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Effects of low-volume, high-intensity interval training on maximal oxygen consumption, body fat percentage and health-related quality of life in women with overweight: A randomized controlled trial

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ABSTRACT

Background: Several investigations suggest that high-intensity interval training (HIIT) provokes larger changes in VO_{2max} compared to moderate-intensity continuous training (MICT); other studies associate HIIT with significant decreases in total, abdominal and visceral fat mass. However, some meta-analyses express that the enhancements with HIIT on VO_{2max} are slightly higher concerning MICT. These studies had low-to-moderate methodological quality, and the exercise protocols were completed mostly on treadmills or cycle ergometers. Thus, the objective of this study was to compare the effect of a low-volume HIIT versus a MICT program on VO_{2max}, body fat percentage (BFP), and health-related quality of life (HRQoL) in overweight women. It followed a research protocol with high methodological rigor and good reporting quality.

Methods: After two physical adaptation weeks (run-in period), thirty-five volunteers were randomized to HIIT (n = 16) or MICT (n = 19). Both groups performed 24 sessions on a grass sports field (walking, jogging or running). The HIIT group completed 15 bouts of 30 s [90–95%, maximal heart rate (HR_{max})], while the MICT group completed 30 min of continuous exercise (65–75% HR_{max}).

Results: The difference between HIIT and MICT post-intervention on VO_{2max} was not statistically significant (0.8 ml/kg/min. CI 95%, −1.0 to 2.7, p = 0.37). Similarly, no statistically significant differences were found between groups for BFP and HRQoL.

Conclusions: Low-volume HIIT program has no quantitative advantage compared with that resulting from MICT, in VO2max, BFP, and HRQoL. ClinicalTrials.gov Identifier: NCT03300895.

1. Introduction

The global prevalence of obesity tripled between 1975 and 2016, and is associated with an increased risk of suffering from chronic non-communicable diseases (NCDs), such as high blood pressure, Type 2 Diabetes Mellitus (DM2), coronary heart disease, stroke, some types of cancer and sleep apnea.[1] Being overweight and obese in women is associated with an impaired reproductive cycle and fertility problems; increased risk of polycystic ovary syndrome; endometrial, cervical, breast, and ovarian cancer; with low back pain and knee osteoarthritis.[2] Maximal oxygen consumption (VO_{2max}) is considered the best indicator to assess cardiorespiratory fitness (CRF); it estimates the cardiopulmonary capacity and allows physical exercise control.[3] The VO_{2max} is one of the most important predictors of mortality from cardiovascular disease (CVD), compared to smoking, hypertension, and dyslipidemias.[4]

The increase in VO_{2max} obtained with high-intensity interval training (HIIT) versus moderate-intensity continuous training (MICT) is under discussion. Some studies suggest that HIIT generates significantly greater changes in VO_{2max} compared to MICT.[5,6] Other research associates HIIT with significant decreases in total, abdominal and visceral fat mass.[7,8] Although some meta-analyses

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indicate that the improvements with HIIT on VO_{2max} are only slightly higher concerning MICT,[9,10] others do not report differences on adiposity.[11,12] These meta-analyses come from studies with low-to-moderate methodological quality, small samples, and few randomized controlled trials (RCTs).[9,10,12] A recently systematic review showed that all studies which compared VO_{2max} responses between sprint interval vs. continuous training had an unclear risk of bias and poor reporting quality.[13]

Additionally, the workouts were performed mainly on treadmills or cycle ergometers[10–12]; the HIIT protocols in everyday environments have rarely been investigated; exceptionally, some studies have implemented stair climbing training with positive results on CRF in sedentary adults.[14,15] However, both the feasibility and the results of HIIT are still unclear outside the laboratory,[16] which makes it difficult to generalize these results to people who exercise in open spaces and with basic means, such as walking or running.

It is necessary to carry out research with a high level of evidence, such as RCTs, which allow greater clarity in the cause-effect relationships of HIIT with VO_{2max} and obesity, in addition to clarifying the supposed potential benefits of HIIT over MICT. Therefore, this study followed a research protocol with high methodological rigor and good reporting quality. The primary objective of this study was to compare the effect of a low-volume HIIT program versus a MICT program on VO_{2max} in overweight women. The secondary objective was to identify the effect of both exercise programs on body fat percentage (BFP) and health-related quality of life (HRQoL). We hypothesized that those in the HIIT group would have significantly greater improvements in VO_{2max}, BFP, and HRQoL responses compared to the MICT group.

