Obesity Management

The influence of high-intensity interval training on anthropometric variables of adults afflicted with overweight or obesity: a systematic review and network meta-analysis

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Summary

Objective: The goal of this study was to evaluate the influence of high-intensity interval training (HIIT) on anthropometric variables in adults afflicted with overweight or obesity and to compare the effects with those of moderate-intensity continuous training.

Methods: A computer literature search was performed for HIIT intervention studies that evaluated anthropometric variables in adults afflicted with overweight or obesity.

Results: Of the 857 articles retrieved in the electronic search, 48 met the inclusion criteria. The analyses demonstrated that HIIT was effective in decreasing body mass (−1.45 kg [95% CI: −1.85 to −1.05 kg]), body mass index (−0.44 kg m^{-2} [95% CI: −0.59 to −0.30 kg m^{-2}]), waist circumference (−2.3 cm [95% CI: −3.1 to −1.4 cm]), waist/hip ratio (−0.01 [95% CI: −0.02 to −0.00]), body fat percentage (−1.29% [95% CI: −1.70% to −0.87%]) and abdominal visceral fat area (−6.83 cm^2 [95% CI: −11.95 to −1.71 cm^2]). When considering equalization between the two methods (energy expenditure or workload matched), no differences were found in any measure except body mass (for which HIIT was superior).

Conclusions: High-intensity interval training and moderate-intensity continuous training results were similar, particularly when equalization between the two methods was considered. Thus, HIIT can be used as a secondary method for the treatment of obesity in adults.

Keywords: Body composition, body mass index, overweight, physical exercise.

Abbreviations: AT, anaerobic threshold; BIA, bioelectrical impedance analysis; BMI, body mass index; CI, confidence interval; DEXA, dual-energy X-ray absorptiometry; EPOC, excess post-exercise oxygen consumption; HIIT, high-intensity interval training; LI, low-intensity; MICT, moderate-intensity continuous training; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO, International Prospective Register of Systematic Reviews; SEM, standard error of the mean; SIT, sprint interval training; TESTEX, Tool for the Assessment of Study Quality and Reporting in Exercise; WHR, waist/hip ratio.

Introduction

Overweight and obesity are characterized by abnormal or excessive body fat accumulation, and these conditions carry major health implications. In recent decades, overweight and obesity have reached global epidemic proportions (1,2). It is estimated that being overweight afflicts more than 38% of adults (i.e. body mass index [BMI] $\geq$ 25 kg m^{-2}), while obesity is considered to afflict 13% of adults (i.e. BMI $\geq$ 30 kg m^{-2}) (3,4). Excess weight is one of the most important risk factors for mortality worldwide and is associated with the development of many serious diseases, such as cardiovascular diseases, type 2 diabetes mellitus, musculoskeletal disorders and some cancers (1,5,6). Another significant risk factor that directly contributes to the high prevalence of overweight and obesity (and consequently to global mortality risk) is physical inactivity. Worldwide, more than 31% of adults do not meet the recommended minimum physical activity levels (7); consequently, physical inactivity is responsible for more than five million deaths per year, corresponding to approximately 9% of all deaths (8).

Exercise training and decreasing energy intake are common strategies for reducing body mass by inducing a negative energy balance (9,10). Regarding exercise training, aerobic exercise is a common and effective non-pharmacological intervention for weight and adiposity management (11,12). Current international guidelines for weight management frequently recommend a high volume of traditional moderate-intensity continuous training (MICT) (between 150 and 250 min week^{-1} to prevent weight gain; >150 min week^{-1} for modest weight loss; and >225–420 min week^{-1} for significant weight loss) (12). However, a high volume of exercise might be a barrier for adherence to exercise programmes because lack of time is a commonly cited reason for not engaging in physical activity programs (13).

In recent years, growing evidence has supported the role of high-intensity interval training (HIIT) as an important strategy for reducing body mass, adiposity and cardiometabolic risk factors (14–18). Some studies have shown that HIIT may confer superior benefits to MICT in reducing adiposity in patients afflicted with overweight or obesity (19,20). However, these results are not well established because some studies did not show the effectiveness of HIIT in reducing body fat mass (21,22).

Thus, owing to the increase in publications related to HIIT, overweight and obesity, some recent meta-analyses have been conducted to synthesize scientific findings (23–27). However, owing to methodological aspects, gaps remain in the literature regarding the real effect of HIIT on anthropometric variables and physiological parameters specifically related to health in adults affected by overweight. In particular, previous studies were limited with regard to extrapolation of this population owing to the wide age ranges of study populations and the inclusion of confounding variables such as children and adolescents (24), elderly (23), individuals with normal weight (24) and individuals with certain medical characteristics, such as coronary artery disease, heart transplant recipients, post-myocardial infarction (23), colorectal cancer survivors (24) and non-alcoholic fatty liver disease and rheumatic disease (25). In addition, the lack of a control group that did not undergo exercise (24–27) could be considered to introduce a risk of bias when analysing the effectiveness of HIIT.

Furthermore, the existence of differences in effectiveness between HIIT and MICT is not well established because some studies did not assess equalization between the training protocols, which results in a relevant bias risk. In some of these studies, the analyses compared training methods that presented a significant difference in energy expenditure between the sessions (26,27). For example, Sawyer *et al.* (28) observed that MICT sessions resulted in an energy expenditure ~33% higher than that of HIIT; in a study by Kong *et al.* (29), the energy expenditure of the MICT sessions was ~102% higher than that of the HIIT sessions. Thus, review studies must consider analyses that included isocaloric protocols only (30).

Finally, only a limited number of clinical trials have assessed the effectiveness of HIIT and can be used to compare HIIT and MICT. Faced with this scenario, the use of a network meta-analysis can be an interesting strategy allowing the imputation of control/experimental groups to conduct the necessary analyses. Additionally, the number of identified studies can be expanded by increasing the search databases because, in some existing reviews, only one (23) or two (24,25) electronic databases were included in the search strategy, representing a key limiting factor (31).

Therefore, the goal of this study was to conduct a systematic review with a network meta-analysis to evaluate the influence of HIIT on anthropometric variables of adults afflicted with overweight or obesity on the basis of a comparison with a control group that did not undergo exercise intervention. A secondary study goal was to compare HIIT and MICT and consider the effect of equalization between the interventions.

Methods

Search strategy

This systematic review and network meta-analysis is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (32) and the Cochrane Handbook for Systematic Reviews of Interventions (33). The study protocol was registered (register number: CRD42017062421) in the

International Prospective Register of Systematic Reviews (PROSPERO) platform.

We searched the following electronic databases (up to May 2018) without a period limit: Cochrane Library, PubMed, Science Direct, Scopus, SPORTDiscus and Web of Science. Additionally, a manual search for published studies in Google Scholar was conducted for the grey literature analysis. The initial search comprised the terms 'high-intensity interval training' OR 'high-intensity interval exercise' OR 'high-intensity intermittent training' OR 'high-intensity intermittent exercise' OR 'interval aerobic training' OR 'interval aerobic exercise' OR 'aerobic interval training' OR 'aerobic interval exercise' OR 'intermittent aerobic training' OR 'intermittent aerobic exercise' OR 'high-intensity training' OR 'high-intensity exercise' OR 'sprint interval training' OR 'sprint interval exercise' AND 'overnutrition' OR 'obesity' OR 'overweight' AND 'body weight' OR 'body composition' OR 'body fat' OR 'body mass index'. Only eligible full texts in English, Portuguese or Spanish were considered for analysis.

