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ORIGINAL RESEARCH

High-Intensity Interval Training and Isocaloric Moderate-Intensity Continuous Training Result in Similar Improvements in Body Composition and Fitness in Obese Individuals

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This study aimed to determine the effects of 12 weeks of isocaloric programs of high-intensity intermittent training (HIIT) or moderate-intensity continuous training (MICT) or a short-duration HIIT (1/2HIIT) inducing only half the energy deficit on a cycle ergometer, on body weight and composition, cardiovascular fitness, resting metabolism rate (RMR), respiratory exchange ratio (RER), nonexercise physical activity (PA) levels and fasting and postprandial insulin response in sedentary obese individuals. Forty-six sedentary obese individuals (30 women), with a mean BMI of 33.3 ± 2.9 kg/m^2 and a mean age of 34.4 ± 8.8 years were randomly assigned to one of the three training groups: HIIT (n = 16), MICT (n = 14) or 1/2HIIT (n = 16) and exercise was performed 3 times/week for 12 weeks. Overall, there was a significant reduction in body weight, waist ($p < .001$) and hip ($p < .01$) circumference,, trunk and leg fat mass (FM; $p < .01$) and an increase in trunk and leg fat free mass (FFM; $p < .01$) and cardiovascular fitness (VO_{2max} in ml/kg/min; $p < .001$) with exercise. However, no significant differences were observed between groups. There was no significant change in RMR, RER, nonexercise PA levels, fasting insulin or insulin sensitivity with exercise or between groups. There was a tendency for a reduction in AUC insulin with exercise ($p = .069$), but no differences between groups. These results indicate that isocaloric training protocols of HIIT or MICT (or 1/2HIIT inducing only half the energy deficit) exert similar metabolic and cardiovascular improvements in sedentary obese individuals.

Keywords: exercise, obesity, metabolism, insulin

It is widely accepted that exercise should always be present in any intervention aimed to manage obesity, due to its potential in improving cardiovascular fitness (Ross et al. 2000) and preserving fat-free mass (Stiegler and Cunliffe 2006). However, most reviews and meta-analyses looking at the effect of exercise on weight loss (WL) report disappointing results, with only a moderate WL (2–3kg) being achieved with exercise alone (Catenacci and Wyatt 2007; Shaw et al. 2006).

The most recent international physical activity (PA) recommendations for WL advocate at least 150 min of exercise/week to achieve minimum WL (2–3kg; Donnelly et al. 2009). This duration involves a considerable commitment and is likely to contribute to low compliance from exercise programs, especially in the obese population, with lack of time being the most commonly referred barrier for not exercising in this group (Fox et al. 2012; Rye et al. 2009).

High intensity exercise offers a more time-efficient option, but is potentially a problem because of low tolerance in obese people (De Feo 2013). A solution to this barrier would be to perform bouts of high-intensity exercise alternated with bouts of low-intensity exercise; known as high-intensity interval training (HIIT). Even

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though HIIT has been advocated as the new exercise pill (Boutcher, 2011), the impact of HIIT on body weight and composition is controversial, with some showing better results after HIIT, compared with moderate intensity continuous training (MICT), in normal-weight (Trapp et al., 2008) and obese individuals (Sijie et al., 2012), others no difference (Tjonna et al., 2008) or even superiority of MICT (Keating et al., 2014; Nybo et al., 2010). More research is, therefore, needed to test the potential superiority of HIIT (vs MICT) on body weight and composition and metabolism in general.

Therefore, the aim of this study was to compare the effects of 12 weeks of isocaloric programs of HIIT or MICT, or a short-duration HIIT, inducing only half the energy deficit of HIIT and MICT (1/2 HIIT), performed on a cycle ergometer, on body weight and composition, fasting and postprandial insulin response and cardiovascular fitness in obese individuals. Moreover we were interested in investigating the potential role of fat oxidation and nonexercise PA levels on the superiority of HIIT. It was hypothesized that HIIT would result in a larger weight and fat mass loss than MICT and that 1/2HIIT would produce similar results to MICT.

Subjects and Methods

Subjects

Forty six sedentary obese individuals (30 female, 16 male), with an age of 34.4 ± 8.8 years, a weight of 98.5 ± 14.3kg and a BMI of 33.3 ± 2.9 kg/m^2 were recruited for this study.

