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REVIEW ARTICLE

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Efficacy of high-intensity interval training in individuals with type 2 diabetes mellitus: An umbrella review of systematic reviews and meta-analyses

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Abstract

High-intensity interval training (HIIT) has gained attention as a potentially effective alternative to traditional exercise modalities for individuals with type 2 diabetes mellitus (T2DM). Previous studies have evaluated this exercise strategy with various regimens, comparator groups and outcomes, limiting the generalisability 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 glycaemic control and other clinically relevant cardiometabolic health outcomes in individuals with T2DM, as compared with traditional moderate-intensity continuous training (MICT) and/or non-exercise control (CON). This umbrella review followed the Preferred Reporting Items for Overviews of Reviews guideline. Seven databases were searched until August 2024. Systematic reviews with meta-analyses comparing HIIT with MICT and/or CON were included. Literature search, data extraction and methodological quality assessment (A MeaSurement Tool to Assess systematic Reviews 2 [AMSTAR-2]) were conducted independently by two reviewers. Ten systematic reviews with meta-analyses, encompassing 76 primary studies and 2954 unique participants, met the inclusion criteria. The data indicated that HIIT significantly improves glycosylated haemoglobin and cardiorespiratory fitness compared with CON (weighted mean difference [WMD]: −0.83% to −0.39% and 3.35–6.38 mL/kg/min) and MICT (WMD: −0.37% to −0.07% and 1.68–4.12 mL/kg/min) in individuals with T2DM. HIIT is also effective in improving other glycaemic parameters, including fasting blood glucose, fasting blood insulin and HOMA-IR. Improvement in body composition, lipid profiles and blood pressure has also been observed following HIIT. Most systematic reviews received

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moderate to low AMSTAR-2 score. This umbrella review supports HIIT as an efficacious exercise strategy for improving glycaemic control and certain relevant cardiometabolic health outcomes in individuals with T2DM. Our findings offer a comprehensive basis that may potentially contribute to informing physical activity recommendations for incorporating HIIT into T2DM management strategies.

KEYWORDS
HIIT, interval exercise, public health, T2DM, umbrella review

1 | INTRODUCTION

Type 2 diabetes mellitus (T2DM) has emerged as a significant public health concern, with its prevalence steadily increasing globally.[1] According to the International Diabetes Federation (IDF), approximately 537 million adults were living with diabetes in 2021, a figure projected to rise to 783 million by 2045.[2] Given that the burden of T2DM not only affects individuals' health but also poses significant economic challenges to healthcare systems worldwide,[1] effective lifestyle management strategies are essential to mitigate its impact. In this context, authoritative organisations such as the American Diabetes Association (ADA), American College of Sports Medicine (ACSM) and European Association of Preventive Cardiology (EAPC) have established exercise guidelines that underscore the importance of regular physical activity in managing the condition.[3–5] They generally recommend that adults with T2DM engage in at least 150 min of moderate to vigorous intensity aerobic exercise per week, complemented by resistance training on two or more days each week. These guidelines emphasise the importance of regular physical activity as a cornerstone of diabetes management, alongside dietary modifications and pharmacotherapy.[3–5] However, adherence to these recommendations remains a challenge for many individuals with T2DM, often due to time constraints, lack of motivation or physical limitations.[6,7]

High-intensity interval training (HIIT) has gained attention as a potentially effective alternative to traditional exercise modalities for individuals with T2DM in the recent decade.[8] HIIT involves alternating short bursts of intense activity with periods of rest or lower intensity exercise, potentially leading to comparable or even superior improvements in cardiovascular fitness, body composition, insulin sensitivity and glycaemic control when compared with moderate-intensity continuous training (MICT).[9–11] Notably, HIIT is typically characterised by performing exercises at an intensity that elicits ≥80%–100% of peak heart rate.[12] This differs from sprint interval training, which requires an 'all-out' or 'supramaximal' effort, equating to or exceeding the pace that elicits ≥100% maximal oxygen uptake (VO_2max).[12] Furthermore, HIIT can be time-efficient, making it an appealing option for individuals with busy lifestyles who may struggle to meet the recommended exercise guidelines.[13] It can also enhance motivation and accommodate physical limitations by offering a variety of engaging workout options that provide equal or greater enjoyment compared with continuous exercise[14] and can be easily modified (e.g., in terms of exercise modalities, work-rest ratios and duration) to suit individual fitness levels and diverse needs.[15] While original studies exploring the efficacy of HIIT in improving glycaemic control and overall metabolic health in populations with T2DM have been conducted and summarised in an increasing number of systematic reviews and meta-analysis in recent years, discrepancies in review findings and conclusions have been observed. These systematic reviews often varied in comparison groups (e.g., non-active or active controls), HIIT modalities with limited samples or outcome measures, limiting the generalisability of the findings. For instance, some individual systematic reviews have shown that HIIT is more effective in improving glycaemic control than MICT,[16,17] while contrasting findings from other reviews have indicated a lack of significant differences.[18–20] The existence of such heterogeneity and discrepancies poses challenges for health and fitness professionals seeking to interpret the body of evidence regarding the comparative impact of various training modalities on glycaemic control and other cardiometabolic outcomes in the T2DM cohort.

