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Systematic Review

Training Mode Comparisons on Cardiorespiratory, Body Composition and Metabolic Profile Adaptations in Reproductive Age Women: A Systemic Review and Meta-Analysis

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Abstract: Purpose: This study aimed to compare the effects of high-intensity interval training (HIT), sprint interval training (SIT) and moderate-intensity continuous training (MICT) on cardiorespiratory fitness (CRF), weight (kg), body fat mass (%), plasma glucose (fasting) and lipid levels in reproductive-age women. Method: The search was conducted in Pubmed, Cochrane Library, Virtual Health Library and Scielo. The meta-analyses were conducted using Review Manager software for random-effects models. The results were presented as standardized mean differences and 95%CI, which were calculated to determine the effect size of HIT/SIT and MICT interventions. Results: Eleven articles meet the inclusion criteria. The analyses demonstrated that all exercise modes improved body composition and metabolic profile, but nevertheless, MICT was significantly better at improving CRF ($mL \cdot min^{-1} \cdot kg^{-1}$) compared with HIT (2.45 $mL \cdot min^{-1} \cdot kg^{-1}$ (95% CI: 1.15 to 3.75 $mL \cdot min^{-1} \cdot kg^{-1}$); $p < 0.05$; I2 = 0%) and with SIT (0.98 $mL \cdot min^{-1} \cdot kg^{-1}$ (95% CI: −0.98 to 2.93 $mL \cdot min^{-1} \cdot kg^{-1}$); $p = 0.33$; I2 = 53%). Conclusion: Both HIT and SIT have the potential to be used as a training modality in reproductive-age women, with similar effects to MICT on body composition/metabolic markers but inferior effects on CRF, suggesting that HIT/SIT may be considered a "time-efficient component" of weight management programs. However, the variability in the secondary outcome measures, coupled with the small sample sizes in studies, limits this finding.

Keywords: high-intensity interval training; sprint interval training; moderate-intensity continuous training; body composition; cardiorespiratory fitness; women

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1. Introduction

In the last 40 years, interval training has become the leading method for exercises linked to cardiorespiratory resistance, such as medium- or long-distance running, swimming and cycling. Currently, variations of this training method are widely used, such as the high-intensity interval training (HIT) [1]. The terminology used to describe HIT varies

among several research groups. A Norwegian research group, in one of its first studies on the subject, preferred the term "aerobic interval training (AIT)" [2,3]. In addition, other research groups used total supramaximal intervals (SIT) to describe >100% VO_2max in studies with healthy individuals [4,5] and high intensity interval training (HIIT) for low volume training, with ~30 s short intervals and with a lower 95% intensity maximum oxygen consumption (VO_2max), or for training between 80–100% of maximum heart rate [5–8]. However, despite the widespread use of the term "HIIT" in the media, several research groups have been using the abbreviation of the term "high-intensity interval training" (with a hyphen) as "HIT" [9–12], the same terminology used in this study.

Characterized as a high cardiorespiratory demand exercise, alternating periods of active or passive recovery, "HIT" involves a smaller volume of training and has provided promising results when compared with Moderate Intensity Continuous Training (MICT) on muscle oxidative activity (during or after exercise) [11,13] and on cardiovascular function [14]. These findings justify the high popularity of its use among athletes and the physically active population, suggesting direct health-related implications [5], such as controlling overweight and obesity [7,15], type 1 and 2 Diabetes Mellitus [16,17], and other risk markers for cardiovascular diseases [5,18].

Noteworthy, most of the findings involving HIT protocols are based on data from male participants and that should not be extrapolated to women. This statement is necessary mainly from a study that indicated a possible difference in the substrate oxidation (lipid and carbohydrate) of women and men who performed endurance exercise [19]. When investigating the application of the HIT alternative protocol in male participants (irregularly active), Marquezi et al. [11] found that six treadmill running sessions (eight sets of 60 s at 100% peak velocity—Vpeak; for 75 s of recovery passive) were efficient to promote changes in the intensities of the occurrence of ventilatory thresholds and to increase lipid oxidation (LIPox) contribution (+23.7%) in energy demand during the continuous training. However, when the HIT protocol was tested on irregularly active women, the authors observed conflicting results with those described in the male participants, with a 25% reduction in LIPox and a 38% increase in carbohydrate oxidation (CHOox) after the training period [20]. Therefore, for a better understanding of the effects of HIT on female energy metabolism, Marquezi et al. [21] randomized 11 women (irregularly active) according to ovarian cycle phases (follicular and luteal phase) and applied the same HIT protocol (eight series of 60 s at 100% Vpeak for 75 s of passive recovery) in 12 training sessions. The authors observed that the ovarian cycle phases influenced the rates of substrate oxidation, with consequent improvement in metabolic inflexibility (follicular and luteal phase) and a decrease in CHOox (luteal phase) [21].

Although the above results indicate the use of sex-dependent energy substrates, there is a lack of robust data that are used to discuss female-specific variables (metabolic flexibility, ovarian cycle and use of contraceptives) in different training protocols applied. In this context, this present systematic review and meta-analysis aimed to compare the effect sizes of HIT/SIT and MICT protocols on body composition, cardiorespiratory capacity and metabolic profile (glucose and lipid metabolism homeostasis) in reproductive-age women.