Sedentary lifestyle was defined as not engaged in strenuous work or in regular brisk leisure physical activity more than once a week or in light exercise for more than 20 min/day on more than three times per week. This was assessed through an exercise history of the 3 months before the study. Exclusion criteria included: being on a weight loss diet or weight unstable (>2kg variation over the last 3 months), taking any medication known to affect appetite or induce WL or having a restraint score derived from the Three Factor Eating Behavior Questionnaire (Stunkard and Messick 1985) >12.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and was approved by the regional Ethics Committee for Medical Research (Ref. 2010/447). Written informed consent was obtained from all participants before enrolling in the study.

Participants were randomly allocated to either HIIT (n = 16), 1/2HIIT (n = 16) or MICT (n = 14) for 12 weeks. However, for various reasons, three withdrew from the HIIT (one due to muscle pain and 2 due to lack of time), one from the MICT (for family reasons) and seven from the S-HIIT groups (three due to muscle pain, three due to lack of time and one for family reasons). There were no significant differences in age, BMI or any of the variables measured, between those who withdraw and those who completed the intervention.

Detailed Description of the Study

Participants underwent a 12-week supervised exercise program and were asked to maintain their normal diet throughout the study. Several measurements were performed before and after the intervention including: anthropometric measurements, body composition, maximal oxygen consumption (VO_{2max}), resting metabolic rate (RMR) and fasting substrate oxidation, habitual food intake, nonexercise physical activity (PA) levels and fasting and postprandial insulin levels.

Exercise Intervention. All participants exercised three times per week for 12 weeks and all sessions were supervised. Exercise was carried out on a Monark cycle ergometer (Ergomedic 839E, Monark 2008, Sweden). Each exercise session started with a 5-min warm-up, and finished with a 5-min cool down. Heart rate (HR) was recorded during each exercise session using Polar F6M heart rate monitor (Polar type 610, Polar Electro Oy, Finland).

The HIIT protocol consisted of 8 s of sprinting (during which participants worked as hard as possible) and 12 s of recovery phase (during which participants turned the pedals as slowly as possible). Participants followed a prerecorded tape, indicating when to start sprinting and when to slow down. The resistance used was that needed to increase the participants HR to 85–90% of their maximal HR (HR_{max}). A ramping approach was used to accommodate any increase in training effect and VO_{2max}. Therefore, resistance and work load were accordingly increased when appropriate. To account for changes in VO_{2max} and body weight, a submaximal VO_{2max} test was performed at week 4 and 8 to recalculate the prescribed exercise duration and energy deficit for all three groups.

The HIIT protocol was designed to induce a 250kcal energy deficit and the duration of the exercise session was individually tailored. Participants in the 1/2HIIT group followed the same protocol as the HIIT group, but aiming at an energy deficit of 125kcal (approximately half of time of the HIIT). The MICT consisted of continuous cycling at 70% of HR_{max}. As in HIIT group, the duration of exercise session was estimated for each participant individually, to induce a 250kcal energy deficit.

Anthropometrics and Body Composition. Weight, height, waist and hip circumference were measured in fasting, after emptying the bladder and with participants wearing underwear only. Weight was measured using an electronic platform scale (Seca 877, Hamburg, Germany) and height using a wall-mounted stadiometer (Seca 217, Hamburg, Germany).

A dual energy X-ray absorptiometry (DXA) scan (Hologic, Discovery A, software version 12.7.4.2. USA.) was used for assessing body composition, three hours after a standardized breakfast. Participants wore underwear during scan procedures and were scanned in supine position. Due to size constrains of the DXA platform, the majority of the participants did not fit in the scan, with parts of the arms being cut. For that reason only

the composition of the trunk (area distal to the head and superior to the pelvis without the upper limbs) and legs were analyzed. Moreover, due to a systematic error, data were only available in 17 out of the 35 participants. All the scans were analyzed by the same person, to minimize interobserver variation.

VO_{2max} Measurement. VO_{2max} was measured on a cycle ergometer (Ergomedic 839E, Monark 2008, Sweden), using the system Oxigen Pro (Viasys Healthcare, Hoechberg, Germany). The test started with a 5 min warm up, at a resistance of 50 W and afterward the workload was gradually increased until maximal resistance. A respiratory exchange ratio of 1.05 or above was set as criteria for achieving VO_{2max}. HR was monitored throughout the test using a Polar F6M HR monitor (Polar type 610, Polar Electro Oy, Finland). Maximal HR was defined by adding five beats to the highest HR value obtained during the VO_{2max} test.

