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High- or moderate-intensity training promotes change in cardiorespiratory fitness, but not visceral fat, in obese men: A randomised trial of equal energy expenditure exercise

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ABSTRACT

This study compared the effects of two exercise programs performed in different intensities, but equal overall energy expenditure (EE). Adult men with obesity (29.6 ± 4.9 years; BMI = 35.1 ± 3.3 kg/m^2) were randomised to one of three groups: High-intensity interval training (HIIT- 10 × 1:1 min 100% VO_{2max}; n = 13); Moderate-intensity continuous training (MICT - ˜35 min 65% VO_{2max}; n = 13) or Control (no training; n = 6). The session EE (HIIT = 278.0 ± 37.1; MICT = 299.4 ± 17.8 kcal) was calculated by adding the aerobic contribution (VO_2 of the session minus VO_2 at rest) and anaerobic (difference between the VO_2 estimated and VO_2 measured in session). The anaerobic contribution in HIIT was 30%, showing that a substantial portion of the energy for 10 x 1 min HIIT comes from non-oxidative metabolism. VO_{2max} improved in both trained groups (p = 0.006), while systolic blood pressure decreased ($p < 0.001$) and diastolic blood pressure was not altered. Visceral and subcutaneous fat stores did not change after the intervention, indicating a longer intervention may be necessary for changes in adiposity. Six weeks of HIIT or MICT were effective in improving cardiorespiratory fitness and blood pressure in previously inactive obese men.

1. Introduction

Low cardiorespiratory fitness (CRF) usually represented by maximum oxygen uptake (VO_{2max}) is considered one of the most important risk factors for mortality worldwide. Low VO_{2max} is even seen as a better predictor of mortality than degree of obesity, although excess adiposity is also clearly important (Di Angelantonio et al., 2016).

Moderate-intensity continuous training (MICT) is adopted to improve CRF and control body fat (Saris et al., 2003; Donnelly et al., 2009; Garber et al., 2011). Nevertheless, high-intensity interval training (HIIT), which can be adopted in various forms, has been shown as an interesting alternative to improve the CRF and to reduce body fat. In addition, some studies showed that HIIT can favourably impact the neuroendocrine axis (such as leptin levels) and improve lipid metabolism in overweight/obese and lean population (Caldeira et al., 2018; Inoue et al., 2018; Blüher et al., 2017).

Despite effectiveness to improve CRF and reduce adiposity, it is unclear whether HIIT is superior to MICT. In studies comparing high and moderate intensity exercise on effects on body and fat mass reduction it is important to consider the energy expenditure (EE) of exercise sessions (Keating et al., 2017; Andreato et al., 2019). Most studies that support HIIT for body mass and/or body fat reduction conducted the sessions without the equalization of EE (Tjønna et al., 2008; Koubaa et al., 2013; Shepherd et al., 2013). Other studies present only the

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oxygen consumption thus providing information only of aerobic metabolism, and therefore may underestimate EE of HIIT (Hwang et al., 2016; Kong et al., 2016).

Recently, we showed that anaerobic metabolism contribution seems to be relevant during acute high-intensity exercise in lean subjects, representing ˜30% total EE (Panissa et al., 2018). However, there is a lack of information about exercise protocols with EE equalization, particularly in obese populations, which makes it difficult to interpret if alterations in fat mass occurred because of differences in exercise intensity or EE.

Thus, the knowledge about accurate EE and energy system contribution in studies comparing HIIT and MICT is important to understand the isolated effect of intensity or pattern because when protocols use poor EE estimations or matching, it is not possible to determine if the effect is due to differences in volume (EE) of exercise intensity performed.

The aim of this study was to analyze different intensities of exercise with isocaloric energy expenditure (considering aerobic and anaerobic energy system contribution) on CRF (maximum oxygen uptake), visceral and subcutaneous fat mass, blood cholesterol, triacylglycerol, HDL-cholesterol, leptin and blood pressure of sedentary obese men. Measures were made pre and post six weeks of training, considering previous studies that showed that short-term aerobic training was able to improve VO_{2max} (Batacan et al., 2017) and body fat even without weight loss (Wewege et al., 2017).

2. Materials and methods

The present study is part of a main project entitled “The impact of two Models of Aerobic Training on Cognitive Function, Morphological and Systemic Immunometabolic Changes of Young People with Obesity”, which is registered with ReBec (Brazilian Clinical Trial Registry - RBR-7pdc8y) and it was developed in accordance with the *Declaration of Helsinki*, approved by the Research Ethics Committee (No. 46948215.8.0000.5402). Participants became aware of all study procedures and signed a consent form.

