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REVIEW

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High-intensity interval training and cardiorespiratory fitness in adults: An umbrella review of systematic reviews and meta-analyses

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Abstract

Background: High-intensity interval training (HIIT) is characterized by repeated bouts of relatively intense exercise interspersed with recovery periods. Previous studies have evaluated this exercise strategy with various population subgroups, regimens, and comparator groups, limiting the generalizability of findings. We performed a novel umbrella review to generate an up-to-date synthesis of the available evidence regarding the effect of HIIT on cardiorespiratory fitness (CRF) in adults as compared to non-exercise control and traditional continuous forms of exercise such as moderate-intensity continuous training (MICT).

Methods: An umbrella review was conducted in accordance with the Preferred Reporting Items for Overviews of Reviews guideline. Seven databases (MEDLINE, EMBASE, Cochrane Database, CINAHL, Scopus, SPORTDiscus, and Web of Science) were searched until February 2024. Systematic reviews with meta-analyses comparing HIIT and active/non-active control conditions were included. Literature search, data extraction, and methodological quality assessment (AMSTAR-2) were conducted independently by two reviewers.

Results: Twenty-four systematic reviews with meta-analyses, representing 429 primary studies and 12 967 unique participants, met the inclusion criteria. Most of the systematic reviews received moderate-to-critically low AMSTAR-2 scores. The data showed that HIIT, including the particularly intense variant "sprint interval training" (SIT), significantly increases CRF in adults compared to non-exercise control (standardized mean difference [SMD]: 0.28 to 4.31; weighted mean difference [WMD]: 3.25 to 5.5 mL/kg/min) and MICT (SMD: 0.18 to 0.99; WMD: 0.52 to 3.76 mL/kg/min). This effect was consistently observed across specific groups of individuals (e.g., apparently healthy adults, individuals with overweight/obesity, older adults, and high-level athletes) and HIIT modalities (e.g., low-volume HIIT, whole-body HIIT, home-based HIIT, aquatic HIIT, and short SIT).

Conclusion: Existing evidence from systematic reviews consistently supports the effect of HIIT on enhancing CRF in adults when compared to non-exercise control and MICT. Our findings offer a comprehensive basis that may potentially contribute to informing physical activity guidelines aimed at improving CRF in the general population.

KEYWORDS

aerobic fitness, HIIT, interval exercise, public health, umbrella review

1 | INTRODUCTION

Physical inactivity is a leading factor contributing to global mortality and increased risk of non-communicable diseases, including cardiovascular diseases, obesity, stroke, cancer, and type 2 diabetes mellitus.[1] A sedentary lifestyle is associated with reduced cardiorespiratory fitness (CRF), which can adversely affect functional capacity.[2] Maximal oxygen uptake (VO_2max; used synonymously here with peak oxygen uptake, VO_2peak) represents the highest amount of oxygen that can be taken up and utilized by the body during strenuous exercise and is a robust marker of CRF.[3] From a public health perspective, CRF is a stronger predictor of mortality compared to other well-established risk factors such as hypertension, smoking, and obesity.[4] Current physical activity (PA) guidelines worldwide generally recommend that adults aged 18–65 years should engage in a minimum of 75–150 minutes of moderate-to-vigorous PA per week to improve health.[3,5] However, insufficient PA remains a significant global issue.[6]

High-intensity interval training (HIIT) involves repeated bouts of relatively intense exercise interspersed with periods of rest of lower-intensity exercise for recovery.[7] While historically practiced by athletes, the idea of utilizing HIIT for improving health in the general population has gained public attention in recent decades.[8,9] As recently discussed by Coates et al.,[10] there is no universal definition of HIIT despite widespread use of the term. With regards to exercise prescription, HIIT is commonly characterized as being performed at an intensity that elicits ≥80–100% of peak heart rate.[3] A particularly intense variant, "sprint interval training" (SIT), is typically distinguished as requiring an "all-out" or "supramaximal" effort equal to or greater than the pace that elicits ≥100% VO_2max.[3] Coates et al.[10] noted that such definitions do not align with common thresholds used to distinguish intensity classifications in a health (i.e., light, moderate, vigorous) or performance context (i.e., moderate, heavy, severe), and there may be value in broadening the definitions to include multiple indicators as opposed to a single metric. Building on the work of others, Coates et al.[10] proposed a conceptual framework that outlined how HIIT can be defined and operationalized in various contexts. Irrespective of the explicit definition used, studies comparing HIIT to traditional moderate-intensity continuous training (MICT) commonly employ protocols in which the total exercise volume is either matched or not matched, typically based on estimated total exergy expenditure.[11]

A common limitation of many studies that have compared the increase in CRF after HIIT versus MICT is relatively small sample sizes and short durations.[10,12,13] Systematic reviews and meta-analyses based on these studies have often focused on specific groups, such as healthy populations,[14–16] individuals with overweight/obese,[17–20] and elite athletes.[21] These reviews and meta-analyses also varied in comparison groups (e.g., non-active or active controls), settings (e.g., community or laboratories settings), or HIIT modalities with limited samples, impacting the generalizability of the findings. For instance, some individual systematic reviews have shown that HIIT is more effective in improving CRF than MICT,[19,22–24] while contrasting findings suggesting the superiority of MICT have also been reported.[17] The existence of such heterogeneity and discrepancies poses challenges for health and fitness professionals seeking to interpret the body of evidence regarding the impact of various training modalities on CRF in the general population.

In this context, umbrella reviews—also known as overviews of reviews or meta-reviews—have been proposed as strategy to comprehensively synthesize of evidence on a given topic.[25] Umbrella reviews summarize existing evidence from systematic reviews and offer a comprehensive basis to potentially inform guidelines. To the best of our knowledge, only one umbrella review has been conducted to date on HIIT and CRF.[26] While this previous study defined three types of HIIT (i.e., "HIIT-normal mixed", "HIIT-long running", and "HIIT-short cycling") and concluded that all increased CRF, the literature search employed included only two databases (i.e., PubMed and Web of Science up until October 2022), which potentially excluded relevant studies accessible through other databases. It also did not differentiate the heterogenous comparison groups into active and non-active controls or consider factors such as compliance or potential adverse events associated with the HIIT interventions. Considering the substantial increase in evidence published through systematic reviews and meta-analyses on relevant topics in recent years,[9,27] an umbrella review that addresses the aforementioned research gaps to further establish the comparative benefits, compliance, safety, and applications of HIIT interventions among the general population appears timely. Therefore, the aim of this study was to undertake the most comprehensive synthesis of evidence to date regarding the effect of HIIT on CRF in adults. We also aimed to critically appraise the methodological qualities of existing systematic reviews on HIIT and CRF to inform future research in the field.

2 | METHODS

2.1 | Search strategy

Our umbrella review of systematic reviews followed the Preferred Reporting Items for Overviews of Reviews (PRIOR) statement[25] and was registered in the PROSPERO database (CRD 42024517095). Seven databases (MEDLINE, EMBASE, Cochrane Database, CINAHL, Scopus, SPORTDiscus, and Web of Science) were searched using subject heading, keyword and Medical Subject Headings (MeSH) term searches for "systematic review", "meta-analysis", "HIIT" and "cardiorespiratory fitness", The search was limited to peer-reviewed systematic review articles published in English language from inception to February 1, 2024. The reference lists of the selected review articles were also examined for other potentially eligible papers. The detailed search strategy is presented in Table S1.

2.2 | Selection procedure and eligibility criteria

The population, intervention, comparison, outcomes, and study type (PICOS) framework was used to develop the inclusion criteria:

2.2.1 | Types of population

The population of interest was men and women aged 18 years or above. No exclusion criteria were applied to participants baseline fitness, sex, and weight status. Reviews that targeted individuals with specific clinical conditions (e.g., heart failure, coronary artery disease, chronic obstructive pulmonary disease, stroke, spinal cord injuries, diabetes, or cancers) were excluded.

