-0838.2010.01069.x. – 26. NYBO L, SUNDSTRUP E, JAKOBSEN MD, MOHR M HORNSTRUP, T, SIMONSEN L, BÜLOW J, RANDERS MB, NIELSEN JJ, AAGAARD P, KRUSTRUP P, Medicine and science in sports and exercise 42 (2010) 1951. doi: 10.1249/MSS.0b013e3181d99203. – 27. MOHR M, NORDSBORG NB, LINDENSKOV A, STEINHOLM H, NIELSEN HP, MORTENSEN J, WEIHE P, KRUSTRUP P, BioMed Research International, (2014) 728289. doi: 10.1155/2014/728289. – 28. MOHR M, LINDENSKOV A, HOLM P, NIELSEN H, MORTENSEN J, WEIHE P, KRUSTRUP P, Scand J Med Sci Sports, 24 (2014) 36. doi: 10.1111/sms.12278. – 29. SKORADAL MB, HELGE EW, JØRGENSEN NR, MORTENSEN J, WEIHE P, KRUSTRUP P, MOHR M, Scand J Med Sci Sports, 28 Suppl 1 (2018) 52. doi: 10.1111/sms.13252. – 30. DA SILVA SOARES DB, SHINJO SK, SANTOS AS, DE CASSIA ROSA DE JESUS J, SCHENK S, DE CASTRO GS, ZANOTELI E, KRUSTRUP P, DA SILVA MER, DE SOUSA MV, Exp Gerontol, 164 (2022) 111831. doi: 10.1016/j.exger.2022.111831. – 31. VIGH-LARSEN JF, ØRTENBLAD N, SPRIET LL, OVERGAARD K, MOHR M, Sports Med, 51 (2021) 1855. doi: 10.1007/s40279-021-01475-0. – 32. GOLLNICK PD, PIEHL K, SALTIN B, The Journal of Physiology, 241 (1974) 45. doi: 10.1113/jphysiol.1974.sp010639. – 33. HASLAM DW, JAMES WP, Lancet, 366 (2005) 1197. doi: 10.1016/s0140-6736(05)67483-1. – 34. ASTORINO TA, EDMUNDS RM., CLARK A, KING L, GALLANT RA, NAMM S, FISCHER A, WOOD KM, Medicine and science in sports and exercise, 49 (2017) 265. doi: 10.1249/mss.0000000000001099. – 35. HELGERUD J, KARLSEN T, KIM WY, HØYDAL KL, STØYLEN A, PEDERSEN H, BRIX L, RINGGAARD S, KVÆRNESS J, HOFF, J. Int J Sports Med 32 (2011) 54. doi: 10.1055/s-0030-1267180..

M. Mohr

Centre of Health Science, Faculty of Health, University of the Faroe Islands, Vestara Bryggja 15, FO-100 Tórshavn, Faroe Islands
e-mail: magnim@setur.fo

UTJECAJ KRUŽNOG TRENINGA CIJELOG TIJELA NA SASTAV TIJELA I KARDIO-RESPIRATORNU KONDICIJU KOD ODRASLIH OSOBA S PREKOMJERNOM TJELESNOM TEŽINOM I SJEDILAČKOG NAČINA ŽIVOTA – RANDOMIZIRANO KONTROLIRANO ISPITIVANJE

S A Ž E T A K

Pretilost i niska kardio-respiratorna kondicija su glavni čimbenici rizika za brojne nezarazne bolesti i smrtnost, te su učinkoviti protokoli liječenja za borbu protiv navedenih stanja iznimno opravdani. Procijenili smo učinak kružnog treninga visokog intenziteta (high-intensity circuit training; CIT) na sastav tijela i kardio-respiratornu kondiciju osoba s prekomjernom tjelesnom težinom i sjedilačkog načina života. Kardio-respiratorna kondicija i sastav tijela utvrđeni su prije i nakon 8-otjednog kružnog treninga (CIT; 4 kružna treninga visokog intenziteta za cijelo tijelo tjedno; dob, 38 ± 9 godina; visina, 174 ± 10 cm; tjelesna masa, 93.1 ± 22.2 kg; < = 32), te 8 tjedana bez aktivnosti (bez treninga ili promjene načina života u razdoblju od tjedna 0 do tjedna 8 (neither training nor lifestyle changes; CON); dob, 39 ± 7 godina, visina, 168 ± 8 cm, tjelesna masa, 89.5 ± 17.5 kg; < = 33). Dvostrana ponovljena mjerenja ANOVA-om otkrila su umjerena do velika smanjenja koja su utvrđena kod tjelesne mase, indeksa tjelesne mase i postotka masti nakon CIT treninga (d=0.43–0.81; P<0.05). S druge strane, svi parametri tjelesnog sastava ostali su nepromijenjeni nakon 8-otjedne neaktivnosti (P<0.05). Utvrđeno je malo do umjereno međusobno djelovanje između parametara grupe i trenutka evaluacije kod tjelesne mase, indeksa tjelesne mase i postotka masti (d=0.10–0.60; P<0.05). Mala poboljšanja uočena su kod VO_{2max} nakon CIT treninga (d=0.48 [0.11–0.85]; P=0.010), dok su mala do umjerena smanjenja utvrđena kod VO_{2max} i PV nakon neaktivnosti (d=0.47 [0.11–0.83], odnosno 0.64 [0.26–1.01]; P<0.05). Utvrđeno je malo međusobno djelovanje između parametara grupe i trenutka evaluacije kod VO_{2max} (d= 0.19 [0.13–0.26]; P<0.001). Naši rezultati ukazuju na to da 8-otjedni kružni trening za cijelo tijelo može poboljšati kardio-respiratornu kondiciju i sastav tijela kod osoba s prekomjernom tjelesnom težinom i sjedilačkog načina života.