Resting Metabolic Rate. RMR was measured using indirect calorimetry (Jaeger Oxycon Pro, Viasys Healthcare, Hoechberg, Germany), following gold standard procedures (Compher et al. 2006). Respiratory Exchange Ratio (RER) was calculated as the ratio of carbon dioxide produced to oxygen consumed.

Nonexercise PA Levels. Non–exercise PA levels were measured using a uniaxial accelerometer monitor (*Actigraph GT1M, Pensecalo, FL*). The epoch interval for the ActiGraph monitor was set at 1 min, and the output was expressed as counts×min^{-1}. Sedentary, light and moderate to vigorous PA were set at 0–99; 100–2019 and > 2020 counts/min, respectively (Troiano et al. 2008).

Participants were asked to use an accelerometer for seven consecutive days before the start of the study and at week 6 and 12. Participants were asked to take off the accelerometer during exercise training, to be able to measure nonexercise PA.

Data were included if the participant had accumulated at least 10h of valid activity recordings per day for at least 4 days (including one weekend day). Five participants were excluded from the analysis for not complying with the previous criteria.

Fasting and Postprandial Levels of Glucose and Insulin. Both before and after the intervention (at least 48 hr after the last exercise session), participants arrived at the research facility after a 12 hr fast. On each occasion an intravenous cannula was inserted into an antecubital vein. A fasting baseline blood sample was taken and after that participants were instructed to consume a standard breakfast (time = zero) (consisting of bread, orange juice, milk, cheese and jam: 600 kcal, 17% protein, 35% fat, 48% carbohydrate) within 10 min. Blood samples were taken at regular intervals for a period of 3 hr (15, 30, 45, 60, 90, 120, 150 and 180 min).

Venous blood was collected into lithium heparin tubes for the measurement of glucose and potassium EDTA-coated tubes, containing 500KIU aprotinin (Pentapharm, Basle, Switzerland)/ml whole blood for the measurement of insulin. Samples were then centrifuged at 2000 g for 10 min and analyzed immediately, for glucose, using standard procedures, or kept at –20 °C for later analyses of insulin. Insulin was measured using a human-specific RIA kit (Linco Research, St Charles, USA). All samples were batch analyzed in duplicate at the end of the study to reduce interassay variability. The sensitivity of the assay was 2.71 uU/ml and the intra-assay coefficient of variation was <10%.

Diet Monitoring. Participants were asked to maintain their normal diet during the exercise training period. Three-day food diaries were collected at baseline and on the last week of training (two weekdays and one weekend day) and analyzed using the program Mat på Data (version 5.1).

Statistical Analysis

Statistical analysis was carried out using SPSS 20.0 (SPSS Inc., Chicago, IL). Only the participants who completed the exercise intervention were included in the analysis. All variables were checked regarding their normal distribution using the Kolmogorov-Smirnov test. Statistical significance was assumed at $p < .05$, unless otherwise stated. A one–way analysis of variance (ANOVA) was performed to assess if there were any differences between groups before the intervention. A mixed between–within subject ANOVA was used to look at differences over time and among groups and interactions. The areas under the curve (AUC) for glucose and insulin were calculated from fasting up to 180 min after breakfast, using the trapezoidal rule.

One outlier was identified in MICT group, who gained 6.3kg during the exercise intervention period and increased 5.0cm in waist circumference and 2.0cm in hip circumference. Statistical analysis performed with or without this participant provided similar results and thus it was decided to keep all participants in the analysis.

Results

The baseline characteristics of the participants who finished the intervention are presented in Table 1. There were no significant baseline differences between groups on any measured variable.

Compliance With the Intervention

All participants who finished the intervention performed all the planned exercise sessions. The average exercise duration/session was of 20, 10 and 32 min for the HIIT, 1/2HIIT and MICT, respectively.

Changes in Anthropometric Indices and Cardiovascular Fitness Level

Changes in anthropometric variables overtime were not significant different between exercise groups (Table 2). There was a significant overall reduction in body weight ($p < .01$), waist ($p < .001$) and hip ($p < .01$) circumference

with exercise, but no significant main effect of group or interactions.

Changes in cardiovascular fitness overtime were also not significant different between exercise groups (Table 2). A significant overall increase ($p < .001$) in VO_{2max} was observed, both in absolute values and adjusted for body weight, with exercise, but no significant effect of group or interaction was found.