2.2.2 | Types of interventions

The operational definition of HIIT used in the present review was based on a conceptual framework put forward by Coates et al.[10] and current PA guidelines by the American College of Sports Medicine.[3] HIIT is characterized as intermittent bouts performed above moderate intensity in a health context or above the heavy-intensity domain in a performance context. It can be demarcated by various indicators that primarily include heart rate, oxygen uptake, perceived exertion, or other physiological indices as outlined in authoritative public health and exercise prescription guidelines. SIT constitutes a particularly intense variant of HIIT that is distinguished as repeated bouts performed with supramaximal effort equal to or greater than the pace that elicits ≥100% VO_2max, or with an "all-out" effort. Reviews were eligible irrespective of HIIT modalities (e.g., treadmill running, cycling, or bodyweight exercises), settings (e.g., laboratory or community facility), or dose (frequency and duration). Reviews that combined HIIT with other exercise and/or dietary interventions were excluded.

2.2.3 | Type of comparator

Reviews that involved active and/or non-active control comparison groups were included. Reviews with no comparison groups or those comparing with baseline values only were excluded.

2.2.4 | Types of outcomes

The primary outcome of interest in this umbrella review was CRF, as indicated by VO_2max (or VO_2peak) determined using an incremental exercise test to exhaustion.

2.2.5 | Types of studies

Systematic reviews with meta-analyses were selected.

2.3 | Data management and extraction

Search results were imported into EndNote X10 (Clarivate, Philadelphia), where duplicates were removed. Two independent reviewers (EP and JL) conducted title/abstract and full-text screening in duplicate. Inter-reviewer disagreements were resolved by consensus or arbitration by a third reviewer (RH). Data were extracted using a standardized extraction form, and two independent reviewers (EP and JL) performed the data extraction in duplicate. The extracted data included the lead author, year of publication, design of original studies, population characteristics, number of original studies, description of HIIT interventions (protocols, intensity, and duration), comparison, and major findings. Discrepancies were resolved through consensus or arbitration by a third reviewer (RH).

2.4 | Methodological quality assessment of included systematic reviews

Two independent reviewers (EP and JL) assessed the methodological quality of the included reviews in duplicate using the A MeaSurement Tool to Assess Systematic Reviews (AMSTAR-2) tool.[28] Discrepancies were resolved through consensus or arbitration by a third reviewer (RH). The AMSTAR-2 tool consists of 16 items, each scored as "yes", "partial yes" or "no." In this review, six items were considered "critical", and 10 were considered "non-critical." The critical domains included protocol registration, adequacy of search strategy, risk of bias assessment, appropriateness of meta-analysis methods, use of risk of bias during interpretation, and assessment of publication bias. Reviews were rated as having "high confidence" (0 critical weakness and <3 non-critical weaknesses), "moderate" (one critical weakness and <3 non-critical weaknesses), "low" (>1 critical weakness and <3 non-critical weaknesses), or "critically low" (>1 critical weakness and ≥3 non-critical weaknesses).

2.5 | Umbrella review synthesis methods

The overlap in component primary studies included in all eligible reviews was assessed using the Corrected Covered Area (CCA) formula[29]: $CCA=(N-r)/(rc-r)$, where N is the sum of total primary studies included in all the reviews, r is the number of unique primary studies, and c is the total number of reviews. The CCA ranges from 0% to 100%, with 100% indicating that all the reviews in our umbrella review included the same component original studies and 0% indicating that each review included entirely unique original studies. The CCA was categorized based on the following cutoffs: 0%–5% as "slight overlap"; 6%–10% as "moderate"; 11%–15% as "high" and >15% as "very high" overlap.[29]

Meta-analysis results from each review were presented using forest plots. Separate forest plots were created for meta-analyses reporting standardized (e.g., standardized mean difference [SMD]) and unstandardized effect sizes (e.g., weighted mean difference [WMD]). SMD was calculated by dividing the difference in means between the intervention group and control group by the pooled standard deviation, whereas WMD was calculated by taking the difference in means between the intervention group and control group and weighting it by the inverse of the square root of the variance. For meta-analyses that reported standardized effect sizes, subgroup analyses were conducted for participants' health status and HIIT modalities.

3 | RESULTS

3.1 | Overview of search results

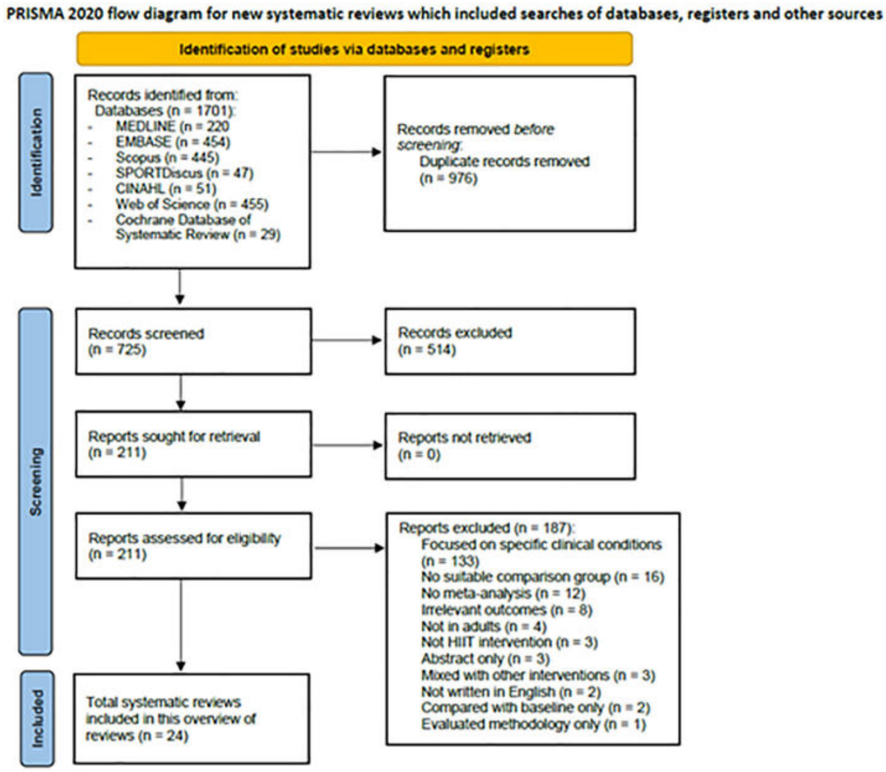
The search strategy yielded a total of 1701 records from seven electronic databases. After removing duplicates, 725 records remained, out of which 514 were subsequently excluded based on title and abstract screening. The full texts of the remaining 211 articles were assessed, and 24 systematic reviews and meta-analyses that met the inclusion criteria were included in this umbrella review (refer to Figure 1 for the PRISMA flowchart).

3.2 | Characteristics of included reviews

Table 1 presents a summary of the author, year, study type, participant characteristics, features of HIIT intervention and comparators, and main findings of the included systematic reviews. The sample sizes of the 24 systematic reviews ranged from 163[30] to 2369.[31] A total of 429 unique primary studies with 12 967 unique participants were listed in the included systematic reviews, with a CCA of 2.07% indicating slight overlap. The age of participants ranged from 18 to 84 years. Sixteen systematic reviews consisted solely of randomized controlled trials (RCTs),[15,17,19,20,22,24,30–39] while other included reviews included a combination of RCT and non-RCTs.[14,16,18,21,23,40–42] Eleven reviews encompassed participants with mixed health or disease conditions,[24,30–33,36–39,41,42] six involved healthy individuals without specific diseases only,[14–16,22,23,40] while four focused on individuals with overweight/obesity.[17–20] Notably, two reviews specifically focused on women,[34,35] two included older adults,[22,32] while one review solely involved high-level athletes.[21]

The characteristics of HIIT interventions and comparison groups are summarized in Table 1. For the HIIT interventions, 18 reviews involved HIIT only,[16,18–21,23,30–39,41,42] three focused solely on SIT,[14,15,40] and three considered both HIIT and SIT.[17,22,24] Two reviews examined low-volume HIIT,[39,42] while one each focused on aquatic HIIT,[34] whole-body HIIT,[36] home-based HIIT,[37] and short-SIT,[14] respectively. All reviews included studies with a minimum intervention period of 2 weeks and a frequency of 1–7 times per week. Various exercise modalities were

FIGURE 1 PRISMA flowchart of literature selection on systematic reviews.



used in HIIT interventions, such as cycling, running, rowing, boxing, paddling, non-weight bearing all-extremity ergometer, circuit-based dynamic body-weight exercise, and walking/jogging. The reviews used a variety of comparators to evaluate the efficacy of HIIT in CRF improvement. Fourteen reviews compared HIIT with non-exercise controls,[15,16,19,20,31,32,34–39,41,42] 17 reviews compared HIIT with MICT,[15–19,22–24,30,32,33,37–42] while four reviews[14,21,35,36] used other exercise training regimens, such as vigorous-intensity continuous training, high-volume low-intensity training, and usual training, as comparators.