Two investigators (the first and third authors) independently performed searches in the electronic databases, and disagreements were solved by consensus. The literature search strategy used for the PubMed database and the search results from all databases are available in the Supporting Information (Box S1 and Box S2).

Eligibility criteria

This meta-analysis included original studies (randomized or non-randomized) for which the full texts were available that performed interventions with HIIT, included two or more weeks of follow-up, involved adult individuals (aged: >18 and <65 years), included both sexes, included individuals afflicted with overweight or obesity (BMI ≥ 25 kg m^{-2}; body fat $> 15\%$ for men and $>25\%$ for women) and evaluated anthropometric variables (body mass, BMI, waist circumference, waist/hip ratio [WHR] or body composition) before and after the intervention as outcomes. If there was divergence between BMI and body fat percentage for the indication of overweight, the latter parameter prevailed.

High-intensity interval training is usually considered to include exercise with an intensity equal to or greater than ~90% of the maximal oxygen uptake (VO_{2max}) (34). However, in this study, which analysed a special population (i.e. adults afflicted with overweight or obesity), interventions with an intensity of $\geq$80% VO_{2max}, $>$80% of the heart rate reserve or $>$85% of the maximum heart rate (HR_{max}) were included.

Additionally, the following exclusion criteria were adopted to reduce confounding factors: duplicate publications or sub-studies of included studies, studies involving other comorbidities or pathologies (except those of metabolic syndrome such as dyslipidaemia, diabetes mellitus and systemic arterial hypertension) and studies associating exercise with nutritional intervention (e.g. nutrition counselling, balanced or hypocaloric diets, and supplements) or pharmacological drugs. Studies involving crossover protocols were also excluded because the wash-out times for HIIT effects are not well known for the different variables analysed. Studies that performed HIIT associated with other interventions involving physical training (e.g. MICT and strength training) were not considered.

Selection study and data extraction

The titles and abstracts of the selected articles were independently assessed by two researchers (the first and fourth authors). The reviewers were not blinded to the authors, institutions or journals associated with the manuscripts. Abstracts that provided insufficient information about the inclusion and exclusion criteria were retrieved for full-text analysis. Furthermore, the researchers independently analysed the full text and determined the eligibility of the studies, and disagreements were resolved by consensus. The agreement rate between reviewers was 83% (k = 0.45; moderate) for the eligibility criteria of the study.

To avoid double-counting patients or to clarify questions about the methods, the corresponding authors were contacted if necessary. Furthermore, when necessary, the corresponding author was contacted via e-mail to provide data not included in the published research. Two researchers (the first and second authors) independently performed the data extraction, and disagreements were resolved by consensus.

Assessment of risk of bias

The study quality and reporting were assessed using the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX), which was specifically developed to evaluate interventions involving exercise training by considering their specificities (35). This tool evaluates aspects related to study quality (eligibility criteria, randomization specification, allocation concealment, similarity of the groups at baseline and blinding of the assessor) and study reporting (evaluation of the primary outcome measures in $\geq$85% of patients, adverse events, session attendance, analysis by intention to treat, between-group statistical comparison for the primary and for at least one secondary outcome measure, use of point measures and measures of variability, activity monitoring in control groups and periodic adjustment to maintain the same relative exercise intensity and exercise description). Thus, the maximum possible score is 15 points. In accordance with the TESTEX recommendations, studies without clear descriptions of any of the items evaluated were considered to not meet these criteria.

The evaluation was performed by two independent investigators (the second and third authors). Disagreements were solved by consensus, and if disagreement persisted, by a third reviewer (first author). Definitions of levels of evidence were guided by Hall *et al.* (36) on the basis of the Cochrane tool. This tool uses the study quality ranges obtained by TESTEX. The quality score of the papers was based on tertiles, where 0–5 points were considered low quality, 6–10 points were considered medium quality and 11–15 points were considered high quality.

Data analyses

Absolute changes (final value − initial value) in body mass, BMI, waist circumference, WHR and body fat percentage were reported as differences between arithmetic means before and after the interventions. The results of intention-to-treat analyses were always used when available in the selected studies. Calculations were performed using a random-effects model. The results of the HIIT group were compared with the results of the control group (non-exercise) or the MICT group. For all variables, in the comparisons between HIIT and MICT, the studies were stratified by considering the presence of equalization. A study was considered equalized when the design adopted HIIT and MICT protocols with similar energy expenditures or similar workloads. This information should be mentioned in the article or presented in the results. When this information was not presented, the study was classified as non-equalized. For body fat percentage, one analysis considering all methods of assessment and another analysis considering only studies that estimated body fat percentage via dual-energy X-ray absorptiometry (DEXA) were conducted.

The level of significance was set at 5%. For statistical heterogeneity of the treatment effect between the studies, a threshold P value of 0.1 estimated by the Cochran Q test was rated as statistically significant. For heterogeneity, values greater than 50% in the inconsistency I^2 test were considered indicative of high heterogeneity. Because some studies had more than one HIIT group with a single control group, this shared control group was divided into two or more groups with smaller sample sizes and was weighted in relation to the different exercise interventions. This procedure was performed to obtain reasonably independent comparisons and overcome a unit-of-analysis error for studies that could contribute to multiple and correlated comparisons, as suggested by the Cochrane Handbook for Systematic Reviews of Interventions (33).

Transformation methods were used for studies that presented results as the standard error of the mean, confidence intervals or interquartile ranges (37). Data not available and not made available by the corresponding author were imputed. In those situations, the weighted average of all available studies for the variable in question was considered. To conduct the multiple comparisons (HIIT vs. MICT, and HIIT vs. control), a network model was adopted. For this, the weighted average of all available studies was considered for group imputation.

To add robustness to the findings, sensitivity analyses were performed by deleting each study separately to analyse the influence of each study on the overall results. All analyses were performed using REVIEW MANAGER software, version 5.3 (Cochrane Collaboration, London, UK).

When significant results were found, a meta-regression using a linear analysis was performed to determine the impact of the type of interval training (sprint interval training [SIT], HIIT with short interval and SIT with long interval), the total number of sessions, sex, age and study quality score on the anthropometric variables included in this study.

Sprint interval training was defined as a protocol involving all-out sprints (>100% VO_{2max}) (24). HIIT included a protocol between 80% and 100% of the VO_{2max} (24), with a subdivision between short intervals (<60 s) and long intervals (>60 s) (34). The meta-regression was performed using SPSS software (IBM Corp. Released 2011; IBM SPSS Statistics for Windows, version 20.0, IBM Corp., Armonk, NY).

Results

Studies included in this review

The electronic database searches resulted in 857 articles. After adding relevant studies from other sources and applying the eligibility criteria, we included 48 studies in the present systematic review. Figure S1 shows a flow chart illustrating the different phases of the search and study selection.

A total of 1,222 subjects were investigated from the 48 studies (HIIT: 678 subjects; MICT: 293 subjects; control: 251 subjects). Among all studies, 58 groups received HIIT interventions, 24 groups received MICT interventions and 21 groups served as controls.

Of the studies evaluating HIIT (Table S1), 37.3% evaluated both men and women, 22.0% evaluated men only, 39.0% evaluated women only and 1.7% did not differentiate the sex of the participants. The mean follow-up time was 9.6 weeks, with a range of 2 (6.8%) to 24 weeks (1.7%); most studies had a follow-up time of 12 (33.9%) or 6 weeks (18.6%). The weekly frequency of HIIT was also reported in the 48 studies that evaluated HIIT interventions: HIIT was performed three times a week in 41 studies, three to four times a week in two studies, four times a week in three studies and five times a week in two studies. Regarding the exercise modality, 30 studies adopted cycling, and 18 studies adopted running/walking (12 on a treadmill, three in indoor sports courts, one outdoors and one on both a treadmill and in a training room, and one did not report the ergometer/training location).