2. Methods

2.1. Study design and sample size

A two-arm parallel group RCT was conducted following the Consolidated Standards of Reporting Trials.[17] Overweight women between 18 and 44 years old were summoned. The sample size was calculated with: alpha error 0.05; beta error 0.20; 95% confidence level; difference to detect between groups 3.5 ml/kg/min in $VO_{2máx}$ as the minimum effect necessary to reduce the risk of CVD[18]; standard deviation (SD) for the experimental group 3.1 and 3.9 for the control group, according to Sijie et al.,[19] with a ratio between simple sizes of 1:1. Using Epidat software (version 4.1), a sample size of 17 participants per group was calculated, with a 10% increase due to possible losses, for a total of 37.

2.2. Recruiting and research site

Participants were recruited through posters, Email, and social networks. All participants signed an informed consent after receiving all relevant study information. The University of Antioquia Research Ethics Committee of the University Institute of Physical Education and Sports reviewed and endorsed the project in session number 017, dated May 24, 2016. The evaluations and interventions were carried out at the university facilities. The data were stored in password-protected file cabinets, which were only accessible to the researchers.

2.3. Eligibility criteria

Women with physical activity ≥600 MET/min/sem (measured by the Global Physical Activity Questionnaire, GPAQ).[20] Those with a personal history of asthma, DM2, uncontrolled NCDs, motor or sensory disorders that limited exercise practice were excluded, as well as those in treatment with anticoagulants, steroids or medications that alter the heart rate (beta-blockers, calcium antagonists, bronchodilator). Women with a personal history of surgical procedures in the last three months and uncontrolled mental illnesses were also excluded. All individuals were examined by a Sports Medicine specialist, who authorized the admission of each participant. The evaluations were carried out before starting the interventions and – at the end of the exercise period – at the same time and under the same conditions.

2.4. Evaluations of outcomes

To know the changes in $VO_{2máx}$, a maximum stress test on a treadmill (Trackmaster® Model TMX 425C) was implemented, using a K4b2 gas analyzer (Cosmed Inc, IL, USA). Details of the protocol can be consulted in a previous study.[21] wt, body mass index (BMI), and BFP were evaluated with an Omron® HBF-510 bioelectric impedance scale (Omron Healthcare, Inc. Bannockburn, IL, USA), following the manufacturer's indications. Height and waist circumference were evaluated according to the guidelines in another study.[21] The perception of HRQoL was measured using the SF-12 Questionnaire, which is summarized in the physical health and mental health scores expressed as Z values with respect to the average of the United States population, which – for both components – is 50 points with a standard deviation of 10; that is, the values reported above or below the average indicate an increase or decrease in the quality of life for the population average.[22] The reliability in the Colombian population for adults between 18 and 44 years of age for the physical component is 0.74 and for the mental component, 0.71.[23]

2.5. Randomization

The random allocation sequence was carried out in permuted blocks of 4 and 6 using Random Allocation Software, Version 1.0. Opaque, sealed, and sequentially numbered envelopes were used to conceal the randomization sequence. Assignment to interventions was carried out in the order of the participants' admission to the research. An external researcher carried out these processes.

All the participants were informed in detail about the evaluation requirements and were motivated to maintain their lifestyle habits during the research. Proper calibration of the instruments used was guaranteed, as well as the personnel trained in their handling. There was no blinding of the investigators in charge of the evaluations, nor of the persons who carried out the statistical analyses. Exercise interventions are difficult to hide from both participants and those who lead them; therefore, there was no blinding of participants or trainers. Each participant's data was filed, and only the investigators in charge had access.

2.6. Interventions

The interventions consisted of 30 exercise sessions (walking-jogging-running) outdoors on a grass sports field, three times a week on alternate days, led by a trained trainer. Five minutes of warm-up (50–60% HR_{max}) and strength exercises with blue Theraband. Two sets of 10 repetitions were executed for hip flexion, hip extension, hip adduction, and hip abduction in a standing position. Two sets of 10 repetitions were performed for standing knee flexion and seated knee extension. Two sets of 10 repetitions for dorsiflexion, plantarflexion, inversion, and eversion movements were performed in a sitting position for the ankle joint. These strength exercises were added after modifying the initial protocol (with authorization from the Ethics Committee) due to the appearance of overuse injuries, which caused the suspension of the

interventions in some of the participants. During the six initial sessions, 30 min were performed between 55 and 65% HR_{max} (physical conditioning period), treated as the "run-in" period,[24] which was used to measure attendance, compliance with instructions, and response to exercise. Based on this phase, a decision was made as to who was eligible to be randomly assigned to the study groups.