2. Materials and Methods

2.1. Research Strategy

This systematic review was conducted between July and December of 2021. It was performed following the guidelines for conducting systematic reviews and meta-analysis of the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [22]. The search for academic articles was performed on databases and/or electronic libraries: Medical Literature Analysis and Retrieval System Online (Med-Line/PubMed), Cochrane Library, Latin American and Caribbean Literature on Health Sciences (LILACS), Virtual Health Library (BVS)/Latin American and Caribbean Center on Health Sciences Information (Bireme) and Scientific Electronic Library Online (SCI-ELO). The "PICo" strategy (P = population; I = intervention; and Co = context) had keywords and/or descriptors

combined with each other, using the Boolean operators "OR" and "AND", in an integrated search of the title, abstract and subject fields: women OR females AND exercise OR "high-intensity interval" OR "aerobic interval" OR "sprint interval" AND substrate OR "fuel metabolism" OR "fat metabolism/utilization/oxidation" OR "carbohydrate metabolism/utilization/oxidation". All references from selected studies were also reviewed to complement the research.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria for the studies in our analyzes were as follows: (a) subjects—women (18–35 years old); (b) types of studies—clinical trials; (c) languages—Portuguese, English and Spanish; (d) training method—HIT at different effort intensities; (e) outcome—effects of HIT on body composition, cardiorespiratory capacity, glucose homeostasis and lipid metabolism; and (f) publication period—between 2011 and 2021. In addition, the exclusion criteria for the studies in our analyzes were as follows: duplicate articles, case studies, cohort studies, case–control, prevalence, letters, abstracts, dissertations, theses, reviews and cross-sectional studies. Incomplete or not fully available articles were also excluded.

2.3. Selection of Studies

For the selection of the articles, the titles related to the topic in question were initially evaluated. At the end of the search, duplicate titles were excluded. Then, a detailed reading of the articles' abstracts was performed to select those that exclusively addressed the effects of HIT in reproductive-age women. Finally, the full texts were evaluated, and those that met the inclusion criteria were included as a result of the search.

2.4. Data Assessment and Methodological Quality

The articles identified in the search strategy had their title and abstract evaluated by two independent and "blind" researchers. In case of disagreement, a third senior researcher decided to include or exclude the text. To assess the methodological quality, the Cochrane risk of bias tool was used, assessing the risk of bias in the studies through five domains: (1) bias in the randomization process, (2) deviations from the intended intervention, (3) bias due to the missing data, (4) bias in measuring outcomes and (5) bias in reporting outcomes. These domains signal questions addressed, such as (a) random sequence generation, (b) allocation concealment, (c) blinding of participants and professionals, (d) blinding of outcome evaluators, (e) incomplete outcomes, (f) selective outcome reporting and (g) other sources of bias. After analysis and application, the domains were classified as "low risk of bias," "uncertain risk of bias," or "high risk of bias." It is noteworthy that the scale was used as an indicator of scientific evidence, not as an eliminatory indicator [23].

2.5. Statistical Analysis

A random effects meta-analysis was conducted to determine the pooled effect size of HIT/SIT and MICT on cardiorespiratory fitness (CRF), body composition and metabolic parameters markers, using Review Manager software (version 5.4) to calculate the mean difference. We performed analyses to determine the effect of the change in body composition, CRF and metabolic parameters for HIT/SIT vs. MICT in each study. The distribution of effect size (ES) was determined to be heterogeneous if Q reached a significance level of $p < 0.05$, and the sampling error accounted for less than 95% of the observed variance. Consistency (i.e., homogeneity) of effects was assessed using I2, whereby values of <25, 50 and 75 were considered to indicate low, moderate and high heterogeneity, respectively [19].

3. Results

3.1. Study Selection

The initial search in the databases (Pubmed, Cochrane Library, Virtual Health Library and Scielo) resulted in the identification of 1644 articles. After a systematic analysis, 1633

of them were excluded: 1410 by not meeting the methodological criteria stipulated in this present review and 223 by being duplicated in different databases (Figure 1).

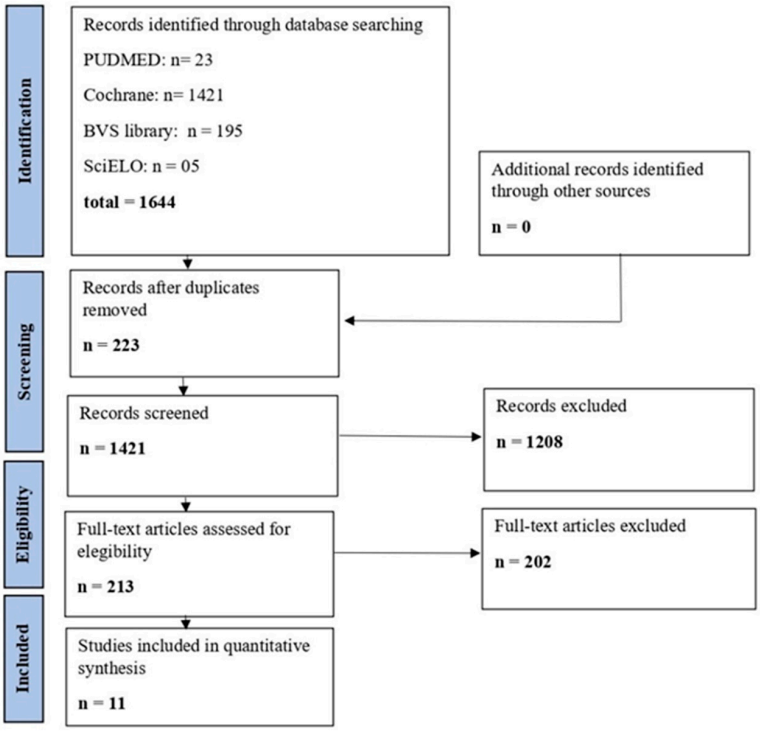

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses flow diagram for study selection.

3.2. Study Characteristics

The general characteristics of the included studies are summarized in Table 1. In total, 459 subjects completed the interventions: 98.0% (n = 450) women [24–34] and 2.0% (n = 9) men [27]. Regarding nutritional status, ten studies (90.9%) evaluated overweight and/or obese women [24–26,28–34], and one study (9.1%) evaluated eutrophic women [27]. Only two studies (18.2%) randomized the female participants regarding the ovarian cycle [24,32] during the application of the protocol. In five studies (45.4%), there was control regarding the use of oral contraceptives [24,25,30,32,34]. All studies were performed while maintaining the usual normal diet [24–34].

Table 1. Characteristics of studies included.