In this context, umbrella reviews—also known as overviews of reviews or meta-reviews—have been proposed as a strategy to comprehensively synthesise evidence on a given topic.[21] Umbrella reviews summarise existing evidence from systematic reviews and offer a comprehensive basis to potentially inform guidelines. While several umbrella reviews have recently been published regarding the efficacy of HIIT in apparently healthy individuals[9,10,22,23] and those with mixed physical health conditions,[24] to the best of our knowledge, none have specifically focused on HIIT and T2DM. Given the alarmingly rising prevalence rates of T2DM and the substantial increase in evidence published through systematic reviews and meta-analyses on relevant topics in recent years,[25,26] an umbrella review that addresses the aforementioned research gaps to further establish the comparative benefits, compliance, safety and applications of HIIT interventions among individuals with T2DM appears timely. This would assist in establishing evidence-based recommendations for incorporating HIIT into T2DM management strategies. Therefore, the aim of this study was to undertake the most comprehensive synthesis of evidence to date regarding the effect of HIIT on glycaemic control and other clinically relevant cardiometabolic health outcomes in individuals with T2DM. We also aimed to critically appraise the methodological qualities of existing systematic reviews on HIIT and T2DM 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[21] and was registered in the PROSPERO database (CRD42024613965). Seven databases (MEDLINE, EMBASE, CINAHL, Scopus, SPORTDiscus, Cochrane Database and Web of Science) were searched using subject heading, keyword and Medical Subject Headings (MeSH) terms related to 'HIIT', 'T2DM', 'systematic review' and 'meta-analysis'. The search was limited to peer-reviewed systematic review articles published in English language from inception to 15 August 2024. The reference lists of the selected review articles were also examined for other potentially eligible papers. The detailed search strategy is presented in Data 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 humans who had been diagnosed with T2DM based on recognised diagnostic criteria established by authoritative organisations (such as WHO, IDF and ADA).[2,27] No exclusion criteria were applied to participants' habitual physical activity level at baseline. Systematic reviews and meta-analyses that combined data from populations with prediabetes 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.[28] HIIT is characterised as intermittent bouts performed above moderate intensity in a health context or above the heavy-intensity domain in a performance context, in which intensity 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. Reviews were eligible irrespective of HIIT modalities (e.g. cycling, running, walking or bodyweight exercises), settings (e.g. laboratory, hospitals or community facility) or dose (frequency and duration). Reviews that combined HIIT with other exercise and/or dietary intervention were excluded.

2.2.3 | Type of comparator

Reviews that involved active (e.g., MICT) 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 measures for this umbrella review were glycaemic responses, as indicated by glycosylated haemoglobin (HbA1c), fasting blood glucose (FBG), fasting blood insulin (FBI) and homeostatic model assessment for insulin resistance (HOMA-IR). Secondary outcome measures related to cardiometabolic health, including cardiorespiratory fitness (CRF; indicated as VO_2max/VO_2peak), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), body fat percentage (BF%), fat-free mass (FFM), fat mass (FM), waist circumference (WC), body weight (BW), body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP) and flow-mediated dilation (FMD), were also included in the analyses.

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 HL) conducted title/abstract and full-text screening in duplicate. Inter-reviewer disagreements were resolved by consensus or arbitration by a third reviewer (AK). Data were extracted using a standardised extraction form, and two independent reviewers (EP and HL) 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 (AK).