Changes in Body Composition

Changes in body composition overtime were not significant different between exercise groups (Table 3). Overall, trunk FM was significantly reduced overtime ($p < .01$), while trunk FFM increased significantly ($p < .01$) with exercise. However, no significant main effect of group or interactions was found.

Leg FM was also significantly reduced overtime ($p < .01$), while leg FFM increased significantly with exercise. However, no significant main effect of group or interactions was found.

Changes in Resting Metabolic Rate and Substrate Oxidation

No significant main effect of time, group or interaction was found for RMR or RER (data not shown).

Changes in Physical Activity Levels

No significant effect of time, group or interaction was found on the amount of time spent on sedentary activities, light, or moderate to vigorous PA, as well as on total counts per minute outside of the training period (Table 4).

Table 1 Baseline Characteristics of the Participants

	HIIT	1/2HIIT	MICT
Age (years)	33.9 ± 7.8	34.1 ± 7.1	33.0 ± 9.9
Male/Female ratio	0.4	0.8	0.6
Body mass (kg)	97.5 ± 17.0	96.1 ± 11.1	101.1 ± 14.1
BMI (kg/m^2)	33.2 ± 3.5	32.4 ± 2.9	33.3 ± 2.4
VO_{2max} (l/min)	3024 ± 540	2831 ± 674	3145 ± 665
VO_{2max} (ml/kg/min)	31.1 ± 4.9	29.6 ± 6.2	31.1 ± 5.3

Note. Data are presented as mean ± *SD*. HIIT = high-intensity intermittent training; 1/2HIIT = 1/2 duration HIIT; MICT = moderate-intensity continuous training; BMI = body mass index. One-way ANOVA showed no significant difference in baseline characteristics between the training groups.

Table 2 Changes in Anthropometric Indices and Cardiovascular Fitness after 12 Weeks of Training

Group	Weight (kg)	Waist (cm)	Hip (cm)	VO_{2max} (l/min)	VO_{2max} (ml/kg/min)
HIIT	-1.3 ± 2.1	-1.8 ± 4.0	-1.4 ± 3.4	219 ± 272	2.8 ± 2.6
1/2HIIT	-1.8 ± 1.7	-4.7 ± 3.0	-2.4 ± 4.1	370 ± 266	4.4 ± 2.2
MICT	-0.8 ± 3.2	-2.6 ± 4.6	-1.3 ± 2.4	260 ± 238	2.9 ± 2.9

Note. Results are expressed as mean ± *SD*. HIIT, high-intensity intermittent training; 1/2HIIT, 1/2 duration HIIT; MICT moderate-intensity continuous training. Mixed between-within subjects ANOVA showed a significant main effect of time for all variables ($p < .01$ for weight and hips, $p < .001$ for waist and VO_{2max}), but no main effect of group or interaction.

Table 3 Changes in Body Composition After 12 Weeks of Training

Group	Trunk, % fat	Trunk, % lean	Leg, % fat	Leg, % lean
HIIT	-0.6 ± 1.8	0.5 ± 1.8	-1.0 ± 1.7	1.0 ± 1.7
1/2HIIT	-0.5 ± 2.0	0.5 ± 2.0	-1.0 ± 1.7	0.9 ± 1.6
MICT	-0.01 ± 2.9	-0.1 ± 2.7	-0.01 ± 2.6	-0.1 ± 2.6

Note. Results are represented as mean ± *SD*. HIIT, high-intensity intermittent training; 1/2HIIT, 1/2 duration HIIT, MICT, moderate-intensity continuous training. Analysis using mixed between-within subjects ANOVA showed a significant main effect of time for all variables ($p < .01$) but no main effect of group or interaction. Data were available in only 17 participants (6 in HIIT, 5 in 1/2 HIIT and 6 in MICT group).