The recruitment of participants was performed by digital and television media and the interested participants were interviewed. The interview considers the following criteria of inclusion: being male, between 18 and 35 years old, BMI ≥ 30 (kg/m^2) and not practicing regular physical activities (≤ two times per week and VO_2max < 47 mL/kg/min). Individuals with established illnesses, smokers, with high consumption of alcohol and those who practiced regular physical exercises were not included in the study. For the present analyses, the results of those who completed < 75% of training sessions were not included. Recruitment procedures were repeated five times in waves of 7–17 participants (n = 173). In total 115 participants did not meet inclusion criteria, 26 did not perform the principal evaluations of the study (performance variables and arterial blood pressure) leaving a sample size of 32 participants (n = 13 in High-Intensity Interval Training (HIIT), n = 13 in Moderate-Intensity Continuous Training (MICT) and n = 6 in Control Group) (Fig. 1).

2.1. Experimental design

Prior to initiating the specific project procedures, all subjects were referred to a cardiologist for cardiopulmonary health evaluation. After the official consent of the cardiologist and the evaluations of VO_2 and visceral fat, the participants were randomized into three groups: (1) High-Intensity Interval Training (HIIT); (2) Moderate-Intensity Continuous Training (MICT) and (3) Control group, who did not perform any type of exercise. The randomization was stratified according to visceral fat and VO_2max values. The protocol of exercise training had a frequency of three times per week and was performed over six weeks. The tests were performed before the start the training program (*Pre*) and at the end of the sixth week of training (*Post*) (Fig. 2). There was no nutritional intervention provided, but the participants were requested to keep their habitual food intake and avoid of other types of physical training throughout the 6 weeks of the study.

2.2. Body composition assessments

The evaluation of the body composition was performed by bioelectrical-impedance with an eight-electrode device (InBody 720 - Biospace, Seoul, Korea). The evaluation of visceral (VF) and subcutaneous fat (SF) were performed by ultrasonography device (TOSHIBA-Eccocee, convex transducer of 3.7 MHz, Tokyo, Japan) operated by a physician in a specialized institution in imaging diagnostics. The parameters and methods for determination of VF and SF were based on previously described procedures presented by Ribeiro-Filho et al. (2003).

2.3. Familiarisation and incremental test

Before treadmill testing, all participants were familiarized with the protocol and use of the treadmill (Inbramed, ATL model, Brazil). Familiarization consisted of walking and jogging with practice exiting the treadmill safely.

The maximal incremental test had the objective to measuring the maximum oxygen consumption (VO_{2max}), as well as the maximum aerobic velocity (MAV). All participants performed a warm-up of 7 min walking at 5 km/h before test. The initial speed was 5.5 km/h, with increments of 0.5 km/h every minute and ended with voluntary exhaustion of the participant. Throughout the test treadmill inclination was maintained at 1% and the gases analysis were collected breath-by-breath with a silicon mask connected to the gas analyzer (Quark PFT - Cosmed®, Rome, Italy). This protocol was also applied after the third week for intensity adjustment and at the end of the sixth week in order to evaluate the adaptations after the intervention period.

The VO_2 values were analyzed with averages of the last 20 s of each stage and the VO_{2max} was assumed as the highest average value attained during the test, while the highest sustained velocity during the entire stage was assumed to be MAV. When the participant reached the exhaustion before the end of the stage the formula proposed by Kuipers et al. (1985) was applied to determine MAV: MAV = velocity of last stage completed + (time (s) remaining in the last stage / duration of stage (s)) multiplied by velocity of increment.

2.4. Submaximal intensity tests

The participants performed four tests with submaximal intensities of *7-min* to determine the total EE of training sessions. The intensities were 40, 50, 75 and 85% of the MAV of each participant. These tests were performed in random order over a period of 24–72 hours before training

2.5. Energy expenditure estimative and equalization between intensities

The EE calculation was considered as the sum of aerobic and anaerobic metabolism, with the aerobic metabolism contribution assumed as integral VO_2 area during effort and the anaerobic metabolism assumed as the method of oxygen deficit (Medbo et al., 1988). For oxygen deficit determination, the average VO_2 values of the last minute of each submaximal test were considered to develop a linear regression and estimate the required VO_2 (VO_2demand) in MAV (Fig. 3). The difference between VO_2 measured on each minute of effort during HIIT sessions was subtracted from the value of VO_2demand (estimated by the linear regression). This value was considered as the anaerobic contribution to perform efforts in MAV (Fig. 3).