Author	Purpose	Sample	Protocol		Results
Kong et al. [24]	BM, BMI, TFM, TBF, %BF, TLM, regional body composition, VO_2peak, PPO, GLU, Testosterone, Cortisol, GH, Leptin and FGF-21, RPE	n = 18 ♀ Overweight Obese Folicular stage Ø OC	20–25 sessions 4–5 d/wk 5 weeks	MICT—40 min cycling at 65% VO_2peak HIT—60 × 8 s cycling at ~90% VO_2peak 12 s recovery	HIT = MICT ↔ body composition ↑ VO_2peak/↑ PPO ↓ GLU ↔ systemic hormones RPE < HIT
Zhang et al. [25]	BM, TFM, %BF, regional body composition, AVFA, ASFA, VO_2peak, GLU, TG, TC, INS, GH and EPI	n = 59 ♀ Obese Undefined Ø OC	36–48 sessions 3–4 d/wk 12 weeks	CONT—no exercise MICT—cycling at 60% VO_2peak (200 kJ) HIT—4 min cycling at ~90% VO_2peak 3 min recovery (200 kJ) $SIT_{all\text{-}out}$-40 × 6 s cycling "all-out" sprint 9 s recovery SIT_{120}—1 min cycling at ~120% VO_2peak 1.5 min recovery (200 kJ)	All groups ↓ body composition HIT/SITs > MICT ↓ AVFA ↓ GH ↓ EPI SIT > time-efficient

Table 1. *Cont.*

Author	Purpose	Sample	Protocol		Results
Zhang et al. [26]	BM, TFM, %BF, regional body composition, AVFA, ASFA, VO_2peak	*n* = 43 ♀ Obese Undefined Undefined	36–48 sessions 3–4 d/wk 12 weeks	CONT—no exercise MICT—cycling at 60% VO_2peak (300 kJ) HIT—4 min cycling at ~90% VO_2peak 3 min recovery (300 kJ)	HIT = MICT ↓ BM/↓ TFM/↓ BF/↓ regional body composition ↓ AVFA/↓ ASFA ↑VO_2peak
Bonafiglia et al. [27]	BM, VO_2peak, LT, PPO, HR_{submax}	*n* = 21 ♀= 12/♂= 9 Eutrophic Undefined Undefined	12 sessions 4 d/wk 3 weeks	MICT—30 min cycling at ~65% VO_2peak SIT—8 × 20 s cycling at ~170% VO_2peak 10 s recovery	SIT = MICT ↑ VO_2peak ↑ LT/↑PPO/↓ HR_{submax}
Fedewa et al. [28]	BM, %BF, TC, HDL, LDL, TG, HOMA-IR, INS, CRP, VO_2peak	*n* = 44 ♀ Overweight Obese Undefined Undefined	18 sessions 3x/wk 6 weeks	MICT—20–30 min cycling at ~60–70% HRR HIT—5–7 × 30 s cycling at near-maximal 4 min active recovery	MICT ↓ CRP HIT ↓%BF ↑VO_2peak
Higgins et al. [29]	BM, BMI, TFM, %BF, TLM, regional body composition, VO_2peak	*n* = 52 ♀ Overweight Obese Undefined Undefined	18 sessions 3x/wk 6 weeks	MICT—20–30 min cycling at ~60–70% HRR SIT—5–7 × 30 s cycling at "all out" 4 min active recovery	SIT > MICT ↔ BM/↓TFM/↓%BF ↑VO_2peak
Mingzhu et al. [30]	BM, BMI, TFM, %BF, TLM, regional body composition, VO_2peak, PACES	*n* = 66 ♀ Overweight Obese Undefined Ø OC	36 sessions 3x/wk 12 weeks	CONT—no exercise MICT—~65 min cycling at ~60% VO_2peak (200–300 kJ) HIT—4 min cycling at ~90% VO_2peak 3 min recovery (300 kJ) SIT—80 × 6 s cycling "all-out" sprint 9 s recovery	HIT/SIT > MICT ↓ BM/↓ %BF ↑ VO_2peak SIT > time-efficient
Nazari et al. [31]	BM, BMI, %BF, VO_2peak, Salusin α e β, HDL, LDL, VLDL, TC, TG	*n* = 40 ♀ Overweight Obese Undefined Undefined	24 sessions 3x/ws 8 weeks	CONT—no exercise MIIT—30 s cycling at 75–80% HRmax 30 s recovery HIT—30 s cycling at 90–95% HRmax 30 s recovery	HIT = MIIT ↓ TG/↓ VLDL/↑ HDL ↑ Salusin α/↓ Salusin β
Sun et al. [32]	BM, BMI, GLU, INS, HOME-IR, VO_2peak, HRmax, RPE	*n* = 42 ♀ Overweight Stage control Ø OC	36 sessions 3x/ws 12 weeks	MICT—~61 min cycling at 60% VO_2peak HIT—~9 × 4 min cycling at 90% VO_2peak 3 min recovery (~300 kJ) SIT—80 × 6 s cycling at 90–95% HRmax 9 s recovery (~300 kJ)	MICT ↓GLU HIT/SIT = MICT ↓ BM ↑ VO_2peak HIT/SIT ↑ INS e ↑HOMA-IR SIT > time-efficient HOMA-IR
TaheriChadomeshin et al. [33]	BM, BMI, %BF, WHR, GLU, INS, HOME-IR, TC TG, HDL, LDL, VLDL, chemerin, TNF-α	*n* = 28 ♀ Overweight Undefined Undefined	24 sessions 3x/ws 8 weeks	CONT—no exercise HIT—20 m × 30 s runnig at maximum speed 20 m × 30 s walking	HIT ↓ BMI/↓%BF ↓TC/↓TG/↓LDL/↑HDL ↓chemerin ↓TNF-α
Tong et al. [34]	BM, %BF, regional body composition, AVFA, ASFA, VO_2peak, RPE	*n* = 46 ♀ Obese Undefined Ø OC	36–48 sessions 3–4x/ws 12 weeks	CONT—no exercise HIT—4 min cycling at 90% VO_2peak 3 min recovery (200–400 kJ) SIT—80 × 6 s cycling at "all out" 9 s recovery	HIT < SIT ↓ BM/↓%BF ↓ regional body composition ↓ AVFA/↓ ASFA, ↑ VO_2peak