2.4 | Methodological quality assessment of included systematic reviews

Two independent reviewers (EP and HL) assessed the methodological quality of the included reviews in duplicate using the A MeaSurement Tool to Assess systematic Reviews 2 (AMSTAR-2) tool.[29] Discrepancies were resolved through consensus or arbitration by a third reviewer (AK). 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 (RoB) assessment, appropriateness of meta-analysis methods, use

of RoB 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[30]: $CCA = (N - r)/(rc - r)$, 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 categorised based on the following cut-offs: 0%–5% as 'slight overlap', 6%–10% as 'moderate', 11%–15% as 'high' and >15% as 'very high' overlap.[30]

Meta-analysis results from each review reporting either standardised (i.e., standardised mean difference [SMD]) or unstandardised effect sizes (i.e., weighted mean difference [WMD]) were presented using tables. 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.

3 | RESULTS

3.1 | Overview of search results

The search strategy yielded a total of 501 records from seven electronic databases. After removing duplicates, 252 records remained, out of which 202 were subsequently excluded based on title and abstract screening. The full texts of the remaining 50 articles were assessed, and 10 systematic reviews and meta-analyses that met the inclusion criteria were included in this umbrella review (refer to Figure 1 for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] flowchart and Data S2 for the list of excluded studies).

3.2 | Characteristics of included reviews

Table 1 presents a summary of the author, year, participant characteristics, features of HIIT intervention and comparators, and main findings of the included systematic reviews. The sample sizes of the 10 systematic reviews ranged from 67[34] to 1347.[31] A total of 76 unique primary studies with 2954 distinct participants were included in these systematic reviews (after removing the duplicates; see Data S3 for the full list), with a CCA of 14.3% indicating high overlap. The age of participants ranged from 15.3 to 80. Four included reviews reported the mean duration of T2DM among participants,[17,32,33,35] ranging from 1 to 20.5 years. Nine systematic reviews consisted solely of randomised controlled trials (RCTs),[16–20,32–35] while one included review included a combination of RCT and non-RCTs with experimental or quasi-experimental design.[31] Additionally, four systematic reviews reported the medications used,[17,20,31,33] and one review detailed the dietary controls adopted by participants in the original studies.[31]

The characteristics of HIIT interventions and comparison groups are summarised in Table 1. All reviews included studies with an intervention period 2–24 weeks and a frequency of 2–6 times per week. Various exercise modalities were used in HIIT interventions, such as cycling, running, walking/jogging, unassisted exercise and resistance band. The reviews used a variety of comparators to evaluate the efficacy of HIIT in individuals with T2DM. Six reviews compared HIIT with both MICT and non-exercise controls,[18–20,31,33,35] two reviews compared HIIT with MICT only,[16,34] one review compared HIIT with non-exercise controls only,[17] while one review used a control group combined with MICT, resistance training, routine care groups and static stretching,[32] as the comparator.

3.3 | Methodological quality of included reviews

Table 2 provides a summary of the AMSTAR-2 scores. Four reviews received a moderate score, while five reviews received a low score, and one received a critically low score. Specifically, the majority of reviews (70%) fully referred to a predefined methodology (item 2). However, 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). All reviews accounted for RoB when interpreting the results (item 9), and 80% discussed heterogeneity (item 14). All reviews used appropriate methods for statistical combination of results (item 11) and investigated publication bias (item 15) when conducting meta-analyses. However, only three reviews (30%) assessed the impact of RoB on the results (item 12).

3.4 | Meta-analysis results

3.4.1 | HIIT versus CON

Table 3 presents a comprehensive summary of the meta-analysis results from all 10 systematic reviews. In comparison with CON, all reviews consistently demonstrated that HIIT significantly improves HbA1c levels. The WMD reported across six systematic reviews ranged from −0.83% to −0.39% (Figure 2A), while one review reported a