3.3 | Methodological quality of included reviews

Table 2 provides a summary of the AMSTAR-2 scores. The majority of the reviews received a low ($n=12$) score, while six reviews received a moderate score, and six received a critically low score. Specifically, only 50% of reviews fully referred to a predefined methodology (item 2). None of the studies provided a list of excluded studies with reasons for exclusions (item 7) or reported on the sources of funding for the included studies (item 10). The majority of reviews (96%) accounted for Risk of Bias (RoB) when interpreting the results (item 9), and 63% discussed heterogeneity (item 14). All reviews used appropriate methods for statistical combination of results (item 11), and 20 (83%) investigated publication bias (item 15) when conducting meta-analyses. However, only five reviews (21%) assessed the impact of RoB on the results (item 12).

3.4 | Meta-analysis results

Table 3 presents a comprehensive summary of the meta-analysis results from all 24 systematic reviews. In comparison to non-exercise controls, all reviews consistently demonstrated that HIIT significantly improves CRF. The SMD ranged from 0.28 to 4.31, and the WMD ranged from 3.25 to 5.5 mL/kg/min (Figure 2A,B). Sub-group analyses indicated significant improvements for both healthy individuals (two reviews; SMD range: 0.69 to 1.81) and individuals with overweight and obesity (three reviews; SMD range: 1.13 to 4.31). Additionally, significant improvements were observed with specific protocols, such as SIT (one review; SMD: 0.69) and low-volume HIIT (two reviews; SMD range: 0.79 to 1.19) protocols (Figure S1).

When compared to MICT, the majority of reviews indicated that HIIT leads to similar or greater improvements in CRF. The SMD ranged from 0.18 to 0.99, and the WMD ranged from 0.52 to 3.76 mL/kg/min (Figure 3A,B). Sub-group analyses revealed consistent trends in both healthy individuals (two reviews; SMD: 0.04 to 0.64) and individuals with overweight and obesity (three reviews; SMD range: 0.26 to 0.99). Similar trends were observed with SIT (three reviews; SMD range: 0.04 to 0.18) and low-volume HIIT (two reviews; SMD range:

TABLE 1 Summary of included systematic reviews.

Reference	Included Studies and Populations	Sample Size	HIIT/SIT Intervention	Comparator	Main findings
Bonafiglia 2022[40]	*N* = 27 (CCTs) Age: 18–65 Without specific diseases	SIT: 360; MICT:359 Total: 719	Intervention: SIT Duration: 2–16 weeks Frequency: 2.7–5 times/week Intensity: all-out/supramaximal Mode: cycling, running	MICT	A lack of superiority between SIT and MICT for improving VO_2max regardless of baseline VO_2max.
Bouaziz 2020[32]	*N* = 15 (RCTs) Age: ≥65 No restriction to any specific medical condition	Total: 480	Intervention: HIIT Duration: 4–28 weeks Frequency: 2–4 times/week Intensity: "high" (90–95% of Hrmax) or "maximal" Mode: cycling, walking, running	1. Non-exercise 2. MICT	When compared with non-exercise controls; both types of training elicit large improvements in VO_2peak among seniors. When HIIT and MICT were directly compared, there was a beneficial effect for HIIT.
Boullosa 2022[14]	*N* = 18 (RCTs, CCTs) Age: 18–40 Healthy young and middle-aged athletes and active adults	Total: 438	Intervention: short-SIT (sSIT; sprints of ≤10 s of duration) Duration: 2–15 weeks Frequency: 2–3 times/week Intensity: all-out/high-intensity effort Mode: cycling, running, boxing exercise, canoe paddling, functional fitness exercises, hand-cycling, and squatting + cycling	1. Non-sSIT (either no exercise or continuing usual training without sSIT) 2. ET (other exercise training regimens)	A very high effectiveness of sSIT protocols was observed. No significant differences for all outcomes when comparing sSIT vs. HIIT/CT in different exercise modes to improve $\dot{V}O_2$max in physically active young healthy adults and athletes.
Edwards 2023[31]	*N* = 56 (RCTs)[a] Age: ≥18 No predetermined limitations on health or disease state	Total: 2369	Intervention: HIIT Duration: 2–52 weeks Frequency: 2–5 times/week Intensity: 70–100% Hrmax/75–100% HRR/≥80% VO_2max/≥80% PPO/≥14 RPE/all-out Mode: cycling, running, walking, stair climber, stepping, boxing, gym HIIT, circuit training, Tabata	Non-exercise	There was a significantly greater improvement in VO_2peak in walking/running HIIT protocols compared with cycling HIIT protocols.
Gist 2014[15]	*N* = 16 (RCTs) Age: 23.5 ± 4.3 Healthy, young individuals	Total: 318	Intervention: SIT Duration: 2–10 weeks Frequency: 2–3.5 times/week Intensity: all-out/supramaximal Mode: cycling, running, rowing	1. Non-exercise 2. MICT	SIT improves aerobic capacity in healthy, young people. Relative to MICT, SIT presents an equally effective alternative with a reduced volume of activity.
Guo 2023[33]	*N* = 29 (RCTs) Age: 18–60 (mean: 33.82 ± 11.6) No restriction on medical comorbidities	HIIT:404 MICT:403 Total: 807	Intervention: HIIT Duration: 2 weeks–6 months Frequency: 1–5 times/week Intensity: 80–100% Hrmax or VO_2peak/≥80% PPO/≥15 RPE/all-out Mode: cycling, running, home-based HIIT, boxing	MICT	The effect of HIIT on CRF in the young and middle-aged is similar to or better than MICT, which might be influenced by age (18–45 years), complications (obesity), duration (>6 weeks), frequency, and HIIT interval.

TABLE 1 (Continued)

Reference	Included Studies and Populations	Sample Size	HIIT/SIT Intervention	Comparator	Main findings
Jelleyman 2015[41]	*N* = 50 (controlled and uncontrolled trials) Age: 21–68 With normal weight, overweight/obesity	Total: 2033	Intervention: HIIT Duration: 2–16 weeks Frequency: NR Intensity: 65% VO_2max to all-out effort Mode: cycling, running, walking	1. Non-exercise 2. MICT	HIIT conveys benefits to cardiometabolic health which in the cases of VO_2max may be superior to the effect of traditional continuous training
Kwok 2022[34]	*N* = 18 (RCTs) Age: ≥18 Women only	HIIT: 261; Control: 215 Total: 476	Intervention: Aquatic HIIT Duration: 8–24 weeks Frequency: 2–3 times/week Intensity: >75% VO_2max/>80%–95% Hrmax/>15 RPE Mode: aquatic exercise	Non-exercise	Aquatic HIIT has a moderate effect in improving cardiometabolic and physical health markers in women.
Lindner 2023[35]	*N* = 20 (RCTs) Age: ≥18 Women only	Total: 551	Intervention: HIIT Duration: 2–14 weeks Frequency: 2–5 times/week Intensity: >80% Hrmax or VO_2max Mode: cycling, running, rowing, water-based exercise, free weight, bodyweight exercises and sprinting	1. Non-exercise 2. MVICT	MVICT and HIIT are equally effective strategies for improving $\dot{V}O_2max$ and indicate an effect of age on its response to training in women.
Ma 2023[21]	*N* = 9 (CCTs) Age: 18.1–26.0 (mean) High-level athletes at the national level	Total: 176	Intervention: HIIT Duration: 3–8 weeks Frequency: 2–3 times/week Intensity: >85% PPO or Hrmax or VO_2peak or maximal aerobic power or velocity of the VO_2peak Mode: cycling, running, rowing, paddling	Conventional training (e.g. MICT, high-volume low-intensity training, high-intensity continuous running)	HIIT shows superiority over conventional training methods in improving VO_2max, promoting aerobic capacity, in elite athlete.
Maturana 2021[24]	*N* = 55 (RCTs) Age: <30, between 30 and 50, >50 (defined as terciles from the included studies data) No predetermined limitations on health or disease state	HIIT+SIT: 775; MICT: 754 Total: 1529	Intervention#1: HIIT Duration: 2–24 weeks Frequency: 2–5 times/week Intensity: 75–120% VO_2max/80%–100% Hrmax or HRR/85%–100% PPO Mode: cycling, running Intervention#2: SIT Duration: 2–12 weeks Frequency: 3–4 times/week Intensity: all-out/supramaximal Mode: cycling, running	MICT	HIIE showed to be more effective in improving CRF than MICT. HIIE showed a higher effect over MICT for older participants in improving VO_2max