ASFA: abdominal subcutaneous fat area; AVFA: abdominal visceral fat area; BM: body mass; BMI: body mass index; %BF: percentage of body fat; CONT: control group; CRP: c-reactive protein; EPI: epinephrine; FGF-21: fibroblast growth factor 21; GH: growth hormone; GLU: fasting glucose; HDL: high-density lipoprotein; HIT: high-intensity training; HOMA-IR: homeostatic model assessment of insulin resistance; HRR: heart rate reserve; HRsubmax: submaximal heart rate; INS: serum insulin; LDL: low-density lipoprotein; LT: lactate threshold; MICT: moderate-intensity continuous training; MIIT: moderate-intensity interval training; OC: oral contraceptive; PACES: Physical Activity Enjoyment Scale; PPO: peak power output; RPE: rating of perceived exertion; SIT: sprint interval training; SITall-out: all-out sprint interval training; SIT120: supramaximal sprint interval training (120% VO_2peak); TBF: total body fatness; TC: total cholesterol; TFM: total fat mass; TG: triglyceride; TLM: total lean mass; TNF-α: tumor necrosis factor-alpha; VLDL: very low-density lipoprotein cholesterol; VO_2peak: peak oxygen consumption; WHR: waist-hip ratio; Ø: "has not been measured"; ↔: "has not changed"; ↑: an increase; ↓: a decrease; ♀: female gender; ♂: male gender; <: the variable is smaller; >: the variable is larger; =: equal.

The interventions ranged from 12 to 48 sessions, with three to four sessions per week, for all groups (HIT, SIT or MICT). The sessions' average durations were 23.5 ± 18.2 min, 20.0 ± 5.8 min and 39.0 ± 10.8 min for the HIIT, SIT and MICT groups, respectively [24–34].

As for intensity control, the studies were conducted as follows: six studies (54,5%) with HIT used ~90% of VO_2max or VO_2peak [24–26,30,32,34]; two studies (18.2%) used from 90 to 95% of maximum or reserve heart rate [31,32]; and two studies (18.2%) used the control of intensity by load and displacement speed (1 kg + 5 kg/5% of body weight) [28,33]. Two studies (18.2%) did not have a HIT group [27,29]. Concerning SIT studies, one study (9.1%) included protocols that used ~120% of VO_2max/VO_2peak [25] or 170% of peak power output [27], while four studies (36.4%) included protocols that used the control of intensity per load and displacement speed (1 kg + 5 kg/5% of body weight) [25,29,30,34]. Five studies (54.5%) did not have a SIT group [24,26,28,31–33]. Intensity control in MICT studies included the following markers: six studies (54.5%) used 60 to 65% of VO_2max or VO_2peak [24–27,30,32]; three studies (27.3%) used 60 to 80% of maximal or reserve heart rate on prescription [28,29,31], and two studies (18.2%) did not have an MICT group [33,34].

3.3. Meta-Analysis

Regarding the effectiveness of training, it is observed that five (45.4%) and four studies (36.4%) described favorable outcomes for HIT [25,28,30,32,33] and SIT [25,29,30,32], respectively; six studies (54.5%) had similar outcomes across the three training models [24–27,31,32]; in two (18.2%) studies, the MICT was superior in comparison to HIT and SIT [28,32]; and in one study (9.1%), the HIT was more efficient than SIT [34]. Concerning the favorable outcomes for HIT/SIT, it is noted that eight studies (72.7%) highlighted improvements in body composition [25,26,28–30,32–34] and/or in CRF [24,26–30,32,34] of the participants, and four studies (36.4%) reported improvements in metabolic parameters [24,31–33].

3.3.1. Body Composition

Regarding the included studies, nine studies (81.8%) analyzed body composition in relation to body fat percentage (%BF) [24–26,28–30,32,34]; the methods of analysis included seven studies (77.8%) that evaluated by the method of dual emission x-ray absorptiometry (DEXA) [24–26,28–30,34]; three studies (33.3%) that evaluated by means of computed tomography [25,26,34]; one study (11.1%) evaluated by bioimpedance [32]; two studies (18.2%) evaluated by determination of body mass index [27,33]; one study (9.1%) evaluated by determination of waist-hip ratio [27]; and one study (9.1%), although describing values for %BF, did not present the evaluation method used [31].

The overall number of women included in the HIT vs. MICT was 173 for BM outcomes (−0.62 kg; 95%CI: −2.98, 1.75; p = 0.61; I2 = 0%) [24–26,28,30,32], 99 for BMI (−0.16; 95% CI: −1.11, 0.80; p = 0.75; I2 = 0%) [24,25,30,32] and 101 for %BF (−0.08; 95% CI: −1.09, 0.94; p = 0.88; I2 = 0%) [24–26,30]. The meta-analysis demonstrated a significant reduction in body composition, with similar effects between both training methods (Figure 2).

For SIT vs. MICT, 179 women were included for BM analysis (−0.15 kg; 95% CI: −2.71, 2.42; p = 0.91; I2 = 0%) [25,27,29,30,32], 103 were included for BMI (−0.08; 95% CI: −1.05, 0.88; p = 0.87; I2 = 0%) [25,30,32] and 127 were included for %BF (−1.50; 95% IC: −3.74, 0.73; p = 0.19; I2 = 64%) [25,29,30]. There was no significant difference in the reduction in any of the body composition parameters between the SIT vs. MICT (Figure 3).