Table 4 Changes in PA Levels After 12 Weeks of Training

	Total Counts	Total Counts/Min	Inactive Time (min)	Light Activity (min)	MTV Activity (min)
HIIT baseline	264087 ± 93672	310 ± 118	565 ± 105	253 ± 63	33 ± 22
HIIT 6w	229557 ± 53345	289 ± 89	540 ± 86	234 ± 35	28 ± 16
HIIT 12w	230599 ± 67926	296 ± 100	538 ± 66	223 ± 69	28 ± 15
1/2HIIT baseline	306924 ± 98238	352 ± 106	532 ± 97	315 ± 96	33 ± 22
1/2HIIT 6w	275480 ± 82077	328 ± 02	522 ± 78	296 ± 92	29 ± 20
1/2HIIT 12w	261199 ± 83498	306 ± 95	544 ± 82	289 ± 96	27 ± 20
MICT baseline	221612 ± 63869	275 ± 75	538 ± 66	241 ± 49	26 ± 12
MICT 6w	228578 ± 50865	278 ± 65	544 ± 82	249 ± 44	26 ± 12
MICT 12w	221291 ± 71666	312 ± 182	573 ± 78	239 ± 51	28 ± 15

Note. Data are presented as mean ± *SD*. HIIT, high-intensity intermittent training; 1/2HIIT, 1/2 duration HIIT; MICT, moderate-intensity continuous training; MTV. Moderate to vigorous; BMI, body mass index. Mixed ANOVA showed no significant effect of time, group or interaction.

Table 5 Changes in Fasting Glucose, Insulin and Insulin Sensitivity After 12 Weeks of Training

Group	Glucose (mmol/L)	Insulin (uU/ml)	Si (%)
HIIT	-0.2 ± 0.4	-3.3 ± 6.5	9.8 ± 21.4
1/2HIIT	0.2 ± 0.3	1.6 ± 4.2	0.9 ± 24.0
MICT	-0.1 ± 0.3	-1.1 ± 7.1	6.4 ± 20.4

Note. Results are represented as mean ± *SD*. HIIT, high-intensity intermittent training; 1/2HIIT, 1/2 duration HIIT; MICT, moderate-intensity continuous training. Analysis using mixed between-within subjects ANOVA showed no significant main effect of time, group or interaction.

Changes in Fasting and Postprandial Levels of Glucose and Insulin

No significant main effect of time, group or interaction was found in fasting levels of glucose or insulin or insulin sensitivity (HOMA Si, %) (see Table 5) or AUC for glucose (data not shown). There was a tendency for a reduction in AUC for insulin over time (p = .069), but no effect of group or interaction Figure 1).

Diet

No significant effect of time, group or interaction was found on energy or macronutrient intake (expressed as a percentage of EI) (data not shown).

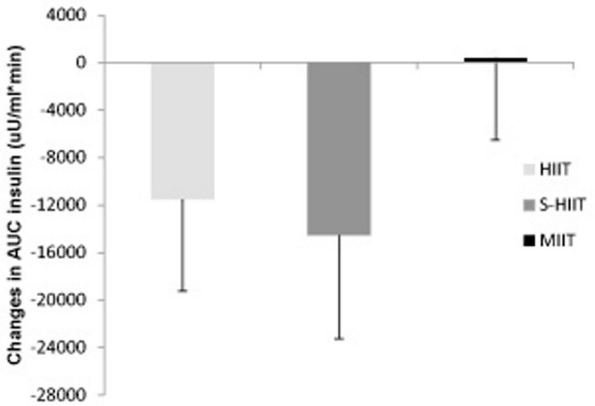

Figure 1 — Changes in AUC (0–180 min) for insulin after 12 weeks of training. Results are expressed as mean± *SD*. HIIT, high-intensity intermittent training; 1/2HIIT, half duration high-intensity intermittent training, MICT, moderate-intensity continuous training. Analysis using mixed between-within subjects ANOVA showed a tendency for an effect of time (p = .069), but no effect of group or interaction on insulin AUC.

Discussion

The major finding of this study was that all training programs lead to similar improvements on body weight and composition, metabolism (insulin sensitivity, RMR and substrate oxidation) and cardiovascular fitness. Our findings are in contrast with a previous study using an identical HIIT cycling protocol, showing that HIIT, was superior to MICT, in inducing FM loss and improving insulin sensitivity (Trapp et al., 2008). However, other studies using treadmill protocols, in "healthy" overweight and obese subjects, have not shown any difference in body weight and composition between isocaloric program of HIIT and MICT (Schjerve et al., 2008; Tjonna et al., 2008). Although it can be hypothesized that exercise mode is implicated in the above described discrepancies,

a more likely explanation is the duration of the HIIT intervals. The studies employing treadmill (Schjerve et al., 2008; Tjonna et al., 2008) used longer exercise intervals, while those with cycling (Trapp et al., 2008) used short- to medium-intervals. There is evidence to suggest that the metabolic responses to HIIT vary depending on the duration of the work:rest periods (Christmass et al., 1999; Essen and Kaijser, 1978; McGarvey et al., 2005; Schjerve et al., 2008; Trapp et al., 2007). Nevertheless, we found no difference between exercise programs in terms of FM loss in the current study.