(Continues)

TABLE 1 (Continued)

Reference	Included Studies and Populations	Sample Size	HIIT/SIT Intervention	Comparator	Main findings
Milanovic 2015[16]	$N=28$ (RCTs, non-RCTs) Age: 18–45 Healthy individuals	Total: 723	Intervention: HIIT Duration: 3–24 weeks Frequency: 2–5 times/week Intensity: 90%–95% Hrmax/all-out Mode: NR	1. Non-exercise 2. MICT	In healthy, young to middle-aged adults, HIIT improves VO_2max to a greater extent than traditional MICT.
Oliveira 2022[30]	$N=6$ (RCTs) Age: ≥18 Both genders, non-athletes and with no restrictions of physical activity levels	Total: 163	Intervention: HIIT Duration: 4–12 weeks Frequency: 2–4 times/week Intensity: 80–100% Hrmax/80% VO_2max Mode: cycling, running, air bike	MICT	HIIT was superior in increasing CRF than MICT
Poon 2021[22]	$N=14$ (RCTs) Age: ≥40 Healthy men and women not suffering from any kind of acute or chronic disease	Total: 429	Intervention#1: HIIT Duration: 2–52 weeks Frequency: 3–4 times/week Intensity: ≥80% Hrmax Mode: cycling, fast walking, jogging, non-weight-bearing all-extremity ergometer Intervention#2: SIT Duration: 2–52 weeks Frequency: 3 times/week Intensity: all-out/supramaximal Mode: cycling	MICT	HIIT and SIT both resulted in superior VO_2max gain than MICT.
Rugbeer 2021[17]	$N=26$ (RCTs) Age: 18–60 With overweight/obesity	HIIT: 292 SIT: 130 MICT: 362 Total: 784	Intervention#1: HIIT Duration: 2–15 weeks Frequency: 3–5 times/week Intensity: ≥60% VO_2R or HRR/≥77%Hrmax Mode: cycling, walking, jogging Intervention#2: SIT Duration: 2–12 weeks Frequency: 3 times/week Intensity: all-out/supramaximal Mode: cycling	MICT	MICT was significantly better at improving CRF than SIT in persons with overweight/obesity.
Scoubeau 2022[36]	$N=22$ (RCTs) Age: 20–75 Healthy participants, adults with obesity, and women with sarcopenia	Total: 657	Intervention: Whole-body HIIT (WB-HIIT) Duration: 4–20 weeks Frequency: 2–7 times/week Intensity: perform as many repetitions as possible, Mode: body weight and multi-joint exercises	1. Non-exercise 2. Traditional aerobic exercise (e.g., MICT/VICT)	WB-HIIT is a low-cost, easy to implement, and effective way for improving CRF. Effects of WB-HIIT on CRF were associated with total training time.

TABLE 1 (Continued)

Reference	Included Studies and Populations	Sample Size	HIIT/SIT Intervention	Comparator	Main findings
Su 2019[18]	N = 22 (RCTs, CCTs) Age: ≥18 With overweight/obesity	HIIT: 310 MICT:310 Total: 620	Intervention: HIIT Duration: 4–12 weeks Frequency: 3–5 times/week Intensity: ≥85% VO_2max or Hrmax or PPO/all-out Mode: cycling, running, walking, jogging	MICT	HIIT appears to provide similar benefits to MICT for improving VO_2max, but HIIT spent less time than MICT by 9.7 min on one session. HIIT is superior to MICT in improving CRF when durations of HIIT training interval ≥2-min or energy expenditure of HIIT same as MICT.
Sultana 2019[42]	N = 47 (RCTs, non-RCTs) Age: ≥18 With normal-weight, overweight and obesity, regardless of physical activity and health status	Total: 1458	Intervention: Low-volume HIIT (≤500 MET-min/week) Duration: 4–16 weeks Frequency: 2–5 times/week Intensity: 75–100% Hrmax/80–170% VO_2max/60–140% PPO/all-out Mode: cycling, running, walking	1. Non-exercise 2. MICT	Despite its lower training volume, low-volume HIIT induces greater improvements in CRF than a non-exercise control and MICT in normal weight, overweight and obese adults. Low-volume HIIT appears to be a time-efficient treatment for increasing fitness.
Tsuji 2023[37]	N = 15 (RCTs) Adults regardless of disease or handicap status	Total: 770	Intervention: Home-based HIIT Duration: 4 weeks–12 months Frequency: 1–6 times/week Intensity: ≥80% Hrmax or maximal aerobic power/RPE ≥15/20 or 6/10 Mode: weight-bearing exercise, stationary cycling, or use of outdoor/indoor equipment	1. Non-exercise 2. MICT	Home-based HIIT was an effective intervention for improving CRF in healthy adults and patients. There were no significant differences in CRF between home-based HIIT, lab-based HIIT and MICT, highlighting its comparable effectiveness and potential as a practical and valuable exercise intervention.
Van Baak 2021[19]	N = 18 (RCTs)[a] Age: ≥18 With overweight/obesity	Total: 836[a]	Intervention: HIIT Duration: 2–16 weeks Frequency: 1–5 times/week Intensity: ≥85%Hrmax or PPO/≥75% HRR/all-out Mode: cycling, running, walking, boxing	1. Non-exercise 2. MICT	HIIT was slightly more effective than MICT in improving VO_2max.
Wang 2021[20]	N = 19 (RCTs) Age: 19–57 With overweight/obesity	Total: 543	Intervention: HIIT Duration: 3–14 weeks Frequency: 1–5 time/week Intensity: ≥80–100% Hrmax/≥80% VO_2max or HRR/all-out Mode: cycling, running	Non-exercise	HIIT was a highly effective approach for improving CRF in adults with overweight/obesity. Effects were modified by sex and baseline CRF level.

(Continues)

TABLE 1 (Continued)

Reference	Included Studies and Populations	Sample Size	HIIT/SIT Intervention	Comparator	Main findings
Wen 2019[38]	*N* = 53 (RCTs) Age: 19–47 Healthy, overweight/obese and athletic adults	Total: 1514	Intervention: HIIT Duration: 2–16 weeks Frequency: 2–5 times/week Intensity: ≥80% VO_2max or VO_2peak/≥ 85%Hrmax/≥90%v/pVO_2max/all-out Mode: cycling, handcycling, running, walking, swimming, and rowing	1. Non-exercise 2. MICT 3. Regular training (athletic population)	Short-intervals (≤30s), low-volume (≤5 min) and short-term (≤4 weeks) HIIT represent effective and time-efficient strategies for developing VO_2max, especially for the general population. To maximize the training effects on VO_2max, long-interval (≥2 min), high-volume (≥15 min) and moderate to long-term (≥4–12 weeks) HIIT are recommended.
Wu 2021[23]	*N* = 29 (RCT sand CCTs) Age: 61.6–84 (mean) Healthy subjects not restricted by BMI, sex, pathologies, or ethnic origin	Total: 1156	Intervention: HIIT Duration: 4–24 weeks Frequency: 2–5 times/week Intensity: maximal effort/≥75% VO_2peak/≥75% HRR/≥85% Hrmax Mode: elliptical devices, cycling, circuit-based interval exercise, Xbox 360 s	MICT	HIIT may be a more potent stimulus influencing VO_2peak relative to MICT in older adults.
Yin 2023[39]	*N* = 21 (RCTs) Age: ≥18 Any health condition	Total: 849	Intervention: Low-volume HIIT (≤5 min high-intensity exercise within a ≤15-min session) Duration: 2–24 weeks Frequency: 2–4 times/week Intensity: ≥77%Hrmax/RPE ≥14/all-out Mode: cycling, running, jump	1. Non-exercise 2. MICT	Low-volume HIIT appears at least equivalent to MICT in improving CRF, despite only requiring 14%–47% of an exercise time commitment compared to MICT.