As of session seven, each participant started the exercise sessions according to the group to which she was assigned. The experimental group (HIIT) performed 15 loads of 30 s between 90 and 95% HR_{max}, with 60 s of recovery between loads at 50–60% HR_{max}. The control group (MICT) performed 30 continuous minutes between 65 and 75% HR_{max}. All exercise sessions were monitored using a heart rate monitor (Polar FT1™; Polar, Lake Success, NY). The intensities in each training session were recorded on individual sheets, which allowed the exercise dose to be controlled.

2.7. Statistical considerations

Statistical analyses were performed using Stata (StataCorp. 2013. Release 13). The Shapiro-Wilk and Levene tests were used to test normality and homoscedasticity, necessary to use the Student's t tests and ANCOVA to correct for the baseline value in VO_{2max} and BFP, and adjust for possible confounding variables. Results are shown as mean and SD. When it was not possible to comply with any of the assumptions, the Mann-Whitney *U* test was used, and the results are presented in medians and interquartile ranges (IQR). Qualitative variables are shown in proportions. Intention-to-treat principle (ITT) and per-protocol analysis (PP compliance ≥70% of exercise sessions) were performed. Differences with a p-value ≤ 0.05 were considered statistically significant, and a 95% confidence level was used. Multiple imputation techniques were used to treat the data lost in VO_{2max}.

3. Results

The recruitment began in July 2017 and ended in November 2018. A total of 215 women responded; 74 did not meet the criteria and 141 were eligible to enter. Forty-four women were summoned for evaluation and one was excluded for presenting a lower BMI than required. Thus, 43 participants started the run-in period. At the end of this period, seven declined for personal reasons and one due to a muscle injury. Finally, 35 women were randomly assigned, 16 to the HIIT group and to the MICT group (See Fig. 1).

In the initial analyses, differences between groups were only identified in the mental health component (see Table 1). The final results following ITT analysis did not show statistically significant differences between groups in VO_{2max} (Δ 0.8 ml/kg/min; Confidence Interval (CI) 95% −1.0 to 2.7, p = 0.37). There were also no significant differences between groups in the variables BFP, physical health, and mental health in HRQoL. In PP analysis, similar results were evidenced in all the variables studied (see Table 2).

There were 12 overuse injuries during the intervention, 10 (62.5%) in HIIT and two (10.5%) in MICT (p = 0.001). HIIT had three cases of bilateral periostitis, three with goose-foot tendonitis, one with patellofemoral pain, one with ankle pain, one with hamstring