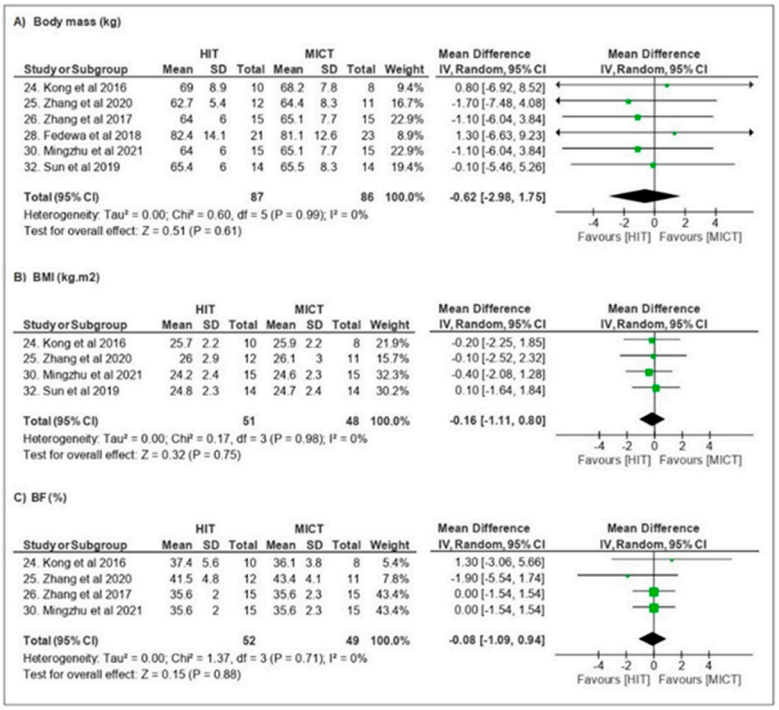

Figure 2. Forest plot of the effects of HIT vs. MICT intervention on outcomes: (**A**) body mass, (**B**) body mass index (BMI) and (**C**) percentage of body fat (BF%); HIT: high-intensity interval training; MICT: moderate intensity continuous training; IV—inverse of the variance; CI: confidence interval; SD: standard deviation.

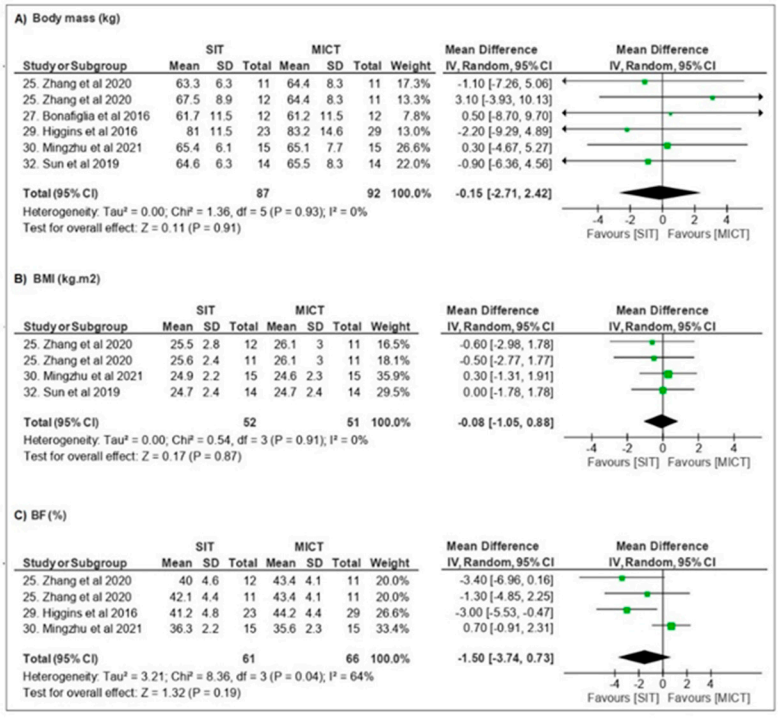

Figure 3. Forest plot of the effects of SIT vs. MICT intervention on outcomes: (**A**) body mass, (**B**) body mass index (BMI) and (**C**) percentage of body fat (BF%); SIT: supramaximal intervals; MICT: moderate intensity continuous training; IV—inverse of the variance; CI: confidence interval; SD: standard deviation.

3.3.2. Cardiorespiratory Fitness

As for CRF, it is observed that ten studies (90.9%) of the studies analyzed it by means of spirometry in a cycle ergometer [24–32,34] and only one study (9.1%) analyzed it from the maximal 40 m shuttle run test [33]. The total number of women included in the meta-analysis was 173 for HIT vs. MICT (2.45 $mL \cdot min^{-1} \cdot kg^{-1}$) (95% CI: 1.15, 3.75; $p < 0.01$; I2 = 0%) [24–26,28,30,32] and 179 for SIT vs. MICT (0.98 $mL \cdot min^{-1} \cdot kg^{-1}$) (95% CI: −0.98, 2.93; $p = 0.33$; I2 = 53%) [25,27,29,30,32]. The MICT demonstrated superior results for the improvement in CRF when compared with HIT. There was no significant difference in the improvement in CRF between SIT vs. MICT (Figure 4).

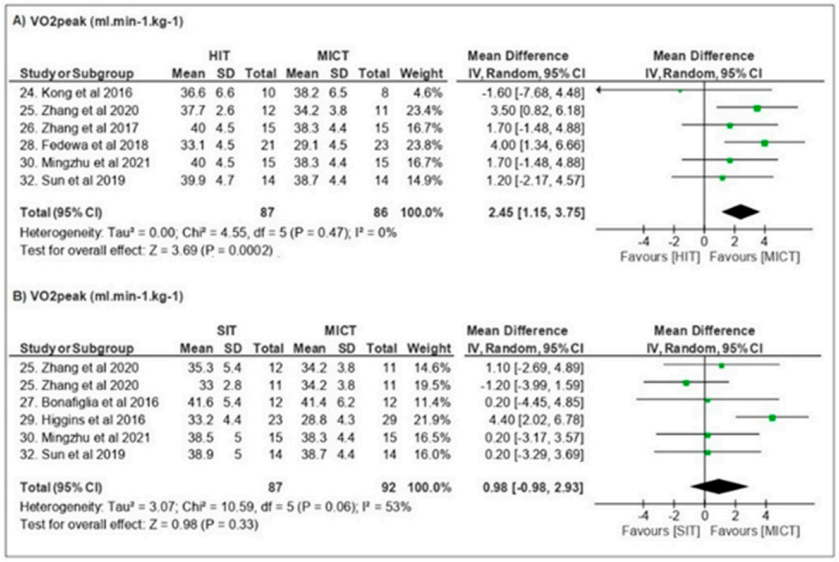

Figure 4. Forest plot of VO_2peak: (**A**) HIT vs. MICT; (**B**) SIT vs. MICT.