HIIT has also been claimed to be superior in terms of enhancing fat oxidation (Boutcher 2011), even though studies comparing isocaloric protocols of HIIT and MICT have not, from our knowledge been perfomed, and this could be one of the mechanisms leading to more fat mass loss after HIIT. However, we found no difference between training protocols in term of changes in fasting substrate oxidation with exercise, which is in line with the similar improvements in body composition observed after HIIT and MICT in the current study.

Several studies, using treadmill protocols, in overweight and obese individuals, have shown the superiority of HIIT vs MICT in improving cardiovascular fitness (VO_{2max}; Schjerve et al., 2008; Tjonna et al., 2008). However, we, as Trapp and colleagues (2008), reported similar improvements in VO_{2max} regardless of the exercise program. Interestingly, a recent study in our laboratory showed that one 4-min interval of intense (90% HRmax) training (3 times/week for 10 weeks) on a treadmill produced the same improvement in VO_{2max} compared with four 4-min intervals of intense training, in sedentary overweight males (Tjonna et al., 2013). This, together with the findings of the current study, suggests that a short bout of high-intensity exercise may be enough to reduce cardiovascular risk in overweight and obese individuals.

It is rather surprising that the 1/2HIIT, demanding only half of the time of the HIIT, produced exactly the same results as HIIT or MICT, showing that in sedentary obese individuals, even a very small volume of exercise can induce improvements in metabolic and cardiovascular risk factors. Although there is some evidence suggesting that exercise alters eating behavior and food choice (Finlayson et al., 2009; King, 1999), we found no differences in energy intake or, indeed nonexercise PA between groups. Moreover, the three exercise programs had an identical impact on substrate oxidation (RER). Therefore, the larger than expected WL in the 1/2HIIT group remains unexplained. Interestingly, in a recent published study, a similar weight and FM loss was reported in sedentary overweight men, regardless of exercise dose (30 min vs 60 min of exercise/day, respectively), potentially due to differences in nonexercise activity and energy intake in response to the two exercise doses (Rosenkilde et al., 2012).

Unexpectedly, we found no changes in fasting insulin plasma levels or insulin sensitivity and only a tendency toward a reduction in insulin AUC, and no differences between groups. The impact of HIIT on insulin sensitivity is controversial, with some showing significant improvements (Trapp et al., 2008; Whyte et al., 2010) and others no change (Gillen et al., 2013; Heydari et al., 2012). Differences in exercise protocols and study populations (gender, BMI, baseline fasting insulin levels) are likely to play a role.

There is a large controversy regarding the impact of exercise on nonexercise PA levels, even though the overall trend is for nonexercise PA to decrease (Melanson et al. 2013). Unfortunately, no study had, up to now, evaluated the impact of isocaloric programs of HIIT vs MICT, on nonexercise PA. We found no changes in nonexercise PA over time or between groups in our study.

Our study is strengthened by the fact that the exercise prescriptions were ramped to accommodate any training effect. One limitation is that we were unable to measure total body composition and could only report changes in FM and FFM in the trunk and legs. However, given that abdominal fat is more strongly correlated with metabolic abnormalities than total fat (Wiklund et al., 2008), we believe a reduction in trunk FM is more relevant than a reduction in total body FM. Moreover, our study has a relatively small sample size and short duration and, therefore, larger and longer studies are needed to determine the impact of HIIT on body weight and composition, cardiovascular fitness ad insulin sensitivity.

The present study adds new important data to the current controversy regarding the efficacy of HIIT versus MICT, on body weight and composition and metabolism in general. The novelty of the current study was that the 8s:12s HIIT cycling protocol had not been previously investigated in an obese sedentary population and that few of the previous studies had employed isocaloric exercise protocols. Future research should try to elucidate further the role of exercise mode (jogging/running versus cycling) and the duration of the work:rest periods on the potential metabolic benefits of HIIT.