All subjects of this study performed HIIT exercise before the start of the intervention in order to determine anaerobic contribution. The protocol adopted was composed by 10 efforts at 100% of MAV with *1-*

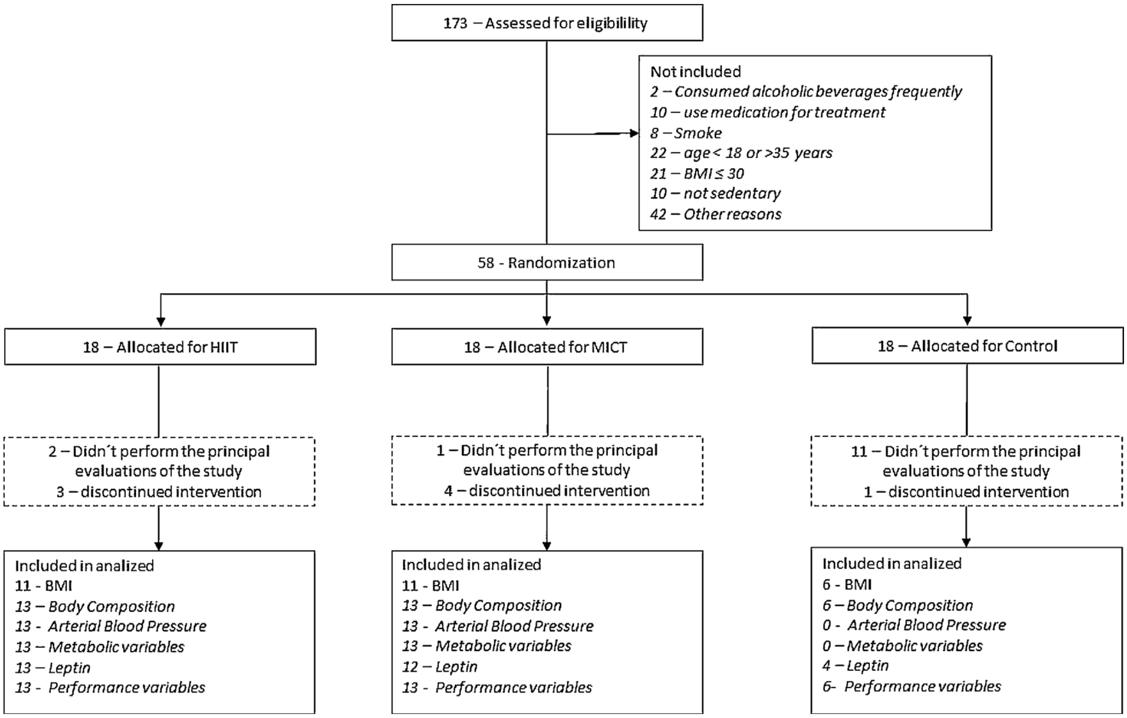

Fig. 1. Graphical diagram of the recruitment process and randomization of the participants in the three groups.

min duration interspersed by *1-min* passive recovery interval (10 × 1:1 min). Before and after each session of HIIT or MICT participants completed *5-min* at 5 km/h for warm-up and cool down.

In addition to the HIIT group, the members of the MICT group also performed the same protocol and the EE values served as reference in the prescription of the continuous model. For this, they underwent a session of 30 min to 65% of the MAV. In this model of evaluation, VO_2 stabilizes after the initial minutes and is maintained until the end. This enabled the quantification of the energy cost per minute (kcal/min), and from that value, the session volume was calculated to match the EE in the HIIT (previously performed). These calculations were performed individually and considered the cost of 20.92 kJ (˜ 5 kcal) of each 1 L of O_2 utilized. Thus, each subject in the MICT group had their EE equated with the HIIT test itself.

2.6. Blood measurements

2.6.1. Arterial blood pressure

The measurements of systolic (SBP) and diastolic blood pressure (DBP) were made with an aneroid sphygmomanometer and performed before the first and last day of training. The participants remained at rest between 10 and 15 min prior to the measurements.