Of the studies involving MICT (Table S2), 37.5% evaluated both men and women, 25.0% evaluated men only and 37.5% evaluated women only. The mean follow-up time was 9.3 weeks, with a range of 2 (8.3%) to 16 weeks (4.2%); the most frequent follow-up periods were 12 (50.0%) and 6 weeks (16.7%). The weekly frequency was also reported in the 24 studies assessing MICT interventions: MICT was performed three times a week in 16 studies, three to four times a week in two studies, four times a week in two studies and five times a week in four studies. Regarding the exercise modality, 15 studies adopted cycling, and nine adopted running/walking (six on a treadmill, one outdoors and one on a treadmill and in a training room, and one did not report the ergometer/training location).

In studies involving a control group (non-exercise), 28.6% evaluated both men and women, 23.8% evaluated men only and 47.6% evaluated women only. The mean follow-up time was 10.9 weeks, with a range of 3 (4.8%) to 16 weeks (14.3%); the most frequent follow-up periods were 12 (52.4%), 6 (14.3%) and 16 weeks (14.3%).

In total, 31 studies evaluated body composition. To assess that variable, 17 studies used DEXA, ten adopted bioelectrical impedance analysis (BIA), three used the skin-fold thickness method and one performed an analysis using a combination of DEXA, plethysmography and BIA.

Only three studies evaluated the abdominal visceral fat area and the abdominal subcutaneous fat area; one used magnetic resonance imaging, and two used computed tomography.

Body mass

High-intensity interval training (579 subjects) compared with the control (589 subjects) was effective in decreasing body mass (−1.45 kg [95% CI: −1.85 to −1.05 kg]; I^2: 77%; P for heterogeneity: <0.001) (Fig. S2). Additionally, MICT (589 subjects) decreased body mass to a greater degree than did HIIT (579 subjects) (0.40 [95% CI: 0.09 to 0.72 kg]; I^2: 40%; P for heterogeneity: 0.002) (Fig. 1). When the protocols were not equalized, MICT also decreased body mass to a greater degree than did HIIT (0.72 kg [95% CI: 0.35 to 1.10 kg]; I^2: 39%; P for heterogeneity: 0.009). However, considering only equalized studies, the reduction observed in body mass was superior in the HIIT group (−0.41 kg [95% CI: −0.79 to −0.02 kg]; I^2: 0%; P for heterogeneity: 0.97) (Fig. 1).

Body mass index

High-intensity interval training (486 subjects) compared with the control (504 subjects) was effective in reducing BMI (−0.44 kg m^{-2} [95% CI: −0.59 to −0.30 kg m^{-2}]; I^2: 57%; P for heterogeneity: <0.001). Additionally, MICT (444 subjects) decreased BMI to a greater degree than did HIIT (486 subjects) (0.12 [95% CI: 0.01 to 0.22 kg m^{-2}]; I^2: 0%; P for heterogeneity: 0.82). When the protocols were not equalized, MICT also decreased BMI to a greater degree than did HIIT (0.21 kg m^{-2} [95% CI: 0.09 to 0.33 kg]; I^2: 0%; P for heterogeneity: 0.84). However, considering only equalized studies, there was no difference between HIIT and MICT ([95% CI: −0.31 to 0.08 kg m^{-2}]; I^2: 0%; P for heterogeneity: 0.97).

Waist circumference

High-intensity interval training (332 subjects) compared with the control (339 subjects) was effective in reducing waist circumference (−2.3 cm [95% CI: −3.1 to −1.4 cm]; I^2: 89%; P for heterogeneity: <0.001). However, there was no difference between HIIT (332 subjects) and MICT (287 subjects) ([95% CI: −0.3 to 1.0 cm]; I^2: 0%; P for heterogeneity: 0.97). When the protocols were non-equalized ([95% CI: −0.2 to 1.4 cm]; I^2: 0%; P for heterogeneity: 0.95) or equalized ([95% CI: −1.7 to 0.9 cm]; I^2: 0%; P for heterogeneity: 0.86), there was no difference between HIIT and MICT.

Waist/hip ratio

High-intensity interval training (126 subjects) compared with the control (111 subjects) was effective in decreasing the WHR (−0.01 [95% CI: −0.02 to 0.00]; I^2: 66%; P for heterogeneity: <0.001). Nevertheless, there was no difference between HIIT (126 subjects) and MICT (119 subjects) ([95% CI: −0.01 to 0.01]; I^2: 68%; P for heterogeneity: <0.001). When the protocols were non-equalized ([95% CI: −0.03 to 0.02]; I^2: 80%; P for heterogeneity: <0.001) or equalized ([95% CI: −0.00 to 0.01]; I^2: 9%; P for heterogeneity: 0.36), there was no difference between HIIT and MICT.

Body fat percentage

High-intensity interval training (427 subjects) compared with the control (406 subjects) was effective for decreasing the body fat percentage (−1.29% [95% CI: −1.70% to −0.87%]; I^2: 78%; P for heterogeneity: <0.001) (Fig. S3). Nevertheless, there was no difference between HIIT (427 subjects) and MICT (445 subjects) ([95% CI: −0.44% to 0.19%]; I^2: 55%; P for heterogeneity: <0.001) (Fig. 2). When the protocols were non-equalized ([95% CI: −0.49% to 0.49%]; I^2: 62%; P for heterogeneity: <0.001) or equalized ([95% CI: −0.52% to 0.08%]; I^2: 17%; P for heterogeneity: 0.29), there was no difference between HIIT and MICT (Fig. 2).