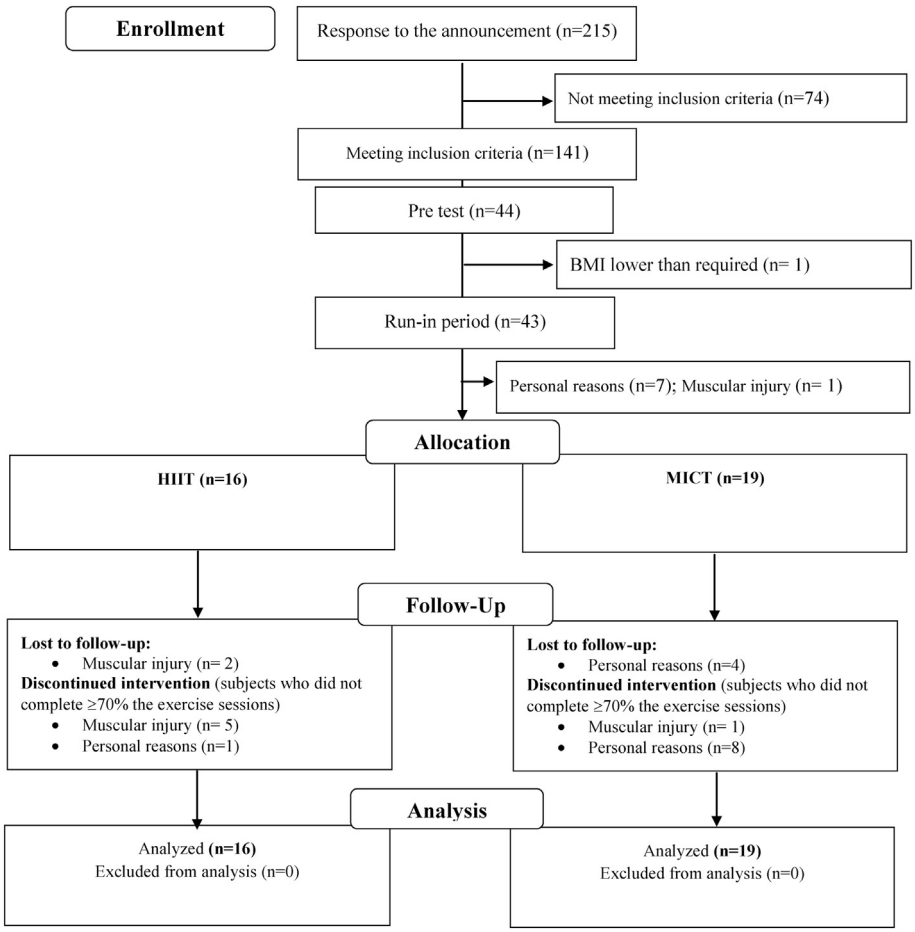

Fig. 1. Participant enrollment flow diagram.

Table 1
Baseline characteristics of study subjects.

	HIIT (n = 16)	MICT (n = 19)	*p*
Age (years)*	29.7 (7.2)	29.5 (8.1)	0.95
WC (cm)**	97.2 (93.1 a 103.8)	95.3 (90.3 a 103.3)	0.67
Weight (kg)*	78.8 (9.2)	74.9 (14.1)	0.34
BMI (kg/m2)**	30.6 (28.5 a 33.3)	29.7 (26.5 a 32.7)	0.41
BFP (%)*	46.4 (4.0)	45.3 (4.5)	0.44
PAL (Mets/min/week)*	148.7 (175.7)	174.7 (181.4)	0.67
VO_{2max} (mL/kg/min)*	28.6 (3.8)	31.1 (5.2)	0.11
Physical health**	53.7 (53.1 a 55.3)	52.5 (47.8 a 55.6)	0.50
Mental health**	55.0 (50.6 a 57.9)	50.7 (34.7 a 55.1)	0.01‡

Waist circumference (WC), body mass index (BMI), body fat percentage (BFP), physical activity level (PAL), maximum oxygen consumption ($VO_{2máx}$). *Values are given as mean ± SD. **Values are given as medians and interquartile ranges. ‡Differences between groups at baseline p < 0.05.

tendinitis, and one with knee tendonitis. Adverse events in MICT were bilateral patellofemoral pain and heel pain. The treatment provided consisted of non-steroidal analgesics plus suspension of training for a period of 72 h.

There were no significant differences (p = 0.89) in adherence (≥70% of exercise sessions) between groups, HIIT (63.3%) and MICT (66.4%). It should be noted that five participants in the HIIT group who had an adverse event culminated in adherence of ≥70% to the programmed exercise; likewise, it occurred with the two women who presented injury in the MICT group. Overuse injuries in HIIT were the causes of poor adherence to the protocol, while in MICT, with the exception of a single case, the low adherence was explained by personal reasons. Compliance with the HIIT loads was evidenced with a HR at the end of the intervals of 190.31 ± 7.19 beats per minute (bpm), corresponding to a percentage of HRmax of 93.16 ± 2.57%.

4. Discussion

The main findings of the study suggest that – after adjusting for confounding variables, such as age, BMI, weight, and height – the HIIT protocol was not superior to MICT in improving VO_{2max} in the study population. A similar result was found in BFP after adjusting for age and waist circumference.

For VO_{2max}, our findings indicate that high-intensity, low-volume intervals, such as the one proposed in this study, appear not to have a superior effect on CRF than MICT in overweight women. This result is similar to a previous study that applied the same HIIT and MICT protocols in healthy men, where no differences were found in VO_{2max} after eight weeks of training.[25] Controversially, the meta-analysis by Sultana et al.[16] indicates that low-volume HIIT equals or exceeds MICT to increase CRF. Although the authors present this result as positive, it should be interpreted with caution due to the low-effect size reported (−0.171 CI 95% −3.328 to −0.030) and the heterogeneity of the individuals included (19–70 years, BMI of 21.2–35.7 kg/m2). Other meta-analyses, also with small effect size, report that HIIT protocols are superior to MICT on VO2max in overweight and obese people, should have intervals of ≥2 min, sessions of ≥15 min, of duration ≥12 weeks, and with similar energy costs.[26,27]

Our results did not show significant differences between post-intervention groups in BFP. These results coincide with some meta-analyses that included different obesity indicators,[16,27,28] where no differences were found even when caloric expenditure was equal between the intervention groups[28] or when HIIT was compared against a non-exercise group.[16] Our data also did not show significant differences between groups in the physical and mental health components in HRQoL. Similar results are reported in inactive adults with overweight/obesity, who were intervened for 16 weeks with low-volume HIIT, high-volume HIIT or MICT.[29]