2.6.2. Blood samples

Blood samples were obtained by venipuncture of an antecubital vein. After 12 h of overnight fasting, 8.5 mL of blood was collected in separator gel tubes (BD SST® II Advance®, Becton Dickinson), *Pre* and *Post* six weeks of training. The tubes were then centrifuged at 3000 rpm for 15 min at 4 °C and the aliquots stored in polypropylene tubes and stored at – 80 °C.

Total cholesterol, triacylglycerol (TAG) and HDL-cholesterol analysis were performed by the colorimetric method with commercial enzymatic kits (Labtest®, Minas Gerais, Brazil). Leptin (R&D Systems, Minneapolis, MN, USA) was assessed by ELISA commercial kits and according the manufacturer's instruction.

2.7. Statistical analysis

The normality of data was verified using the Shapiro-Wilk test and descriptive data are presented as means and standard deviation (SD). A two-way analysis of variance ANOVA [Time (*Pre* vs *Post*) and Group (Control vs HIIT vs MICT)] with repeated measures was conducted for body composition and exercise testing variables. For blood pressure, lipid profile and leptin the same two-way ANOVA was conducted but only HIIT vs MICT (control group was not included in this analysis) were analyzed. Pearson's correlation was used to evaluate associations between variables. For the non-parametric variables (Total distance and

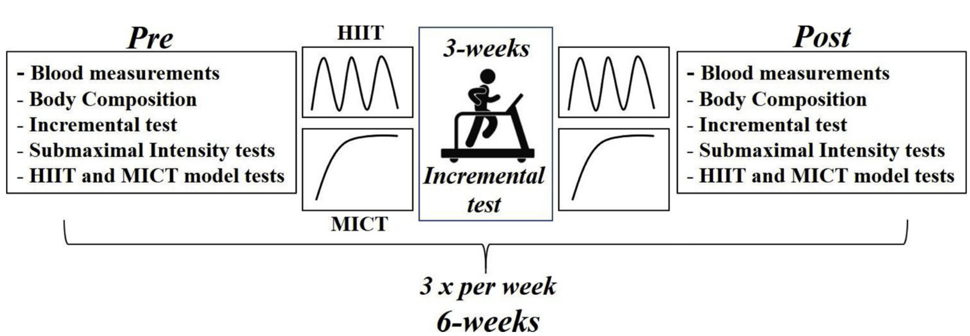

Fig. 2. Graphic scheme of assessments carried out *Pre* and *Post* six weeks of training.

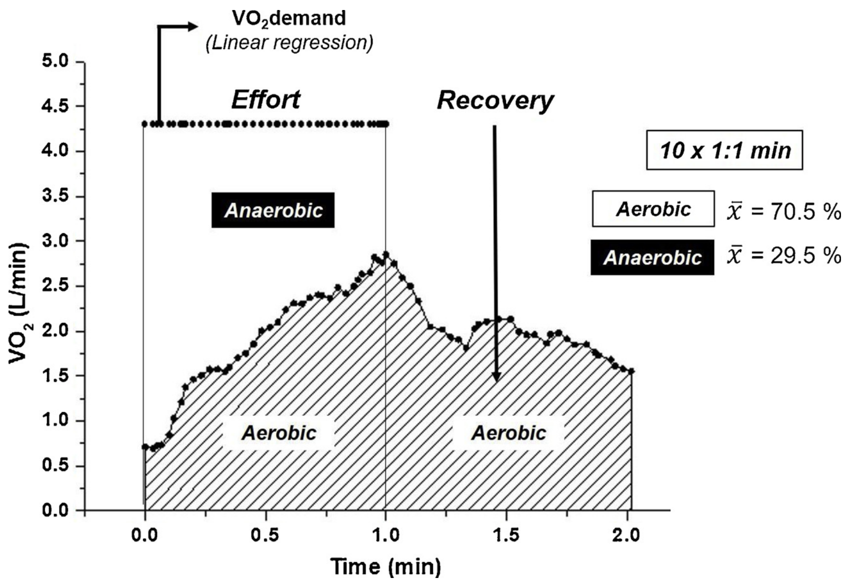

Fig. 3. Contribution of energy supply systems during a training session of the HIIT model.

Session volume) Mann-Whitney analysis was used for independent samples. Statistical significance was set at $p < 0.05$ for all analysis and the calculations were conducted using SPSS version 22.0 (SPSS Inc., Chicago, IL).