Study or Subgroup	HIIT Mean	HIIT SD	HIIT Total	MICT Mean	MICT SD	MICT Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Not equalized								
Alvarez et al. (39)	-0.6	1.12	12	-1.57	2.24	12	2.5%	0.97 [-0.45, 2.39]
Alvarez et al. (40)	-1.6	0.2	13	-1.57	2.24	12	2.8%	-0.03 [-1.30, 1.24]
Alvarez et al. (41) a	-1.4	1.01	6	-1.57	2.24	12	2.4%	0.17 [-1.33, 1.67]
Alvarez et al. (41) b	-2.3	1.01	6	-1.57	2.24	12	2.4%	-0.73 [-2.23, 0.77]
Alvarez et al. (41) c	-1.4	2.02	12	-1.57	2.24	12	2.1%	0.17 [-1.54, 1.88]
Bouri et al. (43)	-0.67	1.27	7	-1.57	2.24	12	2.3%	0.90 [-0.68, 2.48]
Boyd et al. (14)	0	2.5	9	-1.57	2.24	12	1.6%	1.57 [-0.50, 3.64]
Cocks et al. (44)	-1	2.37	8	-2	3.67	8	0.9%	1.00 [-2.03, 4.03]
Cooper et al. (45) d	0.2	1.2	15	-1.57	2.24	12	2.6%	1.77 [0.36, 3.18]
Cooper et al. (45) e	0.9	1.6	15	-1.57	2.24	12	2.4%	2.47 [0.97, 3.97]
Escarate et al. (46)	-0.56	2.54	7	-1.57	2.24	12	1.4%	1.01 [-1.26, 3.28]
Gahreman et al. (47)	-1.65	2.23	12	-1.57	2.24	12	1.9%	-0.08 [-1.87, 1.71]
Gillen et al. (47) f	-0.14	0.87	8	-1.57	2.24	12	2.6%	1.43 [0.03, 2.83]
Gillen et al. (47) g	0.26	1.34	8	-1.57	2.24	12	2.3%	1.83 [0.26, 3.40]
Hormazábal et al. (49)	-0.1	2.18	8	-1.57	2.24	12	1.7%	1.47 [-0.50, 3.44]
Jabbour et al. (50)	-0.6	12.22	12	-1.57	2.24	12	0.2%	0.97 [-6.06, 8.00]
Keating et al. (21)	0.2	2.04	13	-0.8	1.69	13	2.5%	1.00 [-0.44, 2.44]
Kong et al. (29)	0.6	1.5	13	-1.2	1.9	13	2.7%	1.80 [0.48, 3.12]
Kong et al. (51)	0.7	1.5	10	-1.57	2.24	12	2.3%	2.27 [0.70, 3.84]
Larsen et al. (52)	1	2.92	10	-1.57	2.24	12	1.5%	2.57 [0.36, 4.78]
Leggate et al. (22)	-0.3	1.34	12	-1.57	2.24	12	2.4%	1.27 [-0.21, 2.75]
Martins et al. (54) (1/2 HIIT)	-1.8	1.7	9	-0.7	3.3	6	1.0%	-1.10 [-3.96, 1.76]
Mirghani; Yousefi (55) (60:30)	-0.63	0.41	8	-1.57	2.24	12	2.8%	0.94 [-0.36, 2.24]
Mirghani; Yousefi (55) (60:60)	-1.16	0.87	8	-1.57	2.24	12	2.6%	0.41 [-0.99, 1.81]
Mora-Rodriguez et al. (56) (HIITa)	0.4	1.98	12	-1.57	2.24	12	2.1%	1.97 [0.28, 3.66]
Mora-Rodriguez et al. (56) (HIITb)	-0.5	1.87	12	-1.57	2.24	12	2.1%	1.07 [-0.58, 2.72]
Morales-Palomo et al. (57)	-2.5	3.4	23	-1.57	2.24	12	1.8%	-0.93 [-2.81, 0.95]
Nybo et al. (60)	-1.4	2.24	8	-1	3.55	9	1.0%	-0.40 [-3.19, 2.39]
Ortega et al. (61)	-1.3	2.78	18	-1.57	2.24	12	1.9%	0.27 [-1.53, 2.07]
Rowley et al. (63)	-0.7	2.55	5	-0.8	0.76	7	1.4%	0.10 [-2.20, 2.40]
Sawyer et al. (28)	-0.1	4.46	9	0	2.46	9	0.8%	-0.10 [-3.43, 3.23]
Sijie et al. (66)	-6.2	1.32	17	-4.4	1.96	16	3.1%	-1.80 [-2.95, -0.65]
Stensvold et al. (70)	-1.4	2.5	11	-1.57	2.24	12	1.7%	0.17 [-1.78, 2.12]
Stensvold et al. (71)	-1.4	6.02	11	-1.57	2.24	12	0.6%	0.17 [-3.61, 3.95]
Tjønna et al. (72)	-2.1	1.9	13	-1.57	2.24	12	2.2%	-0.53 [-2.16, 1.10]
Whyte et al. (18)	-1	2.25	10	-1.57	2.24	12	1.8%	0.57 [-1.31, 2.45]
Subtotal (95% CI)			**390**			**417**	**70.4%**	**0.72 [0.35, 1.10]**
Heterogeneity: Tau² = 0.49; Chi² = 57.63, df = 35 (P = 0.009); I² = 39%								
Test for overall effect: Z = 3.77 (P = 0.0002)								
1.2.2 Equalized								
Ahmadizad et al. (38)	-1.2	1.06	10	-1.1	1.01	10	3.7%	-0.10 [-1.01, 0.81]
Bækkerud et al. (42) 1-min bouts	-0.9	1.2	9	-0.2	1.3	4	2.4%	-0.70 [-2.20, 0.80]
Bækkerud et al. (42) 4-min bouts	-0.9	1.9	8	-0.2	1.3	5	2.0%	-0.70 [-2.44, 1.04]
Higgins et al. (15)	-0.9	2.5	23	-0.9	1.8	29	3.0%	0.00 [-1.21, 1.21]
Martins et al. (54) (HIIT)	-1.3	2.1	13	-0.7	3.3	7	1.1%	-0.60 [-3.30, 2.10]
Moreira et al. (58)	-1.2	2.38	8	-1.3	2.58	8	1.3%	0.10 [-2.33, 2.53]
Nie et al. (59)	-3.9	2.85	16	-4.2	3.23	14	1.5%	0.30 [-1.89, 2.49]
Panissa et al. (19)	-0.55	0.96	11	0.25	0.92	12	4.0%	-0.80 [-1.57, -0.03]
Robinson et al. (62)	-0.7	3.42	20	-1.4	7.77	18	0.6%	0.70 [-3.19, 4.59]
Sasaki et al. (64)	0.3	1.68	12	0.4	2.08	12	2.4%	-0.10 [-1.61, 1.41]
Sim et al. (67)	-0.8	1.29	10	-0.6	1.85	10	2.6%	-0.20 [-1.60, 1.20]
Tjønna et al. (16)	-2.3	3.08	11	-3.6	4.23	8	0.7%	1.30 [-2.15, 4.75]
Trapp et al. (17)	-1.5	2.16	11	-0.1	1.46	8	2.2%	-1.40 [-3.03, 0.23]
Zhang et al. (20)	-5.2	2.1	12	-4.5	2.9	12	1.6%	-0.70 [-2.73, 1.33]
Zhang et al. (74)	-3.3	6.6	15	-3.4	3.2	15	0.6%	0.10 [-3.61, 3.81]
Subtotal (95% CI)			**189**			**172**	**29.6%**	**-0.41 [-0.79, -0.02]**
Heterogeneity: Tau² = 0.00; Chi² = 5.79, df = 14 (P = 0.97); I² = 0%								
Test for overall effect: Z = 2.05 (P = 0.04)								
Total (95% CI)			**579**			**589**	**100.0%**	**0.40 [0.09, 0.72]**
Heterogeneity: Tau² = 0.47; Chi² = 83.97, df = 50 (P = 0.002); I² = 40%								
Test for overall effect: Z = 2.53 (P = 0.01)								
Test for subgroup differences: Chi² = 16.78, df = 1 (P < 0.0001), I² = 94.0%								