Abbreviations: BMI, Body mass index; CCT, Clinical controlled trial; CRF, Cardiorespiratory fitness; CT, Continuous training; ET, Endurance training HIIE, High-intensity interval exercise; HIIT, High-intensity interval training; Hrmax, Maximal heart rate; HRR, Heart rate reserve; MICT, Moderate-intensity continuous training; MIIT, Moderate-intensity interval training; MVICT, Moderate-to-vigorous intensity continuous training; NR, Not reported; PPO, Peak power output; RCT, Randomized controlled trial; RPE, Rate of perceived exertion; RT, Randomized trial; SIT, Sprint interval training; VICT, Vigorous-intensity continuous training; VO_2max, Maximal oxygen uptake; VO_2peak, Peak oxygen uptake.

[a]Only RCTs examining the effects of HIIT on VO_2max were included.

TABLE 2 AMSTAR-2 ratings of systematic reviews and meta-analyses.

Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Confidence
Bonafiglia 2022[40]	Y	N	N	PY	Y	Y	N	PY	Y	N	Y	N	Y	N	N	Y	Critically low
Bouaziz 2020[32]	Y	N	Y	PY	N	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Low
Boullosa 2022[14]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	N	Y	Y	N	Low
Edwards 2023[31]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Moderate
Gist 2014[15]	Y	N	Y	PY	N	N	N	PY	N	N	Y	N	N	Y	Y	Y	Critically low
Guo 2023[33]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Moderate
Jelleyman 2015[41]	N	N	Y	PY	N	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Low
Kwok 2022[34]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	N	Y	Y	Moderate
Lindner 2023[35]	N	N	Y	PY	N	Y	N	PY	Y	N	Y	N	Y	N	Y	Y	Low
Ma 2023[21]	N	N	N	PY	N	N	N	PY	Y	N	Y	N	N	Y	N	Y	Critically low
Maturana 2021[24]	N	Y	Y	N	Y	N	N	PY	Y	N	Y	N	Y	N	Y	Y	Low
Milanovic 2015[16]	Y	N	Y	PY	Y	Y	N	PY	Y	N	Y	N	N	N	Y	Y	Critically low
Oliveira 2022[30]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	Y	Y	Y	N	Y	Low
Poon 2021[22]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Moderate
Rugbeer 2021[17]	Y	N	Y	PY	Y	N	N	PY	Y	N	Y	N	N	Y	N	N	Critically low
Scoubeau 2022[36]	N	Y	Y	PY	Y	Y	N	PY	Y	N	Y	Y	N	N	Y	Y	Low
Su 2019[18]	Y	Y	Y	PY	Y	N	N	PY	Y	N	Y	Y	Y	Y	Y	Y	Moderate
Sultana 2019[42]	Y	N	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Low
Tsuji 2023[37]	N	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	N	Y	Y	Y	Low
van Baak 2021[19]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	Y	N	N	Y	Y	Low
Wang 2021[20]	Y	N	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	N	Y	Y	Low
Wen 2019[38]	Y	N	Y	PY	Y	N	N	PY	Y	N	Y	Y	Y	Y	Y	Y	Low
Wu 2021[23]	Y	N	Y	PY	Y	N	N	PY	Y	N	Y	N	N	N	Y	Y	Critically low
Yin 2023[39]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Moderate

Note: ITEM – DESCRIPTION.

1. Did the research questions/inclusion criteria include the components of PICO?
2. Did the review contain an explicit statement that the review methods were established prior to the conduct of the review?
3. Did the review authors explain their selection of the study designs for inclusion in the review?
4. Did the review authors use a comprehensive literature search strategy?
5. Did the review authors perform study selection in duplicate?
6. Did the review authors perform data extraction in duplicate?
7. Did the review authors provide a list of excluded studies and justify the exclusions?
8. Did the review authors describe the included studies in adequate detail?
9. Did the review authors assess the RoB in studies that were included in the review?
10. Did the review authors report on the sources of funding for the studies included in the review?
11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?
12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis?
13. Did the review authors account for RoB in individual studies when interpreting the results of the review?
14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?
15. If they performed quantitative synthesis did the review authors investigate publication bias?
16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?

Abbreviations: N, No; NA, Not applicable (no meta-analysis); PY: Partial Yes; Y, Yes.

0.175 to 0.18) protocols (Figure S2). The only exception was the review conducted by Rugbeer et al.,[17] in which MICT was reported significantly more effective than SIT in improving CRF in individuals with overweight/obesity. However, this finding is likely based on erroneous analysis by the original authors (which will be discussed in the subsequent section).

Moreover, most reviews reported comparable or superior benefits of HIIT when compared to alternative exercise training regimens other than MICT. The SMD ranged from −0.40 to 0.58, and the WMD ranged from −0.42 to 3.76 mL/kg/min (Table 2). These alternative regimens include vigorous-intensity continuous training, high-volume low-intensity training, endurance training, and usual training.

TABLE 3 Changes in cardiorespiratory fitness comparing HIIT interventions with control conditions (positive values favor HIIT).

Reference	No. of studies	SMD/ WMD	Comparator	Effect size	95% CI	
					Lower limit	Upper limit
Bonafiglia 2022[40]	27	SMD	MICT	0.06	−0.08	0.07
Bouaziz 2020[32]	4	WMD	Non-exercise	4.61	3.21	6.01
Bouaziz 2020[32]	3	WMD	MICT	3.76	2.96	4.56
Boullosa 2022[14]	12	SMD	Non-sSIT	0.56	0.33	0.79
Boullosa 2022[14]	8	SMD	Endurance training with various exercise regimens	−0.05	−0.30	0.19
Edwards 2023[31] (overall)	56	WMD	Non-exercise	3.895	3.34	4.45
Edwards 2023[31] (SIT only)	13	WMD	Non-exercise	3.25	1.62	4.88
Edwards 2023[31] (HIIT only)	22	WMD	Non-exercise	3.77	2.56	5.00
Gist 2014[15]	16	SMD	Overall	0.32	0.10	0.55
Gist 2014[15]	7	SMD	Non-exercise	0.69	0.46	0.93
Gist 2014[15]	10	SMD	MICT	0.04	−0.17	0.24
Guo 2023[33]	27	SMD	MICT	0.19	0.03	0.34
Jelleyman 2015[41]	18	SMD	Non-exercise	0.28	0.12	0.44
Jelleyman 2015[41]	22	SMD	MICT	0.16	0.07	0.25
Kwok 2022[34]	5	SMD	Non-exercise	0.61	0.019	1.077
Lindner 2023[35]	5	WMD	Non-exercise	4.21	2.47	5.96
Lindner 2023[35]	9	WMD	MVICT	−0.42	−1.43	0.6
Ma 2023[21]	9	SMD	Conventional training (with low to high-intensity)	0.58	0.30	0.87
Ma 2023[21]	7	SMD	Conventional training (with intensity ≤75%)	0.42	0.11	0.73
Maturana 2021[24] (HIIT/SIT)	48	SMD	MICT	0.40	0.24	0.57
Maturana 2021[24] (HIIT only)	29	SMD	MICT	0.5	0.31	0.68
Maturana 2021[24] (SIT only)	19	SMD	MICT	0.18	−0.08	0.44
Milanovic 2015[16]	13	WMD	Non-exercise	5.5	4.3	6.7
Milanovic 2015[16]	19	WMD	MICT	1.2	0.3	2.1
Oliveira 2022[30]	6	WMD	MICT	2.49	1.25	3.73
Poon 2021[22] (HIIT/SIT)	14	WMD	MICT	1.1	0.55	1.64
Poon 2021[22] (HIIT only)	9	WMD	MICT	1.04	0.21	1.88
Poon 2021[22] (SIT only)	6	WMD	MICT	1.18	0.60	1.76
Rugbeer 2021[17] (HIIT only)	17	WMD	MICT	−0.52	−1.18	0.13
Rugbeer 2021[17] (SIT only)	9	WMD	MICT	−0.92	−1.63	−0.21
Scoubeau 2022[36]	8	SMD	Non-exercise	0.75	0.23	1.23
Scoubeau 2022[36]	6	SMD	Traditional aerobic exercise with various intensities	−0.40	−0.7	−0.11