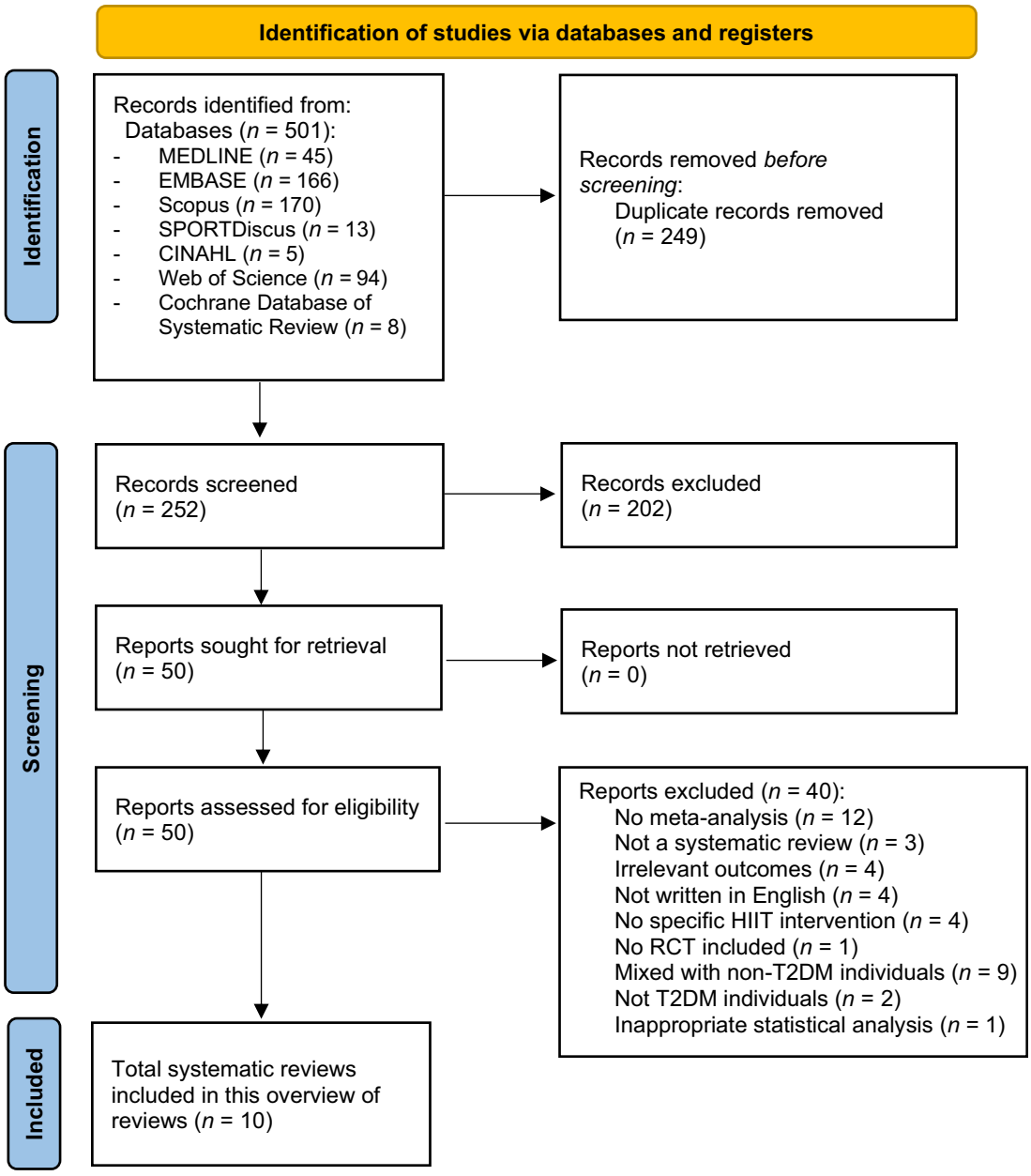

FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses flowchart of literature selection on systematic reviews.

SMD of −0.62. In line with the HbA1c findings, other glycaemic control parameters also showed significant improvements following HIIT, including FBG (four reviews; WMD: −1.15 to −0.74 mmol/L; SMD: −1.04 to −0.31), FBI (three reviews; WMD: −2.27 μIU/mL; SMD: −2.07 to −0.46) and HOMA-IR (three reviews; WMD: −0.88 to −0.18 unit; SMD: −1.60).

Additionally, HIIT consistently demonstrated significant improvements in CRF across five reviews (WMD: 3.35–6.38 mL/kg/min; SMD: 4.03–5.63; Figure 3A) compared with CON. Other clinically relevant cardiometabolic health parameters, including body composition, lipid profiles and blood pressure, also showed general improvements following HIIT (Table 3).

3.4.2 | HIIT versus MICT

The summary of the meta-analyses is presented in Table 4. When comparing HIIT to MICT, all eight reviews reporting changes in HbA1c favoured HIIT. The WMD ranged from −0.37% to −0.07% (Figure 2B), and the SMD ranged from −0.24 to −0.12. Moreover, most reviews reported comparable or superior benefits of HIIT when compared with MICT in other glycaemic outcomes including FBI (five reviews; WMD: −0.53 μIU/mL; SMD: −0.58 to −0.18), FBG (six reviews; WMD: −0.21 to 0.07 to −0.74 mmol/L; SMD: −0.21 to 0.05) and HOMA-IR (four reviews; WMD: −0.17 to 0.13 unit; SMD: −0.31 to 0.01) (Table 4).