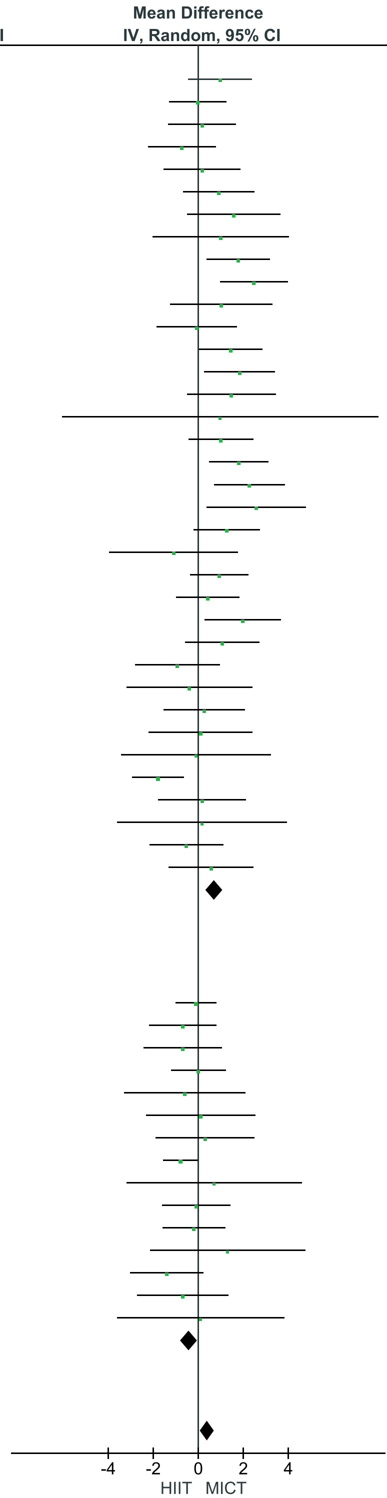

Figure 1 Comparison between HIIT and MICT for body mass. HIIT, high-intensity interval training; MICT, moderate-intensity continuous training; SD, standard deviation; CI, confidence interval. [a]Dyslipidaemia; [b]dyslipidaemia associated with hyperglycaemia; [c]healthy; [d]active recovery; [e]passive recovery; [f]training performed in fed status; [g]training performed in fasted status. [Colour figure can be viewed at wileyonlinelibrary.com]

Study or Subgroup	HIIT Mean	HIIT SD	HIIT Total	MICT Mean	MICT SD	MICT Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Not equalised								
Alvarez et al. (39)	0.2	1.42	12	-0.93	2.12	12	2.8%	1.13 [-0.31, 2.57]
Bouri et al. (43)	-0.3	0.74	7	-0.93	2.12	12	3.1%	0.63 [-0.69, 1.95]
Cocks et al. (44)	-0.4	0.7	8	-1.3	0.9	8	4.8%	0.90 [0.11, 1.69]
Cooper et al. (45) a	0.2	1.4	15	-0.93	2.12	12	2.9%	1.13 [-0.26, 2.52]
Cooper et al. (45) b	-0.2	1.7	15	-0.93	2.12	12	2.7%	0.73 [-0.75, 2.21]
Escarate et al. (46)	-4.6	1.6	7	-0.93	2.12	12	2.3%	-3.67 [-5.36, -1.98]
Gillen et al. (48) c	-0.8	1.06	8	-0.93	2.12	12	2.9%	0.13 [-1.28, 1.54]
Gillen et al. (48) d	-0.7	1.1	8	-0.93	2.12	12	2.9%	0.23 [-1.19, 1.65]
Jabbour et al. (50)	-2.2	3.81	12	-0.93	2.12	12	1.3%	-1.27 [-3.74, 1.20]
Keating et al. (21)	-0.5	2.7	13	-1	3.47	13	1.4%	0.50 [-1.89, 2.89]
Kong et al. (29)	0.2	3.5	13	-1.2	3.4	13	1.2%	1.40 [-1.25, 4.05]
Kong et al. (51)	0.7	2.09	10	-0.93	2.12	12	2.2%	1.63 [-0.14, 3.40]
Larsen et al. (52)	-0.2	3.25	10	-0.93	2.12	12	1.4%	0.73 [-1.61, 3.07]
Lunt et al. (53) (HIIT)	-0.5	2.05	16	-0.5	2.24	8	2.0%	0.00 [-1.85, 1.85]
Lunt et al. (53) (HIIT-SIT)	-1.1	1.9	16	-0.5	2.24	9	2.2%	-0.60 [-2.33, 1.13]
Mirghani; Yousefi (55) (60:30)	-0.65	0.32	8	-0.93	2.12	12	3.4%	0.28 [-0.94, 1.50]
Mirghani; Yousefi (55) (60:60)	-0.46	0.43	8	-0.93	2.12	12	3.3%	0.47 [-0.77, 1.71]
Mora-Rodriguez et al. (56) (HIITa)	-0.3	2.39	12	-0.93	2.12	12	2.1%	0.63 [-1.18, 2.44]
Mora-Rodriguez et al. (56) (HIITb)	-0.7	2.48	12	-0.93	2.12	12	2.0%	0.23 [-1.62, 2.08]
Nybo et al. (60)	-0.5	1.77	8	-1.7	2.13	9	2.0%	1.20 [-0.65, 3.05]
Rowley et al. (63)	-1.7	1.51	5	-2.6	1.13	7	2.5%	0.90 [-0.67, 2.47]
Sawyer et al. (28)	-0.8	2.12	9	-0.3	3.22	9	1.3%	-0.50 [-3.02, 2.02]
Sijie et al. (66)	-4.02	1.58	17	-1.15	1.75	16	3.6%	-2.87 [-4.01, -1.73]
Skleryk et al. (68)	-1.1	2.51	8	0.1	1.76	8	1.7%	-1.20 [-3.32, 0.92]
Smith-Ryan et al. (69) 1-min bouts	-2.18	2.06	11	-0.93	2.12	12	2.3%	-1.25 [-2.96, 0.46]
Smith-Ryan et al. (69) 2-min bouts	-1.52	1.39	10	-0.93	2.12	12	2.7%	-0.59 [-2.07, 0.89]
Tjønna et al. (72)	-0.8	1.1	13	-0.93	2.12	12	3.1%	0.13 [-1.21, 1.47]
Tong et al. (73)	-2.2	2.1	8	-0.93	2.12	12	2.0%	-1.27 [-3.16, 0.62]
Subtotal (95% CI)			**299**			**316**	**68.1%**	**-0.00 [-0.49, 0.49]**
Heterogeneity: Tau² = 1.00; Chi² = 70.59, df = 27 (P < 0.00001); I² = 62%								
Test for overall effect: Z = 0.00 (P = 1.00)								
1.2.2 Equalised								
Ahmadizad et al. (38)	-1	0.78	10	-1.1	0.98	10	4.9%	0.10 [-0.68, 0.88]
Higgins et al. (15)	-1	1.4	23	-0.3	1.1	29	5.1%	-0.70 [-1.40, -0.00]
Moreira et al. (58)	-0.6	2.8	8	-0.6	3.2	7	0.9%	0.00 [-3.06, 3.06]
Nie et al. (59)	-1.9	1.52	16	-1.7	2.31	14	2.9%	-0.20 [-1.62, 1.22]
Panissa et al. (19)	-2.9	2.6	11	-1.3	1.4	12	2.2%	-1.60 [-3.33, 0.13]
Sasaki et al. (64)	-0.5	1.64	12	0.4	2.05	12	2.7%	-0.90 [-2.39, 0.59]
Sim et al. (67)	-1.1	1.06	10	-0.9	2.86	10	2.0%	-0.20 [-2.09, 1.69]
Trapp et al. (17)	-2.7	3.93	11	0.6	4.88	8	0.5%	-3.30 [-7.40, 0.80]
Zhang et al. (20)	-3.1	1.2	12	-2.8	1.4	12	3.9%	-0.30 [-1.34, 0.74]
Zhang et al. (74)	-0.25	0.21	15	-0.24	0.19	15	6.8%	-0.01 [-0.15, 0.13]
Subtotal (95% CI)			**128**			**129**	**31.9%**	**-0.22 [-0.52, 0.08]**
Heterogeneity: Tau² = 0.04; Chi² = 10.79, df = 9 (P = 0.29); I² = 17%								
Test for overall effect: Z = 1.46 (P = 0.14)								
Total (95% CI)			**427**			**445**	**100.0%**	**-0.12 [-0.44, 0.19]**
Heterogeneity: Tau² = 0.37; Chi² = 81.86, df = 37 (P < 0.0001); I² = 55%								
Test for overall effect: Z = 0.78 (P = 0.44)								
Test for subgroup differences: Chi² = 0.59, df = 1 (P = 0.44), I² = 0%								