3.3.3. Metabolic Parameters

Regarding the metabolic markers, it is noted that six studies (54.5%) of the studies analyzed blood samples [24,25,28,31–33]: four studies (66.6%) measured fasting glucose and insulin and/or calculated the HOMA-IR index [25,28,32,33], or measured the lipid profile (total cholesterol and fractions and/or triglycerides) [25,28,31,33]; one study (16.7%) measured the hormonal profile (testosterone, cortisol and growth hormone) [24] or salusin α and β [31]. The total number of women included in the HIT vs. MICT was 95 for fasting insulin (−0.68 μLU/mL) (95% CI: −2.12, 0.76; $p = 0.36$; I2 = 0%) [25,28,32], 69 for fasting glucose (0.00 mmol) (95% CI: −0.43, 0.44; $p = 0.99$; I2 = 79%) [24,25,32] and 67 for triglycerides (−1.17) (95% CI: −1.72, −0.62; $p < 0.01$; I2 = 8%) [25,28] (Figure 5). For SIT vs. MICT, 73 female participants were included for fasting insulin (−0.75 μLU/mL) (95% CI: −2.58, 1.07; $p = 0.42$; I2 = 51%) [25,32] and 73 were included for fasting glucose (−0.10 mmol) (95% CI: −0.61, 0.40; $p = 0.69$; I2 = 87%) [25,32]. The meta-analyses demonstrate a significant reduction in fasting insulin and glucose rates, with similar effects between high-intensity training and MICT. Moreover, HIT demonstrated superior effects compared with MICT for the reduction in the levels of triglycerides. However, the low number of articles related to the effects of SIT vs. MICT on triglyceride levels made this meta-analysis unfeasible (Figure 6).

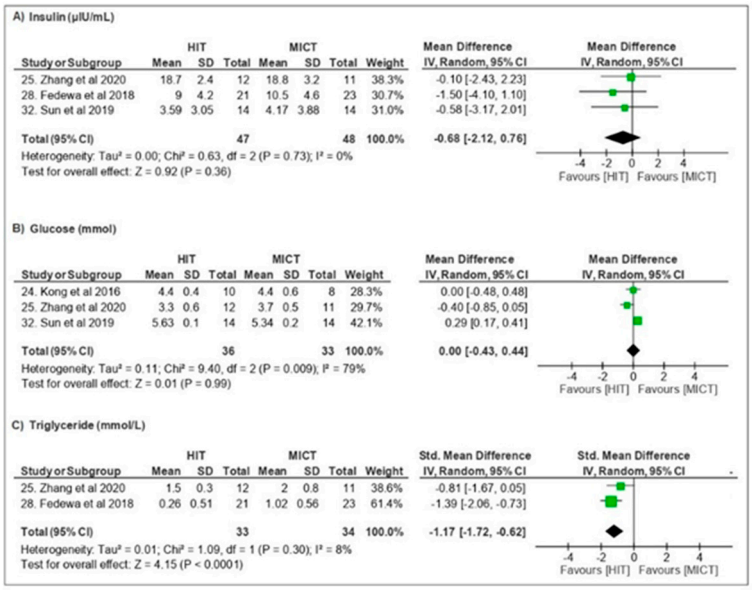

Figure 5. Forest plot of the effects of HIT vs. MICT intervention on outcomes: (**A**) insulin, (**B**) glucose and (**C**) triglyceride; HIT: high-intensity interval training; MICT: moderate intensity continuous training; IV—inverse of the variance; CI: confidence interval; SD: standard deviation.

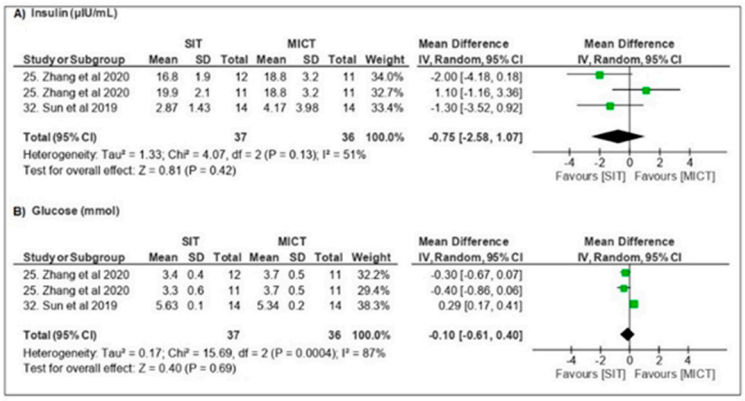

Figure 6. Forest plot of the effects of SIT vs. MICT intervention on outcomes: (**A**) insulin and (**B**) glucose; SIT: supramaximal intervals; MICT: moderate intensity continuous training; IV—inverse of the variance; CI: confidence interval; SD: standard deviation.