TABLE 1 Summary of included systematic reviews.

Reference	Included studies and populations	Sample size	HIIT intervention	Comparator	Outcomes	Main findings
Arrieta-Leandro et al.[31]	$N = 41$ (RCTs and non-RCTs) Age: 20–69.1 Medication: Oral medicine, oral and injectable, medication and lifestyle Diet control: uncontrolled ($N = 28$); controlled ($N = 9$); NR ($N = 4$)	Total: 1347 Dropout: NR	Duration: 4–24 weeks Frequency: 2–5 times/week Time: NR Mode: Cycling, running, walking Intensity: Vigorous, maximal Recovery: NR	1. Non-exercise CON 2. MICT	HbA1c, FBG, FBI, HOMA-IR, BF%, FFM, WC, CRF	HIIT protocols improve all components except FFM. Sprint interval HIIT could be better than other types of HIIT in reducing FBG and HOMA-IR.
Cai et al.[16]	$N = 15$ (RCTs) Age: 38.5–69.2	Total: 371 Dropout: >15%, ($N = 7$)	Duration: 2–24 weeks Frequency: 2–6 times/week Time: 15–60 min Mode: Cycling, walking, running Intensity: 80%–90% HR_{peak} or VO_{2peak}; 90%–100% HRR; 100% VO_2R; 95% W_{peak}; All-out Recovery: Active, passive	MICT	HbA1c, FBG, FBI, CRF, BF %, BW, BMI, FFM, FM	HIIT has greater benefits on CRF and glucose control than MICT, but limited in body composition. The benefits would be influenced by intervention duration, frequency and interval design.
Cavalli et al.[18]	$N = 31$ (RCTs) Age: 57 ± 1.95 BMI: 20.9–36.7 kg/m^2	Total: 1092 Dropout: 130	Duration: 4–24 weeks Frequency: 2–5 times/week Time: 10–60 min/session Mode: Cycling, running, walking Intensity: 70%–90% HR_{max}; 55%–85% VO_{2peak}; 55%–90% HRR; RPE 13–18; 40%–100% VO_2R Recovery: NR	1. Non-exercise CON 2. MICT	HbA1c, FBI, TC, HDL, LDL, TG	HIIT improves lipid profile and glycaemic control. No difference was found between HIIT and MICT, but moderate-term HIIT seems to have a better outcome in cholesterol level.
de Mello et al.[19]	$N = 20$ (RCTs) Age: 57 ± 1.67	Total: 738 Dropout: 97	Duration: 4–16 weeks Frequency: 3–5 times/week Time: 10–60 min/session Mode: Cycling, running, walking Intensity: 70%–90% HR_{max}; 55%–90% VO_{2peak}; 60%–100% HRR; RPE 13–18; 40%–100% VO_2R Recovery: NR	1. Non-exercise CON 2. MICT	HbA1c, CRF	For increasing VO_{2max}, HIIT has superior effects over MICT and CON. For reducing HbA1c, HIIT had a greater effect compared with CON, but no difference as compared with MICT.
Feng et al.[32]	$N = 22$ (RCTs) Age: 34.6–69.6 T2DM duration: 1–14.5 years	Total: 1268 Dropout: 119	Duration: 8–24 weeks Frequency: 2–5 times/week Time: 15–60 min/session Mode: Cycling, running, walking, unassisted exercise, resistance band Intensity: 75%–95% HR_{max} Recovery: NR	The comparison group combined with MICT, resistance training, routine care groups and static stretching	HbA1c, FBG, FBI, TC, TG, HDL, LDL	HIIT improves glucose and lipid metabolism in T2DM patients, especially in HbA1c, TC, TG and HDL.
Liu et al.[33]	$N = 13$ (RCTs) Age: 15.3–70.1 Medication: Metformin, statins	Total: 345 Dropout: 37	Duration: 11–16 weeks Frequency: 2–5 times/week	1. Non-exercise CON 2. MICT	HbA1c, FBG, FBI, HOMA-IR, BW, BMI, BF%, WC,	HIIT is effective for improving CRF, preferable to MICT.