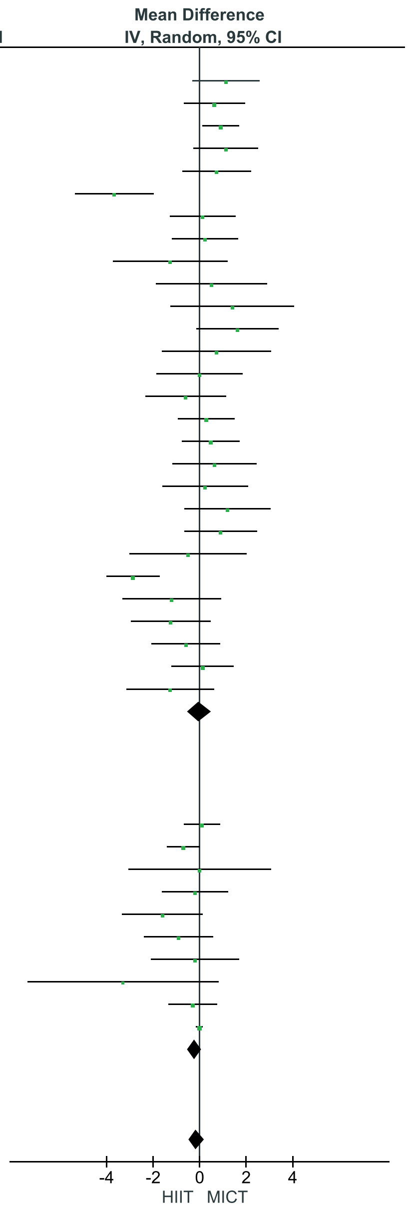

Figure 2 Comparison of body fat percentage between HIIT and MICT. HIIT, high-intensity interval training; MICT, moderate-intensity continuous training; SD, standard deviation; CI, confidence interval. [a]Active recovery; [b]passive recovery; [c]training performed in fed status; [d]training performed in fasted status. [Colour figure can be viewed at wileyonlinelibrary.com]

In the studies that evaluated body composition by DEXA, HIIT (241 subjects) compared with the control (237 subjects) was effective in decreasing body fat percentage (−1.17% [95% CI: −1.77% to −0.57%]; I^2: 68%; *P* for heterogeneity: <0.001). Nevertheless, there was no difference between HIIT (241 subjects) and MICT (252 subjects) ([95% CI: −0.45% to 0.40%]; I^2: 60%; *P* for heterogeneity: <0.001). When the protocols were non-equalized ([95% CI: −0.51% to 0.72%]; I^2: 63%; *P* for heterogeneity: <0.001) or equalized ([95% CI: −0.95% to 0.29%]; I^2: 50; *P* for heterogeneity: 0.11), there was no difference between HIIT and MICT.

Abdominal subcutaneous fat area

High-intensity interval training (39 subjects) compared with the control (37 subjects) did not affect the abdominal subcutaneous fat area ([95% CI: −46.08 to 17.98 cm^2]; I^2: 77%; *P* for heterogeneity: 0.01). Furthermore, when analysing equalized studies, no differences between HIIT (39 subjects) and MICT (39 subjects) were observed ([95% CI: −27.54 to 9.82 cm^2]; I^2: 32%; P for heterogeneity: 0.23). The comparison between HIIT and MICT with subdivision in non-equalized studies was not possible because only equalized studies were found for this variable.

Abdominal visceral fat area

High-intensity interval training (39 subjects) compared with the control (36 subjects) was effective in reducing the abdominal visceral fat area (−6.83 cm^2 [95% CI: −11.95 to −1.71 cm^2]; I^2: 0%; P for heterogeneity: 0.43). However, when analysing equalized studies, no differences between HIIT (39 subjects) and MICT (39 subjects) were observed ([95% CI: −11.12 to 1.45 cm^2]; I^2: 0%; P for heterogeneity: 0.65). The comparison between HIIT and MICT with subdivision in non-equalized studies was not possible because only equalized studies were found for this variable.

Meta-regression

A significant regression was found ($F_{3,44}$ = 6.1, P = 0.001, R^2 = 0.30) between the number of sessions (more reduction with more sessions) (P = 0.004), exercise mode (more reduction in running) (P = 0.035) and age (more reduction with less age) (P = 0.030) for changes in body mass. For BMI, a significant regression was found ($F_{2,41}$ = 10.9, $P < 0.0001$, R^2 = 0.35) with the type of interval training (more reduction in SIT compared with HIIT short or HIIT long) (P = 0.070) and sex (more reduction with more male percentage) ($P < 0.0001$) as predictors of change.

For waist circumference, a significant regression was found ($F_{1,26}$ = 5.8, P = 0.023, R^2 = 0.18) with the exercise mode (more reduction in running) (P = 0.023). No significant regressions were found for WHR. For body fat percentage, a significant regression was found ($F_{1,36}$ = 7.7, $P < 0.009$, R^2 = 0.29) with age (more reduction with more age) (P = 0.009) as a predictor of change in this variable. For abdominal visceral fat area, a significant regression was found ($F_{1,1}$ = 247.3, $P < 0.040$, R^2 = 0.99) with study quality (more reduction with more study quality) ($P < 0.040$).

Study quality

The evaluation of the quality and risk of bias of the studies included in this meta-analysis was as follows: In relation to study quality, 64.6% of the studies met the eligibility criteria, 20.8% presented an adequate specification of the randomization process, 18.8% met the criteria of allocation concealment, 89.6% had similar groups at baseline, and 95.8% met the criteria of blinding the assessor for at least one primary outcome. Thus, of the five criteria evaluated by TESTEX to assess study quality, the average score for these items was 2.9 ± 1.2.

In relation to the study reporting, 37.5% assessed the primary outcome measures in >85% of participants, 39.6% reported adverse events, 50.0% reported the session attendance, 10.4% performed the analysis by intention to treat, 100% described the between-group statistical comparisons for the primary outcome measure and 100% for at least one secondary outcome measure, 83.3% reported the point measures and measures of variability for all reported outcome measures, 16.7% presented activity monitoring in the control groups, 89.6% reported that the training was periodically adjusted to keep the relative exercise intensity constant and 100% adequately presented the exercise characteristics. Thus, of the ten criteria evaluated by TESTEX to assess study reporting, the average score for these items was 6.3 ± 1.3.

Therefore, considering both aspects (study quality and study reporting) evaluated by TESTEX, the studies included in the present study complied with 9.2 ± 2.0 of the 15 possible criteria. All information regarding individual scores for study quality is presented in Table S3.

Level of evidence

Moderate-quality evidence was indicated for body mass, BMI, waist circumference, body fat percentage (evaluated by all methods and by DEXA only), abdominal subcutaneous fat area and abdominal visceral fat area. Limited-quality evidence was indicated for WHR.

Discussion

The main results of this study indicate that HIIT is effective in reducing body mass, BMI, waist circumference, WHR, body fat percentage and abdominal visceral fat area. Although some differences between HIIT and MICT were found, when equalization of the sessions between the two training methods was considered, the only difference remaining was for body mass. Thus, the results show that HIIT can be considered an effective training method for the treatment of obesity, but its superiority in relation to MICT should be viewed with reservation.