In conclusion, isocaloric training protocols of HIIT or MICT, or short duration HIIT (1/2 HIIT) seem to offer a similar metabolic and cardiovascular protection it sedentary obese individuals.

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The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

References

Boutcher, S.H. (2011). High-intensity intermittent exercise and fat loss. *Obesity (Silver Spring, Md.), 2011,* 868305. PubMed

Catenacci, V.A., & Wyatt, H.R. (2007). The role of physical activity in producing and maintaining weight loss. *Nature Clinical Practice. Endocrinology & Metabolism, 3*(7), 518–529. PubMed doi:10.1038/ncpendmet0554

Christmass, M.A., Dawson, B., & Arthur, P.G. (1999). Effect of work and recovery duration on skeletal muscle oxygenation and fuel use during sustained intermittent exercise. *European Journal of Applied Physiology, 80,* 436–447. PubMed doi:10.1007/s004210050615

Compher, C., Frankenfield, D., Keim, N., & Roth-Yousey, L. (2006). Best Practice Methods to Apply to Measurement of Resting Metabolic Rate in Adults: A Systematic Review. *Journal of the American Dietetic Association, 106*(6), 881–903. PubMed doi:10.1016/j.jada.2006.02.009

De Feo, P. (2013). Is high-intensity exercise better than moderate-intensity exercise for weight loss? *Nutrition, Metabolism, and Cardiovascular Diseases, 23*(11), 1037–1042. PubMed doi:10.1016/j.numecd.2013.06.002

Donnelly, J.E., Blair, S.N., Jakicic, J.M., Manore, M.M., Rankin, J.W., & Smith, B.K. (2009). American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Medicine and Science in Sports and Exercise, 41*(2), 459–471. PubMed doi:10.1249/MSS.0b013e3181949333

Essen, B., & Kaijser, L. (1978). Regulation of glycolysis in intermittent exercise in man. *The Journal of Physiology Online, 281*(1), 499–511. PubMed doi:10.1113/jphysiol.1978.sp012436

Finlayson, G., Bryant, E., Blundell, J.E., & King, N.A. (2009). Acute compensatory eating following exercise is associated with implicit hedonic wanting for food. *Physiology & Behavior, 97*(1), 62–67. PubMed doi:10.1016/j.physbeh.2009.02.002

Fox, A.M., Mann, D.M., Ramos, M.A., Kleinman, L.C., & Horowitz, C.R. (2012). Barriers to physical activity in East harlem, new york. *Journal of Obesity, 719140*. PubMed

Gillen, J.B., Percival, M.E., Ludzki, A., Tarnopolsky, M.A., & Gibala, M.J. (2013). Interval training in the fed or fasted state improves body composition and muscle oxidative capacity in overweight women. *Obesity (Silver Spring, Md.), 21*(11), 2249–2255. PubMed doi:10.1002/oby.20379

Heydari, M., Freund, J., & Boutcher, S.H. (2012). The Effect of High-Intensity Intermittent Exercise on Body Composition of Overweight Young Males. *Journal of Obesity*. PubMed doi:10.1155/2012/480467

Keating, S.E., Machan, E.A., O'Connor, H.T., Gerofi, J.A., Sainsbury, A., Caterson, I.D., & Johnson, N.A. (2014). Continuous exercise but not high intensity interval training improves fat distribution in overweight adults. *Journal of Obesity, 834865*. PubMed

King, N.A. (1999). What processes are involved in the appetite response to moderate increases in exercise-induced energy expenditure? *The Proceedings of the Nutrition Society, 58*(1), 107–113. PubMed doi:10.1079/PNS19990015

McGarvey, W., Jones, R., & Petersen, S. (2005). Excess post-exercise oxygen consumption following continuous and interval cycling exercise. *International Journal of Sport Nutrition and Exercise Metabolism, 15*(1), 28–37. PubMed

Melanson, E.L., Keadle, S.K., Donnelly, J.E., Braun, B., & King, N.A. (2013). Resistance to exercise-induced weight loss: compensatory behavioral adaptations. *Medicine and Science in Sports and Exercise, 45*(8), 1600–1609. PubMed doi:10.1249/MSS.0b013e31828ba942

Nybo, L., Sundstrup, E., Jakobsen, M.D., Mohr, M., Hornstrup, T., Simonsen, L. … Krustrup, P. (2010). High-intensity training versus traditional exercise interventions for promoting health. *Medicine and Science in Sports and Exercise, 42*(10), 1951–1958. PubMed doi:10.1249/MSS.0b013e3181d99203