TABLE 3 (Continued)

Reference	No. of studies	SMD/ WMD	Comparator	Effect size	95% CI	
					Lower limit	Upper limit
Su 2019[18]	16	SMD	MICT	0.256	−0.019	0.531
Sultana 2019[42]	25	SMD	Non-exercise	0.788	0.620	0.957
Sultana 2019[42]	27	SMD	MICT	0.175	0.031	0.318
Tsuji 2023[37]	4	SMD	Non-exercise	0.61	0.21	1.02
Tsuji 2023[37]	3	SMD	MICT	0.34	−0.05	0.73
van Baak 2021[19]	10	SMD	Non-exercise	4.31	2.81	5.8
van Baak 2021[19]	18	SMD	MICT	0.99	0.25	1.73
Wang 2021[20]	19	SMD	Non-exercise	1.13	0.93	1.33
Wen 2019[38] (healthy population)	19	SMD	Non-exercise	1.81	1.39	2.22
Wen 2019[38] (overweight/obese)	9	SMD	Non-exercise	1.35	0.81	1.88
Wen 2019[38] (healthy population)	19	SMD	MICT	0.64	0.23	1.05
Wen 2019[38] (overweight/obese)	15	SMD	MICT	0.41	0.08	0.75
Wen 2019[38] (athletic population)	13	SMD	Usual athletic training without HIIT intervention	0.57	0.13	1.01
Wu 2021[23]	6	WMD	MICT	1.74	0.8	2.69
Yin 2023[39]	13	SMD	Non-exercise	1.19	0.87	1.5
Yin 2023[39]	9	SMD	MICT	0.18	−0.06	0.42

Abbreviations: CI, Confidence interval; CT, Continuous training; MD, Mean difference; MICT, Moderate-intensity continuous training; MVICT, Moderate to vigorous-intensity continuous trainings; SIT, Short sprint interval training; SIT, Sprint interval training; SMD, Standardized mean difference.

4 | DISCUSSION

This current umbrella review identified 24 systematic reviews with meta-analyses that examined the effect of HIIT on CRF, involving 429 primary studies and 12 967 unique participants. These reviews involved various HIIT modalities (e.g., SIT, home-based HIIT, whole-body HIIT, low-volume HIIT, and aquatic HIIT) and encompassed participants with diverse demographic profiles (e.g., apparently healthy adults, individuals with overweight/obesity, older adults, and high-level athletes). Our findings highlighted the broad applicability of HIIT interventions and offered a comprehensive basis to potentially inform guidelines for CRF improvements in the general population (Figure 4 for the graphical representation of findings).

4.1 | Effects of HIIT on CRF

The primary finding of the current study is that all included systematic reviews consistently reported superior effects on CRF following HIIT compared to non-exercise control conditions. CRF has been widely recognized as a clinical vital sign in various consensus statements.[43,44] Recent studies have emphasized its significance in predicting major clinical outcomes,[45–47] as well as the potential impact of temporal changes in CRF on morality risk.[48] Low CRF is often associated with a physically inactive lifestyle and is a strong predictor of premature cardiovascular mortality.[4] The effect sizes for CRF improvements ranged from 0.28 to 4.31 for SMD and 3.25 to 5.5 mL/kg/min for WMD, respectively. This magnitude of improvement has considerable clinical and public health significance.[48] A recent meta-analysis of 37 cohort studies with objective measures of CRF in over 2 million adults revealed that everyone's metabolic equivalent (MET, corresponding to oxygen consumption of 3.5 mL/kg/min) increase in CRF is associated with a 11% reduction in the relative risk for all-cause mortality.[49] Moreover, the strength of this strong inverse association was independent of age, biological sex, and follow-up duration.[49] The proposed physiological mechanisms underlying the rapid CRF improvement of HIIT have been outlined in detail elsewhere.[7] In particular, a recent systematic review and meta-analysis suggested that increases in central oxygen delivery via increased stroke volume and cardiac output are responsible for the significant increase in VO_2max observed in response to intense interval training, with relatively less

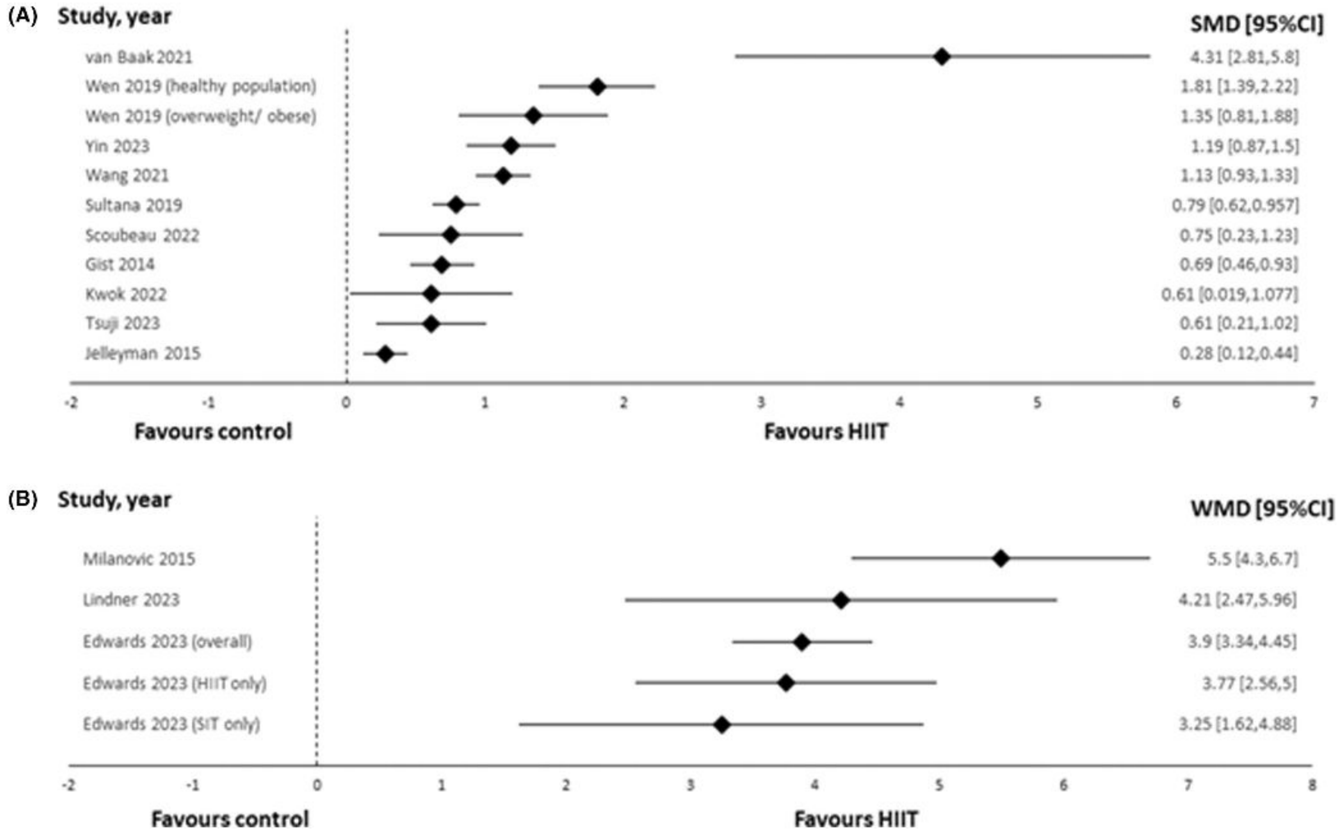


FIGURE 2 Results of meta-analyses that compared HIIT with non-exercise controls for CRF improvements using (A) standardized mean differences and (B) weighted mean difference.