The present review verified that HIIT was effective in reducing body mass (−1.45 kg [95% CI: −1.85 to −1.05 kg]). Additionally, MICT (0.40 kg [95% CI: 0.09 to 0.02 kg]) decreased body mass to a greater degree than did HIIT. However, considering only equalized studies, the reduction observed in body mass was superior in the HIIT (−0.41 kg [95% CI: −0.79 to −0.02 kg]). These results differ from previous studies because previous meta-analyses involving adults with obesity did not verify the effectiveness of HIIT in reducing this variable (23,27), nor did previous studies verify the differences between the HIIT and MICT protocols (27). Unlike the meta-analysis of Batacan *et al.* (23), which did not identify the effectiveness of HIIT in improving nutritional status as evaluated by BMI, the present meta-analysis observed a reduction in BMI (-0.44 kg m^{-2}) but found differences between HIIT and MICT only in the non-equalized protocols.

Regarding adiposity, this meta-analysis showed the effectiveness of HIIT in reducing body fat percentage (-1.29%). Similar results were found in previous meta-analyses that assessed the effect of HIIT in adults with obesity, with reductions of -1.7 (27) and ~2 kg (25) of the total fat mass. In another meta-analysis involving a more diversified sample with a wider age range (10 to 65 years old) and including eutrophic subjects, Keating *et al.* (24) reported reductions in both body fat mass (-1.38 kg [95% CI: -1.99 to -0.77 kg]) and body fat percentage (-1.26% [95% CI: -1.80% to -0.72%]). All these studies considered only the pre-intervention and post-intervention values without the use of a control group (non-exercise) (24,25,27), an inclusion that could reduce the risk of bias of the analyses (30). However, in the present study, which considered a control group, the results remained similar. Additionally, the effectiveness of HIIT remained even when only studies that used DEXA were included, which is considered the gold standard for estimating body adiposity.

Interestingly, in the meta-analysis of Batacan *et al.* (23), only the longer interventions (>12 weeks) were able to generate reductions in body fat percentage. Therefore, although some studies have shown changes in body composition in short protocols (19,69), the duration of the intervention may be a relevant factor in generating more consistent results. This reduction in adiposity is of paramount importance because obesity is responsible for an estimated 5% of deaths worldwide (1), and it is associated with several chronic diseases (4,5).

In addition to the analysis of the effectiveness of HIIT for changes in body composition, an objective of many investigations has been to compare the effectiveness of the HIIT and MICT methods and to identify the best strategy (15,17,19–21,28,29,38,44,51,53,58–60,64,66–68,74). In this present study, the analyses showed that HIIT is similar to MICT for reducing body fat percentage, opposing the findings of the meta-analysis by Türk *et al.* (26) that revealed the superiority of HIIT (-2.01% [95% CI: -3.75% to -0.30%]) in adults with obesity. However, it is worth noting that the mentioned study disregarded the equalization of the energy expenditure or workload between HIIT and MICT, a fact that indisputably creates a bias in the interpretation of results (30). Differences among exercise mode also were observed in comparisons that either did (24) or did not (24,27) include equalization between protocols. Therefore, when only the equalized studies were analysed in the present study, these differences disappeared. Thus, there is a need to consider similar protocols in comparisons between HIIT and MICT.

Beyond merely total body fat, the location of fat accumulation has also been highlighted as relevant for health. Some evidence indicates that the accumulation of fat in the central region is more harmful to health because it causes higher insulin resistance and increases the risk of cardiovascular diseases (75). The present meta-analysis showed that HIIT was effective in reducing the abdominal visceral fat area (-6.8 cm^2), waist circumference (approximately -2.3 cm) and WHR (-0.01). In their meta-analysis of adults with obesity, Maillard *et al.* (25) evaluated the effects of HIIT on abdominal fat mass and visceral fat mass and reported a reduction in these two indicators of central obesity. In other meta-analyses, waist circumference as an indicator of central obesity was analysed (23,27). Wewege *et al.* (27) observed a significant effect of HIIT with a waist circumference reduction of ~3 cm in adults with obesity, while Batacan *et al.* (23) found a reduction only in an extended intervention (>12 weeks), with a decrease of ~2 cm. These reductions in waist circumference can be considered clinically relevant because even modest reductions (<2 cm) confer improvements in almost all risk factors present in metabolic syndrome (76).

It is suggested that HIIT may be very effective for reducing abdominal adiposity (77) because intense exercise promotes a greater secretion of catecholamines (78). As β-adrenergic receptors are located in adipose tissue (79), with a high concentration of these receptors in the abdominal region (80), HIIT could promote a greater decrease in central obesity (77). However, in the present study, although HIIT was shown to be effective in reducing abdominal visceral fat, waist circumference and WHR, the magnitude that can be considered is modest. In addition, no differences between exercise models were observed. Similar results were obtained by Wewege *et al.* (27) in their meta-analysis, which also reported no differences in waist circumference between HIIT and MICT. To the best of our knowledge, this was the first meta-analysis involving adults with obesity to compare the effects of training models (HIIT vs. MICT) on visceral fat, abdominal fat and WHR. Thus, considering the malignant potential of visceral fat (75), it is important to adopt physical activity regardless of the model because exercise alone has been shown to be effective in reducing visceral adiposity regardless of whether it is accompanied by a reduction in body mass (81,82).

Although previous studies have suggested the superiority of HIIT over MICT for the reduction of adiposity in patients with obesity (17,77), the present study found similar responses between these two training models. HIIT achieved superior results to MICT only for body mass, considering equalized protocols. However, it is necessary to pay attention to the clinical relevance of this result. The superiority of HIIT was equivalent to only 410 g of body mass, a magnitude that can be considered clinically irrelevant. Thus, because the results are similar, individual preferences should be considered to guide the choice of exercise type at the time of planning the training programme for adults with obesity.

It is advocated that two mechanisms may be responsible for the effectiveness of HIIT in the reduction of adiposity: possible modulation of the mechanisms of appetite and satiety and/or changes in excess post-exercise oxygen consumption (EPOC) (77). Regarding the mechanisms of appetite and satiety, as final outcome, there is no compensatory increase in energy intake following a period (≥4 weeks of duration) of HIIT/SIT compared with MICT or no exercise (83).

Regarding the EPOC, previous studies reported small differences in EPOC in analyses involving healthy physically active men (~53.7 kJ) (84) and physically active men (~27 kJ) (85). However, these results are limited by the fact that HIIT and MICT have different energy expenditures, with more energy expenditure during MICT (84) or HIIT (85). Thus, HIIT tends to generate a higher EPOC than does MICT. However, although this factor has a positive contribution in the long term, the magnitude of these differences is modest, suggesting that EPOC may be unable to trigger significant changes in body mass and body composition.

Another important factor in the analysis of possible effects of HIIT on reduction of adiposity is that most of the studies did not control the diet of the participants. This fact is extremely important because there is evidence suggesting that exercise programmes without interventions that involve an energetic deficit are ineffective in reducing the total body fat mass (10), although exercise alone is effective in reducing visceral adipose tissue (9,82) and improving different variables of physical fitness (23,86).

Additionally, the central idea of the proposal of HIIT is not to train less but to spend more time training at high intensity, and the caloric expenditure resulting from shorter training sessions may not be as elevated as routinely suggested. For example, a session consisting of a 5-min warm-up at 50–60% HR_{max} + 10 × 1 min periods at 90–95% HR_{max}: 1 min at ~25–50 W + a cool down of 5 min at 50–60% HR_{max} resulted in an energy expenditure of only 753 kJ in men and women with obesity, which is equivalent to the oxidation of ~23 g of fat (28).