Rosenkilde, M., Auerbach, P., Reichkendler, M.H., Ploug, T., Stallknecht, B.M., & Sjodin, A. (2012). Body fat loss and compensatory mechanisms in response to different doses of aerobic exercise–a randomized controlled trial in overweight sedentary males. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology, 303*(6), R571–R579. PubMed doi:10.1152/ajpregu.00141.2012

Ross, R., Dagnone, D., Jones, P.J., Smith, H., Paddags, A., Hudson, R., & Janssen, I. (2000). Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial. *Annals of Internal Medicine, 133,* 92–103. PubMed doi:10.7326/0003-4819-133-2-200007180-00008

Rye, J.A., Rye, S.L., Tessaro, I., & Coffindaffer, J. (2009). Perceived barriers to physical activity according to stage of change and body mass index in the west virginia wisewoman population. *Women's Health Issues, 19*(2), 126–134. PubMed doi:10.1016/j.whi.2009.01.003

Schjerve, I.E., Tyldum, G.A., Tjønna, A.E., Stølen, T., Loennechen, J.P., Hansen, H.E. … Wisløff, U. (2008). Both aerobic endurance and strength training improve cardiovascular health in obese adults. *Clinical Science, 115*(9), 283–293. PubMed doi:10.1042/CS20070332

Shaw, K., Gennat, H., O'Rourke, P., & Del Mar, C. (2006). Exercise for overweight or obesity. *Cochrane Database of Systematic Reviews, 4*, CD003817. PubMed

Sijie, T., Hainai, Y., Fengying, Y., & Jianxiong, W. (2012). High intensity interval exercise training in overweight young women. *Journal of Sports, Medicine, and Physical Fitness, 52*(3), 255–262. PubMed

Stiegler, P., & Cunliffe, A. (2006). The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weigth loss. *Sports Medicine (Auckland, N.Z.), 36*(3), 239–262. PubMed doi:10.2165/00007256-200636030-00005

Stunkard, A.J., & Messick, S. (1985). The Three-factor Eating Questionnaire to measure dietary restraint, desinhibition and hunger. *Journal of Psychosomatic Research, 29*(1), 71–83. PubMed doi:10.1016/0022-3999(85)90010-8

Tjønna, A.E., Lee, S.J., Rognmo, Ø., Stølen, T.O., Bye, A., Haram, P.M. … Wisløff, U. (2008). Aerobic Interval

Training Versus Continuous Moderate Exercise as a Treatment for the Metabolic Syndrome: A Pilot Study. *Circulation, 118*(4), 346–354. PubMed doi:10.1161/CIRCULATIONAHA.108.772822

Tjønna, A.E., Leinan, I.M., Bartnesm A.T., Jenssen, B.M., Gibala, M.J., Winett, R.A., & Wisløff, U. (2013). Low- and high-volume of intensive endurance training significantly improves maximal oxygen uptake after 10-weeks of training in healthy men. *PLoS One, 8*(5), e65382. PubMed doi:10.1371/journal.pone.0065382

Trapp, E.G., Chisholm, D.J., & Boutcher, S.H. (2007). Metabolic response of trained and untrained women during high-intensity intermittent cycle exercise. AJP - Regulatory. *Integrative and Comparative Physiology, 293*(6), R2370–R2375. doi:10.1152/ajpregu.00780.2006

Trapp, E.G., Chisholm, D.J., Freundl, J., & Boutcherl, S.H. (2008). The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. *International Journal of Obesity, 32*(4), 684–691. PubMed doi:10.1038/sj.ijo.0803781

Troiano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*(1), 181–188. PubMed doi:10.1249/mss.0b013e31815a51b3

Whyte, L.J., Gill, J.M., & Cathcart, A.J. (2010). Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men. *Metabolism: Clinical and Experimental, 59*(10), 1421–1428. PubMed doi:10.1016/j.metabol.2010.01.002

Wiklund, P., Toss, F., Weinehall, L., Hallmans, G., Franks, P.W., Nordström, A., & Nordström, P. (2008). Abdominal and gynoid fat mass are associated with cardiovascular risk factors in men and women. *The Journal of Clinical Endocrinology and Metabolism, 93*(11), 4360–4366. PubMed doi:10.1210/jc.2008-0804

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