3.4. Risk of Bias Assessment

The risk of bias for the included studies was assessed with the Cochrane risk of bias tool, and the results are shown in Figure 7. All studies (100%) [24–34] described random sequence generation (selection bias), assessed as low risk at two studies (18.2%) and uncertain risk of bias at nine studies (81.8%). Nine studies (81.8%) did not describe any participant allocation model and had a high risk of bias for this item [24–27,29–34]. One (9.1%) study [28] had a low risk of selection bias for using computer software to allocate participants. In eleven (100%) of the studies, there was no blinding of participants and professionals [24–34], but as the outcomes were not affected by it, eleven studies (100%) had a low risk of detection bias [24–34]. However, when analyzing the blinding of evaluators, eleven studies (100%) presented a high risk of detection bias [24–34], as there was no blind evaluation of outcomes. There was no incomplete presentation of outcome data (attrition bias), reporting bias or other biases in any of the studies [24–34].

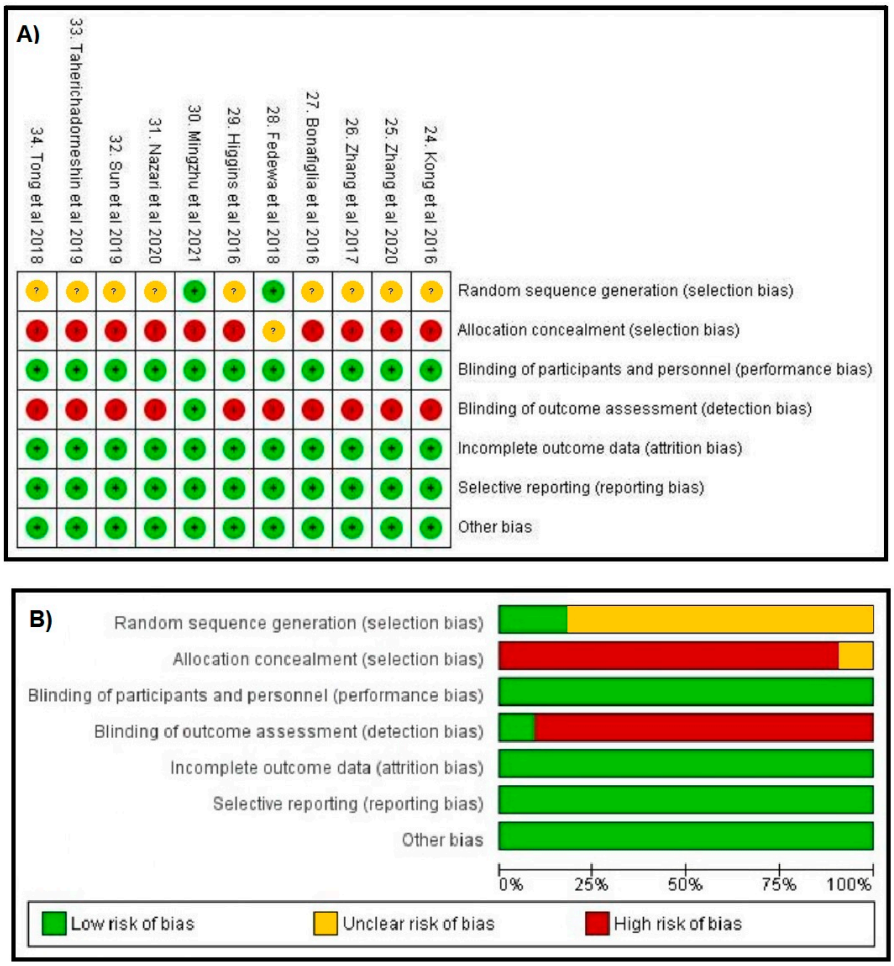

Figure 7. Risk of bias—(**A**) risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies; (**B**) risk of bias summary: review authors' judgements about each risk of bias item for each included study.

4. Discussion

This review proposed comparing the efficiency of HIT or SIT protocols vs. MICT in women between 18 and 35 years old for an initial mapping of the current scientific evidence directed to the female public from the changes in cardiometabolic markers and body composition between both types of training. It is worth noting that, to date, there are no other systematic reviews/meta-analyses with the same objective. This is of a great relevance for current and further discussions on gender differences in the area of sports science.

From the findings compiled in this review, it is possible to point out that interventions from 12 to 48 sessions of HIT or SIT are efficient in reducing body composition, in increasing CRF, in improving insulin sensitivity, in reducing circulating glucose, and in promoting the lipid profile of reproductive-age women (Table 1). According to our findings, the alterations in both CRF and substrates oxidation promoted by high-intensity interval training can be explained by the increase in the oxidative activity of muscle tissue, increasing the use of energy substrates during and after the practice of physical exercise [21]. Furthermore, the different models of high-intensity interval training seem to induce greater synthesis in protein structures directly related to energy metabolism, such as the increase in cellular values of the Peroxisome Proliferator-Activated Receptor Alpha protein (PGC-1α) [35] and increased synthesis of glucose transporters 4 (GLUT4) [36] in muscle tissue. In part, these alterations could explain the greater uptake of circulating glucose and the decrease in insulin levels observed in some studies that are included in this review (via an increase in GLUT 4 and greater mitochondrial oxidative capacity) [24,32].

However, it is important to emphasize that discrepancies in body composition responses (Figure 3C), oxygen consumption (Figure 4A) and metabolic profile (Figure 5C) were observed when the HIT/SIT and MICT groups were compared in this present meta-analysis. In detail, some studies have shown better results after HIT/SIT vs. MICT [25,28–30,32] and others have shown no difference between them [24,26–28,31,32] or even superior effects of MICT vs. HIT/SIT [28,32], for the different outcomes mentioned. This discrepancy in the results of the studies reinforces that the impact of HIT/SIT in women of reproductive age is still controversial compared with a standard training model (MICT). This can be justified by the wide variety of HIT/SIT protocols applied or even by the inherent characteristics of the female sex-totally ignored in the methodology and discussion of the studies selected [24–34].