The idea that HIIT is a time-efficient strategy should be interpreted with caution. To achieve the same energy expenditure, the duration of the HIIT and MICT sessions may be similar, as analysed by some studies with isocaloric protocols, including Schjerve *et al.* (65) (HIIT: 43 min; MICT: 47 min), Bækkerud *et al.* (42) (HIIT: 41 min; MICT: 45 min) and Zhang *et al.* (20) (HIIT: 43 min; MICT: 48 min). In the meta-analysis of Maillard *et al.* (25), when the HIIT protocols had lower time commitments and/or energy expenditures than had the MICT protocols, there was a tendency to favour MICT for total body fat reduction. This highlights the importance of the energy expenditure of the session. Furthermore, it is important to consider the total duration of the session, including the warm-up and cool-down periods, because the idea of a time-efficient strategy has been advocated as a solution to the barrier of lack of time; thus, disregarding these components of the training session is inadequate.

Nevertheless, HIIT can in fact be a time-efficient strategy. In a study by Zhang *et al.* (74), the HIIT group required ~82% to 97% less time than did the MICT group (HIIT: 34.4–37.8 min; MICT: 62.6–74.4 min) to achieve an expenditure of 300 kJ, whereas in the study conducted by Martins *et al.* (54), the HIIT group required ~60% less time (HIIT: ~20 min; MICT: ~32 min) to achieve an expenditure of 1,046 kJ. Protocol characteristics such as the intensity and duration of the effort, intensity, exercise type and duration of pauses will directly influence the energy expended in the session and will determine whether HIIT is a time-efficient strategy: This fact cannot be determined through a simple equation. In a study by Zhang *et al.* (74), an observed characteristic was the long duration of the effort period (4 min at 90% VO_{2max} each bout). In contrast, in the study by Martins *et al.* (54), the main characteristic was all-out intensity with short periods of effort and pause (8 s all-out: 12 s rest). These differences highlight the importance of the duration and intensity of the stimuli to increase the energy expenditure during the session.

Safety is an important aspect of exercise participation. Thus, it is important to understand the safety of HIIT. In populations affected by obesity, previous meta-analyses identified a lack of reports on adverse events (24,27). For example, in the study by Keating *et al.* (24), only 48% of studies reported the frequency and severity of adverse events. In the present study, similar results were found: Only 37% of studies reported adverse effects, and limited information was available about the reasons why subjects dropped out of the studies. However, of the studies that provided this information, no differences in adverse events were found between HIIT and MICT, and no studies reported acute injuries from either training protocol (27).

Additionally, evidence from the population at greater risk may indicate the safety of HIIT prescription for individuals with obesity. For example, no adverse effects were reported from exercise training patients with stable post-infarction heart failure (87), and in a study involving patients with heart failure, there were no differences in serious adverse events between HIIT and MICT during a supervised intervention of 12 weeks or at follow-up at 52 weeks (88). Furthermore, an intervention programme involving HIIT in patients with coronary problems reported 30,000 patient-hours of training without any significant adverse events (89).

Finally, because the efficiency and safety of HIIT and MICT are similar, individual preferences should be considered. In this sense, the physical activity enjoyment experienced by sedentary men affected by overweight (90) or obesity (91) was similar between HIIT and MICT (matched by mechanical work). Furthermore, there were higher ratings of perceived enjoyment for HIIT in isocaloric protocols with recreationally active men (92), although the ratings of perceived exertion (80,91,92) and heart rate were higher in some HIIT protocols (85,90).

Limitations

Study quality is a limiting factor of this meta-analysis. Most of the included studies either did not use a randomized model or reported the results as a randomized study but did not present an adequate specification of the randomization process. Therefore, such studies were classified as non-randomized because they failed to meet the established recommendations by the TESTEX assessment. In addition, most studies did not meet the criteria of allocation concealment. Most studies failed to describe some information, such as adverse events, and half of them did not describe the session attendance. Furthermore, only a small portion of the studies performed their analyses based on intention to treat.

Methodologically, the important biases presented by many studies were the lack of a control group (non-exercise) and the lack of equalization between protocols comparing the effects of HIIT and MICT. In this sense, many studies did not fully describe this process. Another important limiting aspect was the lack of control of the participants' diets. Because body mass control is dependent on the ratio between energy intake/energy expenditure, this limitation is an important risk of bias. Thus, there is a possibility of greater/smaller reductions in adiposity as a result of changes in diet rather than from exercise.

In addition, most of the studies did not monitor the day-to-day physical activity level of the participants, including monitoring activity in the control groups. Such monitoring is crucial to reduce bias in the interpretation of the results due to the possibility of reduced or increased daily activities in individuals who perform exercises at greater or lesser intensity, respectively.

Future indications

To better understand these findings, studies with experimental designs that avoid the main limitations addressed earlier are of paramount importance. In addition, some topics require better understanding, such as food behaviour, control of appetite and satiety, excess post-exercise oxygen consumption, level of physical activity outside the exercise protocol and resting metabolic rate in HIIT programs involving energy demand equivalent to MICT.

New studies involving biochemical and functional variables are important for understanding the effects of HIIT. Additionally, protocol equalization should preferably be performed through a direct analysis of energy expenditure during the session because it has previously been observed that protocols with equivalent work can correspond to different energy expenditures (93).

Conclusions and practical implications

Based on the results obtained, the present study concludes that HIIT promotes reductions in body mass, fat mass (total, percentage and abdominal visceral fat area) and the risk indicators for cardiovascular and metabolic diseases in adults afflicted with overweight or obesity. In addition, HIIT promoted results similar to those of MICT, particularly when these two methods were equalized. Although HIIT promoted greater reductions in body mass than did MICT, the magnitude of this result was not clinically relevant. The quality of the studies included in the analysis was limited, leading to important methodological weaknesses that made it difficult to extrapolate the conclusions of the findings. New original studies must meet the recommendations of clinical trials and include the items that constitute the evaluation criteria of study quality. Thus, HIIT can be used as a secondary method for the treatment of obesity in adults, and individual preferences should be considered to guide the choice of exercise type at the time of planning the training programme for adults afflicted with overweight or obesity.

Conflict of interest statement

No conflict of interest was declared.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article. https://doi.org/10.1111/obr.12766

Box S1 Literature search strategy used for the PubMed database
Box S2 Results of each term of the literature search strategy used for the Cochrane Library, PubMed, Science Direct, Scopus, SPORTDiscus and Web of Science database
Table S1 Characteristics of the exercise structure of the groups that performed high-intensity interval training
Table S2 Characteristics of the exercise structure of the groups that performed moderate-intensity continuous training
Table S3 Study quality assessment of included studies using the Tool for the Assessment of Study Quality in Exercise Training (TESTEX)
Figure S1 Flow chart illustrating the different phases of the search and study selection
Figure S2 Comparison between the HIIT and control groups for body mass. HIIT, high-intensity interval training; SD,

standard deviation; CI, confidence interval. [a]Dyslipideamia; [b]dyslipideamia associated with hyperglycaemia; [c]healthy; [d]active recovery; [e]passive recovery; [f]training performed in fed status; [g]training performed in fasted status

Figure S3 Comparison between HIIT and control groups for body fat percentage. HIIT, high-intensity interval training; SD, standard deviation; CI, confidence interval. [a]Dyslipidaemia; [b]dyslipidaemia associated with hyperglycaemia; [c]healthy; [d]active recovery; [e]passive recovery; [f]training performed in fed status; [g]training performed in fasted status

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