3. Results

As designed, the EE in both training models were not different ($p = 0.678$), ensuring that the sessions were isocaloric; HIIT (278.0 ± 37.1 kcal) and MICT (299.4 ± 17.8 kcal) groups. The energy system contribution in HIIT was (70%:30%; aerobic:anaerobic), showing that when only oxygen uptake is considered EE is underestimated by 30%. Although similar EE between the training models was assured, the session volume (min) was different with lower duration in HIIT than MICT (19.0 ± 0 and 34.0 ± 4.8 min for HIIT and MICT respectively, $p < 0.001$), and promoted a large difference in the total distance performed at the end of the six weeks between the training groups (28.7 ± 2.5 and 60.7 ± 7.2 km for HIIT and MICT respectively, $p < 0.001$).

At the end of the six weeks there was a main effect of time of measurement, with increase in VO_{2max} *Pre* from *Post* (F = 8.891; $p = 0.006$). The mean change in VO_{2max} for HIIT was 2.86 ml/kg/min (95% CI: 1.49, 4.22), for MICT was 1.95 ml/kg/min (95% CI: 0.63, 3.27), and for CTL was −0.14 ml/kg/min (95% CI: −2.16, 1.89). For MAV, there was a significant Group x Time interaction (F = 4.624; $p = 0.018$). The mean change in MAV for HIIT was 0.85 km/h (95% CI: 0.55, 1.16), for MICT was 0.50 km/h (95% CI: 0.21, 0.78), and for CTL was −0.008 km/h (95% CI: −0.44, 0.46)

The Table 1 presents these results, together with body composition values, represented by visceral fat HIIT [HIIT: −0.34 cm (95% CI: -0.93, 0.24); MICT: −0.12 cm (95% CI: −0.68, 0.43); CTL: −0.19 cm (95% CI: −1.04, 0.65)], subcutaneous fat [HIIT: 0.16 cm (95% CI: −0.34, 0.01); MICT: 0.15 cm (95% CI: −0.19, 0.16); CTL: −0.06 cm (95% CI: −0.34, 0.21)] and BMI [HIIT: -0.31 kg/m^2 (95% CI: −0.73, 0.11); MICT: −0.49 kg/m^2 (95% CI: −0.93, −0.04); CTL: 0.05 kg/m^2 (95% CI: −0.56, 0.67)]. The values of the fat depots did not change significantly after six weeks of training, nor did the BMI.

Lipid profile [HIIT: −23.12 mg/dL (95% CI: −44.27, −1.98); MICT: −11.04 mg/dL (95% CI: −31.33, 9.24) for triglycerides, HIIT: −4.34 mg/dL (95% CI: −7.35, −1.33); MICT: −4.34 mg/dL (95% CI: −7.24, −1.43) for HDL and HIIT: −5.36 mg/dL (95% CI: −26.91, 16.18); MICT: −3.48 mg/dL (95% CI: −24.01, 17.05) for NHDL], leptin [HIIT: 0.85 ng/dL (95% CI: 0.55, 1.16); MICT: 0.503 ng/dL (95% CI: 0.21, 0.78)] and DBP [HIIT: −3.99 mmHg (95% CI: −14.84, 6.85); MICT: −10.78 mmHg (95% IC: −21.24, −0.33)] did not change, but the SBP decreased (F = 20.417, $p < 0.001$, main effect of time) after six weeks of training (Table 2). The mean change in SBP for HIIT was -6.62 mmHg (95% CI: −20.92, 7.67) and MICT was −19.70 mmHg h (95% CI: −33.47, −5.93).

4. Discussion

The main finding of the present study was that six weeks of isocaloric training, HIIT or MICT, promoted similar adaptation to CRF and blood pressure values in sedentary obese males. Body composition and leptin levels did not change.

This was the first study to quantify the anaerobic contribution participation (via oxygen deficit) in a HIIT session and considered it for equalization with the MICT model in a longitudinal study involving obese adult males. It is important to note that, the HIIT session of this study (10 × 1:1) was sustained in a proportion of ˜70/30% by aerobic and anaerobic metabolism respectively. A similar proportion was also found in our recent study with active lean subjects (Panissa et al., 2018). If the EE were calculated considering only VO_2 values, the MICT session would have a reduction of approximately 10 min in volume and ˜85 kcal in each exercise session. When these differences are calculated for the six weeks of training, the cumulative value amounts would be ˜1530 kcal.