contributions from changes in hematocrit, blood volume, or plasma volume.[50]

Another highlighted aspect of the present umbrella review was the comparative analysis performed for the effectiveness of HIIT and other traditional training protocols. The majority of reviews indicated that HIIT results in similar or greater improvements in CRF when compared with MICT and other exercise training regimens. Intriguingly, one review[17] included within this umbrella review reported a significant advantage of MICT over SIT (and an insignificant advantage of MICT over HIIT) in improving cardiorespiratory fitness among individuals with overweight/obesity. However, upon closely examining the data reported in the article, it appears that the direction of effects in the forest plots depicting the comparison of SIT versus MICT and HIIT versus MICT were mistakenly swapped. In other words, the CRF data reported in the original review actually favored SIT and HIIT rather than MICT. Thus, caution is warranted when interpreting the conclusions drawn from the original review, as these appear to be based on an erroneous analysis. Overall, the comprehensive evidence compiled in this umbrella review consistently supports the efficacy of HIIT, including its intense variant SIT, in enhancing CRF among adults from diverse backgrounds.

4.2 | Potential moderators of HIIT effects

The majority of reviews (88%) in this umbrella review have explicitly examined the potential moderators of HIIT effects. These investigations were typically conducted through subgroup analysis or linear meta-regression analysis. However, due to the relatively small sample sizes, lack of detailed information, considerable heterogeneity in HIIT intervention protocols and populations, as well as methodological limitations in the original studies included, several systematic reviews were unable to confidently perform quantitative analyses for potential moderators.[21,24,32] Nonetheless, five systematic reviews[16,20,23,32,38] suggested that interventions lasting ≥4–12 weeks may confer greater advantages in improving CRF compared to shorter interventions, although significant improvements in ≤3 weeks of interventions have also been reported.[14,20,38] Additionally, several reviews reported that other intervention components including modality,[31] interval intensity,[23] interval duration,[14,18,23,35,39] work-rest ratio,[16] number of repetition,[23,39] total session time,[23,39] energy consumption,[18] frequency,[20,23] and number of training sessions,[35] as well as participants' characteristics including age,[33,35] sex,[20] and baseline fitness levels[20,24] may moderate the effects of HIIT on CRF,

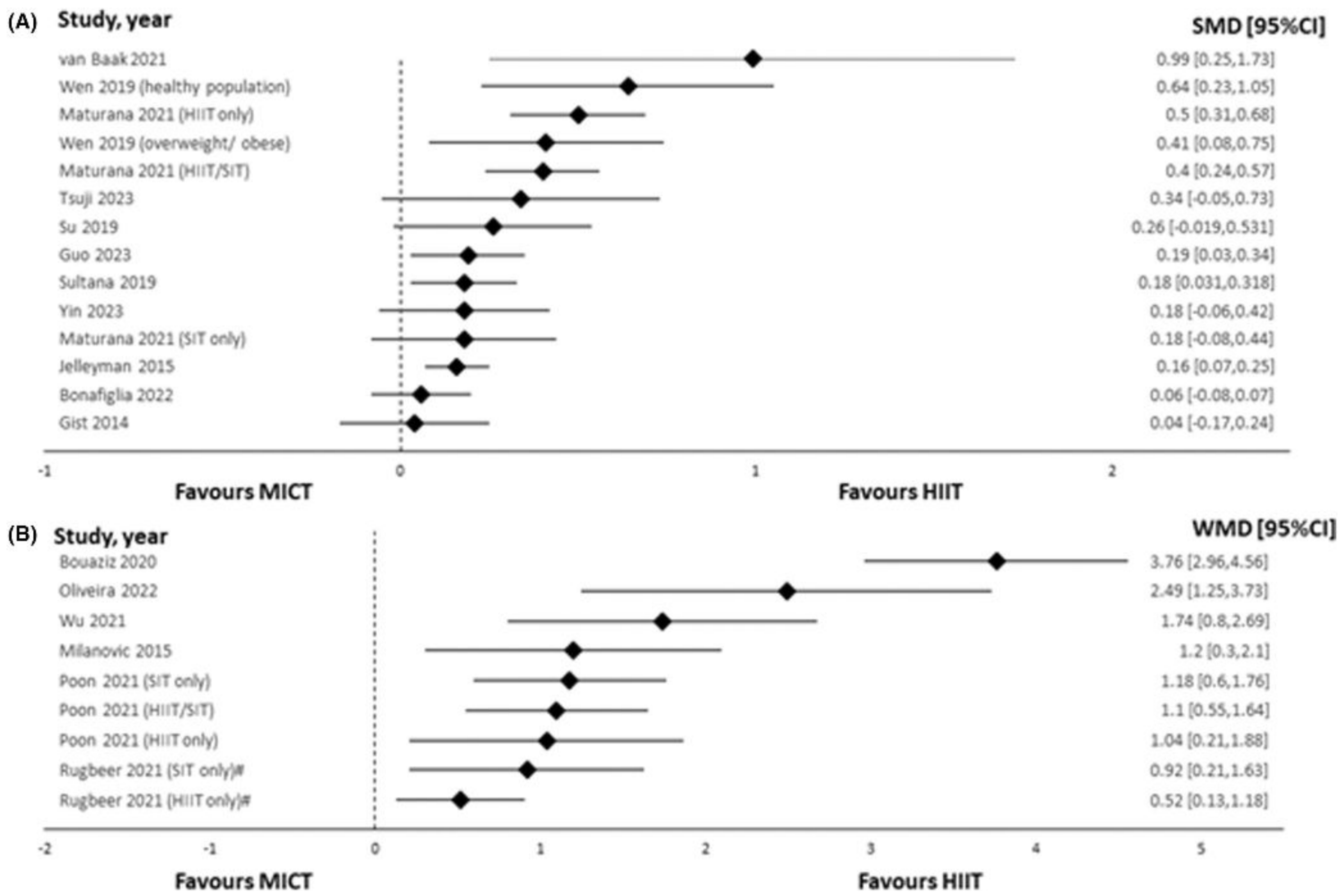


FIGURE 3 Results of meta-analyses that compared HIIT with MICT for CRF improvements using (A) standardized mean differences and (B) weighted mean difference. We conducted a re-analysis of the CRF data reported in the original review by Rugbeer et al.[17] and identified that the direction of effects comparing SIT versus MICT and HIIT versus MICT was likely mistakenly swapped by the original authors. The revised figures reflecting our findings are presented in the current forest plot.

although other reviews did not observe clear moderation effects on these parameters. To determine the most effective protocol, future studies should continue to explore the impact of various intervention components on CRF by employing additional high-quality RCTs. That said, it is also important to note that there may be circumstances where health and fitness professionals need to individualize HIIT program parameters to achieve optimal stimulus for adaptations, particularly in high-level sports in which the demands of different sports events may vary considerably.[21]

4.3 | Practicality and safety of implementing HIIT

There is an understandable concern regarding the practicality and safety of implementing HIIT as a population health promotion strategy. Some critics argued that HIIT is complex and aversive, requiring high levels of supervision and self-regulation.[51,52] Surprisingly, we found that only seven systematic reviews (29%) included in our umbrella review explicitly addressed safety-related matters. Most of these reviews reported musculoskeletal injuries and/or cardiac-related events, which may have resulted in discontinuation of the intervention. For instance, out of the 50 original studies included in the meta-analysis by Jelleyman et al.,[41] which involved a total of 2033 participants, it was reported that 17 studies (34%) documented adverse events. There were 14 musculoskeletal injuries attributable to the HIIT interventions. Similarly, Poon et al.[22] reported four adverse events in the 14 included RCTs analyzed among 429 middle-aged and older adults, including hip pain, persistent cramps, and myocardial infarction. However, while large-scale studies with safety outcomes are currently lacking, some clinical studies have suggested that HIIT appears to be safe, well-tolerated, and attainable, even when applied to relatively high-risk populations with low initial fitness.[53–57] The safety concerns associated with HIIT do not appear to be significantly greater than those associated with MICT. This notion is supported by a recent systematic review that indicated high compliance to HIIT among insufficiently active adults and adults with a medical condition.[57] Among our