Currently, there is evidence that changes in ovarian hormones (estrogen and progesterone) can influence several physiological/metabolic factors related to physical exercise, especially in high intensity and short duration (as, for example, seems to occur in lipoprotein metabolism, in glucose metabolism and in the modulation of inflammatory responses after physical training) [37,38]. In this context, there is evidence that alterations in the menstrual cycle of reproductive-age women seem to significantly influence energy metabolism, especially in the luteal and follicular phases [19,37–40]. Apparently, the increase in progesterone (luteal phase) negatively impacts the uptake and oxidation of carbohydrate energy substrates in muscle tissue, forcing the body to carry out a greater oxidation of lipid structures (bloodstream lipids/intramuscular lipid droplets) and of a greater oxidation of muscle proteins [19,37,40]. In contrast, the progressive increase in estrogen and absence of progesterone (follicular phase) seems to favor greater glucose oxidation and uptake in muscle tissue in reproductive-age women, with a parallel reduction in lipids and protein oxidation [37,40]. Noteworthy, it is important to highlight that it was not the objective of interest to analyze/control the ovarian hormonal fluctuations in any of the studies selected in this review, despite the fact that these hormonal fluctuations are extremely significant confounding factors for the contradictory cardiometabolic results evidenced in different HIT/SIT interventions. vs. MICT [24–34].

In this context, although the articles included in the present review provide robust information on training conditions (type of exercise, duration of exercise, level of physical fitness of the sample) and the nutritional status of the volunteers, these characteristics did not control the inherent and the habitual routine of women (such as information about the use/type of oral contraceptives; hormonal measurements; and more specifically, about the stage of the menstrual cycle that each reproductive-age women were in at the time of the proposed interventions) [24–34]. As a whole, the discrepancy in the results compiled in this meta-analysis reinforces the hypothesis that the less efficient transition of energy metabolism at specific moments in the ovarian cycle (similar to the concept of "metabolic inflexibility") may be a "key element" in the results observed in this present review, reinforcing the importance of a "sex-dependent" methodological care in studies involving HIT/SIT. For better directions, it is interesting that further studies investigate the corporal and cardiometabolic impacts of HIT/SIT interventions among women in different phases of the ovarian cycle (follicular phase or luteal phase) as well as compare women in specific phases of the ovarian cycle to male sex. For this, it is of great interest to consider the hormonal variation among the selected group of women (via the estrogen/progesterone ratio) in their experimental designs or, at least, in their discussions.

Briefly, metabolic flexibility is characterized by the ability of the energy metabolism flow through the oxidation of different energy substrates (carbohydrate, lipids or ketone bodies) in accordance with their availability and energy demand at a given moment [41,42]. In contrast, the term metabolic inflexibility, which is generally associated with chronic non-communicable diseases (obesity, type 2 diabetes mellitus and polycystic ovary syndrome), with visceral fat levels, with level of training physical/sedentary lifestyle and with insulin sensitivity, is characterized by the difficulty in the transition of energetic oxidation of the organism with substantial suppression of certain metabolic pathways (the most classic being a reduction in glucose transport and/or uptake in muscle tissue) [41–43].

17β-estradiol is considered a substance that modulates the oxidation/uptake of energy substrates [21,37,40,44]. This hormone is also able to induce specific transitions in the metabolism of carbohydrates, lipids and proteins of reproductive-age women under physical training conditions [21,37,40,44]. Observing these concepts, our group highlights that further studies involving HIT/SIT vs. MICT should explore "metabolic inflexibility" or "metabolic flexibility" events related to the estrogen/progesterone ratio of the female audience (via your ovarian cycle or the use of oral contraceptives).

In a study of athletes who used progestin-containing contraceptives, a significantly lower respiratory exchange ratio was observed in exercises with MICT at 75% of VO_2max and increased rates of lipid oxidation [43]. Redman et al. [44] suggest that, at high levels, progestin may be associated with greater insulin resistance and reduced use of muscle glycogen. In women who used triphasic contraceptives, it is possible to observe an increase in lipid mobilization, with no change in lipid oxidation rates after 60 min of MICT on a cycle ergometer (45% to 65% of VO_2max), compared with the control group [45]. Braun et al. [46] added that, in obese insulin resistance, the increase in AGIM re-esterification favors a greater availability of lipids during exercise, without, however, implying an increase in their oxidation. Thus, despite the frequent use of contraceptives among women of reproductive age, their effects on performance, body composition and metabolic profile are still poorly explored, and there is a lack of studies investigating their responses to HIT prescriptions in women of reproductive age.

Finally, this review highlights some limitations that must be considered. First, the different types of protocols presented by the inserted studies may provide different metabolic responses. The second point refers to the methodological quality of the included studies (moderate), since none of them describes in detail the blinding of the evaluators. In this present meta-analysis, no studies were found on the effects of HIT/SIT on the pattern of oxidation of energy substrates in women of reproductive age. In addition, the low number of participants and/or low number of identified studies and not description the calculation of sampling power for any outcome evaluated in this meta-analysis, limits this finding.

The novelty of the current study was that the HIT/SIT ratio and the female characteristics had not been previously investigated and/or discussed in women of reproductive age, much less discussed based on scientific evidence related to the different hormonal contexts of the women. Thus, further research is needed to test the potential superiority of HIT/SIT vs. MICT on body composition and general oxidative metabolism as well as to elucidate whether hormonal changes in the female ovarian cycle or the use of different types of contraceptives (estrogen and progesterone) could induce a state of both metabolic "flexibility or inflexibility" effects in the public female under different protocols of HIT/SIT training.

5. Conclusions

HIIT or SIT has the potential to be used as a training modality in women of reproductive age, with similar effects to MICT in body composition and metabolic outcomes but inferior effects on the CRF. The studies that were presented demonstrated that menstrual cycle, OC use and gender may influence relative lipid and CHO metabolism under resting conditions and during physical activity with HIT, SIT or MICT. In addition, the results suggest that HIIT or SIT may be a time-efficient component of weight management programs. However, the variability in the secondary outcome measures, coupled with the small sample sizes in these studies, limits this finding.

Moreover, cellular studies appear to remain necessary to consider the complex inherent mechanisms of such adaptations in women.

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