It is important to observe there with the same EE, the HIIT group completed half of the time and distance when compared with MICT. Previous studies have been showed in lean and active males that running efficiency decreases in highest intensities, these studies included aerobic and anaerobic participation to calculated metabolic demand (Keir et al., 2012; Beneke and Leithäuser, 2017). Thus, this decrease in the mechanical efficiency of running promotes greater energy demand and may allow for greater EE in a shorter session time.

As the main focus of this study was on the changes in CRF many physiological adaptations are related to their changes. Several studies have shown that HIIT and MICT lead to the improvement of ACR in lean and overweight individuals, but in obese individuals without diseases few studies have been performed (Milanovic et al., 2015; Batacan et al., 2017). After six weeks of training, participants showed an improvement in CRF of ˜5–10%. Although there were no differences between MICT and HIIT, the characteristics of the short-term HIIT model may appear

Table 1
Values of body composition and performance variables before and after six weeks of treadmill training for trained groups and (high-intensity interval training - HIIT, and moderate-intensity contiuous trainig - MICT) and control group (not trained).

		Pre Mean (SD)	Post Mean (SD)	Δ%	Effects	F	*p-value*	η^2
BODY COMPOSITION								
BMI	**Control**	35.4 (3.3)	35.5 (3.1)	0.2	Time	2.515	0.124	0.085
(kg/m^2)	**HIIT**	34.3 (2.3)	33.9 (2.6)	−1.0	Group	1.077	0.355	0.074
	MICT	35.9 (4.3)	35.6 (4.4)	−0.7	TxG	1.081	0.354	0.074
Visceral	**Control**	7.0 (1.9)	6.7 (2.2)	−4.5	Time	0.941	0.340	0.031
fat (cm)	**HIIT**	5.8 (1.7)	5.6 (0.9)	0.9	Group	1.797	0.184	0.110
	MICT	7.0 (2.0)	6.9 (2.0)	−0.9	TxG	0.075	0.928	0.005
Subcutaneous	**Control**	3.7 (1.0)	3.7 (1.1)	−0.8	Time	1.292	0.265	0.043
fat (cm)	**HIIT**	3.0 (1.0)	2.9 (1.1)	−6.5	Group	2.231	0.126	0.133
	MICT	2.8 (0.7)	2.8 (0.8)	−0.3	TxG	0.841	0.441	0.055
PERFORMANCE								
VO_{2max}	**Control**	32.6 (4.9)	32.9 (5.3)	1.3	Time *	8.991	0.006	0.237
(mL/kg/min)	**HIIT**	33.6 (3.8)	36.5 (2.9)	9.4	Group	1.052	0.362	0.068
	MICT	34.4 (4.5)	36.1 (3.2)	5.4	TxG	1.666	0.207	0.103
MAV	**Control**	9.1 (1.0)	9.2 (1.1)	0.7	Time *	21.852	0.000	0.430
(km/h)	**HIIT**	9.7 (1.0)	10.6 (0.7)	9.4	Group	2.506	0.099	0.147
	MICT	9.5 (1.0)	10.0 (0.9)	5.9	TxG *	4.624	0.018	0.242

BMI: body mass index; **VO_2max**: maximal oxygen consumption; **MAV**: maximal aerobic velocity. * $p < 0.05$.

to be more efficient (ie less time and total distance traveled) to improve CRF.

Although both protocols were able to increase CRF, neither MICT or HIIT was able to change lipid profile and body composition. These results are in accordance with the meta-analysis performed by Batacan et al. (2017) which analyzed separately short-term HIIT (< 12 weeks) and long-term HIIT (> 12 weeks). In relation to the lipid profile, Batacan et al. (2017) found no evidence that less than 12 weeks of HIIT would improve concentrations of HDL, Col-NHDL or triacylglycerol. Likewise, in the same meta-analysis there were no changes in body fat and %fat after HIIT short-term, although the authors found improvements for waist circumference and this should be considered as a positive response.

Nevertheless, the results found in the present study can also be justified, at least, by lack of specific controlling of food intake, since in our study we did not control diet and it was just recommended to participants maintain their normal eating habits. Therefore, this lack of nutritional control could contribute to the absence of a possible improvement in lipid profile and body composition. On the other hand, longer-term HIIT may be needed to induce changes in body composition and biochemistry parameters in HIIT programs (Keating et al., 2017; Batacan et al., 2017).