Although there were significant differences in the number of lesions in HIIT compared to MICT, we consider that this did not affect the results obtained in the variables analyzed since adherence to the interventions did not show differences between groups; however, adherence in both groups did not exceed 66.4%. A systematic review and meta-analysis that compared HIIT vs. MICT in overweight and obese people[12] presented dropout rates of 23% and 15% associated with adverse events or injuries. There is a lack of information on these injuries, which did not allow an adequate comparison regarding the safety of the interventions. The authors recommend improving the reporting of these events, mainly those related to interventions.

While conditioning sessions were performed prior to the start of the HIIT protocol, and the high intensity loading time per session was short (7.5 min), this was not enough and there were 10 overuse injuries in this group. Another RCT that compared these two training modalities reported that HIIT injuries are more frequent and caused by overload, which led to dropout of the interventions.[25] This coincides with what was reported in an observational study on the incidence of injuries related to exercise, such as burpees, push-ups, lunges and other equipment used in HIIT programs, which report a high incidence of injuries.[30] Therefore, it is advisable before starting any HIIT program to include longer preparation periods with strength exercises in each session to prevent adverse events and improve adherence to exercise.

Table 2
Effects of HIIT versus MICT on Maximum oxygen consumption, body fat percentage, and health-related quality of life after eight weeks. Intention-to-treat analysis and subjects who completed the protocol (≥70% the exercise sessions).

Intention to Treat Analysis				
Variables	HIIT (n = 16)	MICT (n = 19)	Differences between groups (post-intervention)	*p*
VO_{2max} (mL/kg/min)*	30.9 (3.8)	32.0 (5.1)	0.8 (−1.0 a 2.7)	0.37
BFP (%)*	46.4 (3.9)	44.8 (4.4)	0.8 (−0.9 a 2.5)	0.36
Physical health**	51.3 (43.2 a 54.7)	53.2 (44.9 a 55.8)	1.9	0.49
Mental health**	53.4 (51.4 a 57.0)	54.1 (50.3 a 55.9)	0.7	0.57
Subjects who completed the protocol				
Variables	**HIIT** (n = 10)	**MICT** (n = 10)	**Differences between groups (post-intervention)**	***p***
$VO_{2máx}$ (mL/kg/min)*	31.1 (4.5)	34.2 (5.7)	0.7 (−3.0 a 4.4)	0.71
BFP (%)*	45.5 (2.1)	42.9 (3.8)	0.0 (−0.7 a 8.8)	0.82
Physical health**	54.3 (48.7 a 55.5)	53.3 (51.6 a 55.9)	1.0	0.88
Mental health**	56.0 (51.1 a 59.8)	52.3 (48.6 a 55.5)	3.7	0.17

For maximum oxygen consumption ($VO_{2máx}$), values adjusted for baseline and confounding variables (age, body mass index, weight and height). For body fat percentage (BFP), values adjusted for baseline and confounding variables (age and waist circumference). *Values are given as mean ± SD. **Values are given as medians and interquartile ranges. Differences between groups post-intervention p < 0.05. ANCOVA (95% confidence interval) for $VO_{2máx}$ and BFP. Mann-Whitney *U* Test for physical health and mental health.

We can identify some limitations in our study. The energy expenditure in the groups was not controlled; the duration of the sessions and the total training were low, which may explain that no significant differences were found in the variables studied. Finally, what we consider to be a moderate adherence to the interventions (HIIT 63% and MICT 66%), which represents approximately only five weeks of intervention, could affect the results obtained. It is based on previous studies, which indicate a longer intervention time is necessary to find significant differences.[27,31] We identified as strength having included activities of daily living, such as walking and running outdoors as modalities of aerobic exercise carried out in an environment other than the laboratory. In addition, this study followed a research protocol with high methodological rigor and adequate reporting.

5. Conclusion

There are insufficient data to conclude that low-volume HIIT is superior to MICT for improving VO_{2max} in overweight women with a low level of physical activity. Similarly, there were no statistical differences between the groups in BFP, for which longer interventions accompanied with caloric restriction might be necessary. In the HRQoL, no significant differences were identified between the groups. It should be noted that no significant differences were observed between the groups in adherence to interventions. HIIT presented a significant difference compared to MICT in the number of overuse injuries.

Declaration of competing interest

None.

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