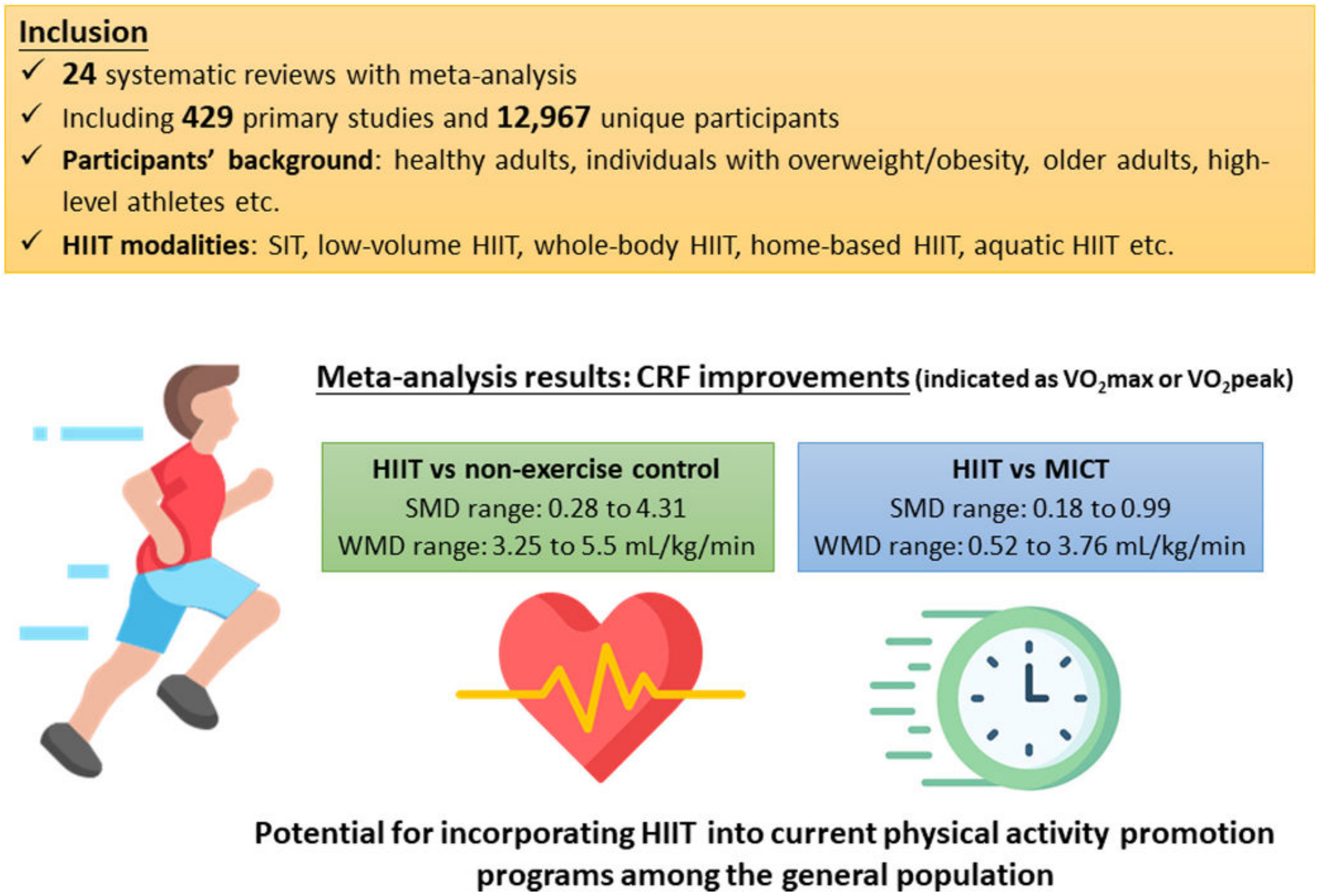


FIGURE 4 Graphical representation of the findings on the efficacy of HIIT in CRF in adults.

included reviews that reported compliance,[20,32,35,37,39,41] the compliance level within HIIT programs was also satisfactory (i.e., ≥80%) in general. Nevertheless, inactive individuals with cardiovascular risk factors should undergo a thorough medical evaluation before initiating any exercise program.[3,5] Low-impact exercises, such as non-plyometric bodyweight workout, cycling, brisk walking, and aquatic activities, were commonly employed HIIT modalities in our included studies. These modalities would appear to be suitable exercise options for less fit or previously inactive individuals, particularly those who live with overweight/obesity or have medical conditions to reduce stress on joints and lower injury risk.[3] Although current research suggests that HIIT is safe for most healthy individuals, it is prudent for fitness and health professionals to conduct proper pre-screening and deliver all exercise programs in a progressive manner with adequate supervision.

4.4 | Strengths and limitations

The strengths of this umbrella review include adherence to PRIOR guidelines and the use of widely recognized benchmarks (e.g., AMSTAR-2) to assess the scientific rigor of the included systematic reviews. We included only the highest level of evidence (i.e., systematic review with meta-analyses) and applied stringent criteria regarding the design of the component original studies to ensure that effects could be confidently attributed to HIIT rather than other intervention components. Moreover, there was only slight overlap (CCA: 2.07%) in the component original studies, increasing our confidence in the findings.

However, this umbrella review had several limitations. First, most of the included systematic reviews were rated as low ($n=12$) or critically low ($n=6$) in quality based on the AMSTAR-2 rating. Specifically, only a small proportion of reviews referred to a predefined methodology or assessed the impact of RoB on the results. None of the studies provided a list of excluded studies with reasons for exclusions or reported on the sources of funding for the included studies. This underscores the importance of exercising caution when interpreting certain included reviews and highlights the need for well-conducted systematic reviews in this particular field. In addition, the target population of this umbrella review was general adults, and therefore caution should be taken when generalizing the results to other populations, such as children and adolescents, as well as individuals with specific clinical conditions. Furthermore, it is noted that most of the included reviews and their primary studies only reported VO_2max in relative values, which are adjusted to body mass. This approach may have been influenced by the prevailing practice in epidemiological research, where the relationship between CRF and mortality or disease risk is often expressed in relative terms (e.g., metabolic equivalents).[47–49] However, future research studies should also consider including VO_2max in absolute values to provide a clearer understanding of the true impact of HIIT interventions on CRF, independent of changes in body composition. Lastly, it is recommended for future studies to establish standardized criteria for defining and assessing VO_2max to increase the comparability and generalizability of findings across studies. This includes using consistent protocols for measuring VO_2max, such as standardized exercise testing procedures and criteria for achieving maximal effort.

Despite these issues, from a practical perspective, our umbrella review findings can provide valuable insights to a wide range of stakeholders involved in health and fitness promotion, including researchers, health organizations, and government entities. These insights can support the ongoing advancement of exist PA guidelines aimed at enhancing CRF among the general population.

5 | CONCLUSION

This novel umbrella review provides comprehensive and up-to-date evidence supporting the efficacy of HIIT in improving CRF in adults when compared to non-active control groups and alternative exercise regimens such as MICT. These findings may have potential implications for PA guideline recommendations and underscore the potential of various HIIT modalities for enhancing CRF in adults with diverse backgrounds. Further research and implementation efforts are warranted to optimize the integration of HIIT into comprehensive fitness and health programs among the general population and to evaluate the long-term impact and safety outcomes of various HIIT interventions.

AUTHOR CONTRIBUTIONS

EP, JL, MG, SW and RH conceived the idea for the review. EP, JL and RH conducted search, study selection, data extraction and quality assessment. EP, JL and RH drafted the initial manuscript. EP, MG and RH contributed to writing the manuscript. All authors reviewed and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

All authors have no conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

The datasets analyzed in this review are available from the corresponding author on reasonable request.

SYSTEMATIC REVIEW REGISTRATION NUMBER

This study was registered in the International Prospective Register of Systematic Review (PROSPERO) database (registration number: CRD42024517095).

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