Similar to lipid profile and body composition, leptin concentrations were unchanged after six weeks of training in both groups. This may be explained by the findings that body fat that did not decrease. However, in two studies conducted by our laboratory we found reductions in leptin concentrations after five (Caldeira et al., 2018) and eight (Inoue et al., 2018) weeks of aerobic training even without a reduction in fat mass. In both studies, participants were young normal weight, physically active males and the reduction in leptin levels seems to be related

Table 2
Values of blood pressure, lipid profile and leptin hormone before and after six weeks of treadmill training for trained groups and (high-intensity interval training - HIIT, and moderate-intensity contiuous trainig - MICT).

		Pre Mean (SD)	Post Mean (SD)	Δ%	Effects	F	*p-valor*	η^2
BLOOD PRESSURE								
SBP	**HIIT**	129.3 (11.5)	122.0 (14.0)	−5.6	Time *	20.417	0.000	0.460
(mmHg)	**MICT**	125.8 (11.3)	115.1 (10.5)	−8.2	Group	1.543	0.226	0.060
					TxG	0.722	0.404	0.029
DBP	**HIIT**	85.5 (8.5)	81.9 (11.6)	−3.4	Time	2.974	0.097	0.110
(mmHg)	**MICT**	86.0 (8.6)	80.8 (8.8)	−5.1	Group	0.010	0.922	0.000
					TxG	0.103	0.751	0.004
LIPID PROFILE								
Triacylglycerol (mg/dL)	**HIIT**	176.5 (47.4)	157.3 (33.7)	−7.1	Time	2.826	0.106	0.105
	MICT	182.9 (49.8)	172.0 (52.1)	−4.2	Group	0.447	0.510	0.018
					TxG	0.214	0.648	0.009
HDL	**HIIT**	33.1 (5.7)	31.7 (5.9)	−3.9	Time	2.111	0.159	0.081
(mg/dL)	**MICT**	34.3 (7.6)	32.4 (3.2)	−3.0	Group	0.241	0.628	0.010
					TxG	0.051	0.824	0.002
Col-NHDL (mg/dL)	**HIIT**	166.7 (51.6)	157.2 (51.5)	−3.8	Time	1.249	0.275	0.049
	MICT	150.9 (37.9)	147.7 (34.2)	0.2	Group	0.586	0.451	0.024
					TxG	0.311	0.582	0.013
HORMONE								
Leptin	**HIIT**	27.8 (10.6)	25.6 (11.2)	−5.1	Time	2.194	0.152	0.087
(ng/mL)	**MICT**	30.2 (23.4)	24.8 (12.7)	−5.9	Group	0.018	0.894	0.001
					TxG	0.375	0.546	0.016

SBP: systolic blood pressure; **DBP**: diastolic blood pressure; **HDL**: high density lipoprotein; **Col-NHDL**: non-HDL cholesterol. * $p < 0.05$.

to a high EE during exercise sessions. These data raise the question whether similar protocols of high EE could be applied to obese participants to decrease leptin, an important inflammatory marker. In addition, de Souza et al. (2018) have found an acute HIIT were able to decrease leptin levels while MICT increased it.

In addition to the results presented above, changes in blood pressure are very important for cardiovascular outcomes. In the present study, after six weeks, both HIIT and MICT promoted reductions in SBP values, and the mean values of DBP also were lower at *Post*, although not significant ($p = 0.097$). Various HIIT models have shown important reduction in BP parameters (Weston et al., 2014) especially those lasting more than 12 weeks (average reduction of 4.57 and 2.94 mmHg of SBP and DBP, respectively) (Batacan et al., 2017). It is believed that reductions greater than 4 mmHg in SBP can reduce mortality from cardiovascular diseases by 5–20% (Taylor et al., 2011). It is relevant to mention that our study lasted only six weeks and promoted mean reductions of 9 mmHg in SBP and 4.3 mmHg in DBP.

5. Conclusions

The results indicate that both proposed training models were effective in improving CRF. However, the HIIT model required a much shorter session time than the MICT. The adequate calculation of the energy expenditure of each exercise model allowed a correct equalization between the groups and showed that the proposed HIIT model is sustained with a significant contribution of the anaerobic metabolism.

Thus, it is concluded that the HIIT may be an alternative of aerobic exercise to minimize the pathogenesis of obesity and attack the lack of time widely reported.

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