TABLE 1 (Continued)

Reference	Included studies and populations	Sample size	HIIT intervention	Comparator	Outcomes	Main findings
			Time: 25–60 min/session; time till 400 kal/session Mode: Cycling, running, walking Intensity: 90%–100% HR_{max}; 50%–85% VO_{2peak}; 80% HRR Recovery: Active, passive		TC, HDL, LDL, CRF	For HbA1c, BW, BMI, the findings were not conclusive.
Liubaoerjijin et al.[34]	$N = 3$[a] (RCTs) Age: 57.5–63 T2DM duration: 3.5–20.5 years	Total: 67 Dropout: 4	Duration: 12 weeks–4 months Frequency: 3–5 times/week Time: 30–60 min/session Mode: Cycling, walking Intensity: 70%–100% VO_{2peak} Recovery: Active	MICT	HbA1c, FBG, FBI	Subgroup analyses provided stronger support for HIIT than continuous exercise of higher intensity.
Mateo-Gallego et al.[20]	$N = 32$ (RCTs) Age: 22–80 Medication: Oral antidiabetics, insulin	Total: 708 Dropout: NR	Duration: 8–16 weeks Frequency: 2–5 times/week Time: 10–135 min/session Mode: Cycling, waking Intensity: 70%–95% HR_{max}; 80%–90% HRR; 70% peak energy expenditure rate, 100% VO_2R; 80%–85% VO_{2peak}; 16–18 RPE; 95% W_{peak} Recovery: Active, passive	1. Non-exercise CON 2. MICT	HbA1c, FBG, FBI, HOMA-IR, BW, BMI, CRF	HIIT has a greater improvement in glucose metabolism parameters compared with CON. HIIT and MICT showed no significant differences for glycaemic control, insulin resistance and BMI, but a higher VO_{2max} is shown in HIIT than MICT.
Qiu et al.[17]	$N = 7$ (RCTs) Age: 58.8 ± 7.5 BMI: 30.4 ± 0.7 kg/m^2 T2DM duration: 8.3 ± 6.6 years Medication: antihyperglycemic (metformin), instructed not to change dosages throughout intervention	Total: 189 Dropout: NR	Duration: 12–16 weeks Frequency: 2–5 times/week Time: 20–60 min/session Mode: Cycling, running, jogging, walking Intensity: 90% peak energy-expenditure rate; 100% VO_2R; 80%–85% VO_{2peak}; 90%–95% HR_{max}; 90%–100% HRR; 16–17 RPE Recovery: Active, passive	1. Non-exercise CON 2. MICT	HbA1c, BMI, BW, FM, SBP, DBP, TG, TC, HDL, LDL, CRF	Low-volume vigorous to maximal HIIT gives larger cardiometabolic benefits than MICT or CON for patients with T2DM, in particular for CRF and glycaemic control.
Qiu et al.[35]	$N = 5$[a] (RCTs) Age: 20–61.2 T2DM duration: 1–8.67 years	Total: 149 Dropout: NR	Duration: 12 weeks Frequency: 3 times/week Time: 19–60 min/session Mode: NR Intensity: 85%–95% HR_{max}; 85% W_{peak}; 80%–85% VO_{2peak} Recovery: Active	Non-exercise CON	FMD	Exercise had beneficial effects in improving FMD in T2DM patients, with HIIT being the most effective intervention type.

Abbreviations: BF%, body fat percentage; BMI, body mass index; BW, body weight; CON, control group; CRF, cardiorespiratory fitness; DBP, diastolic blood pressure; FBG, fasting blood glucose; FBI, fasting blood insulin; FFM, fat-free mass; FM, fat mass; FMD, flow-mediated dilation; HDL, high-density lipoprotein; HIIT, high-intensity interval training; HOMA-IR, homeostatic model assessment for insulin resistance; HR_{max}, maximal heart rate; HRR, heart rate reserve; LDL, low-density lipoprotein; MICT, moderate-intensity continuous training; NR, not reported; RCT, randomised controlled trial; RPE, rate of perceived exertion; RT, randomised trial; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; T2DM, type 2 diabetes mellitus; W_{peak}, peak power output; WC, waist circumference; VO_{2max}, maximal oxygen uptake; VO_{2peak}, peak oxygen uptake; VO_2R, oxygen consumption reserve.
[a]Only RCTs focusing on the effects of HIIT were included.

TABLE 2 A measurement tool to assess systematic reviews 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
Arrieta-Leandro et al.[31]	Y	Y	Y	PY	N	Y	N	PY	Y	N	Y	N	Y	N	Y	Y	Moderate
Cai et al.[16]	N	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	N	N	Y	Y	Low
Cavalli et al.[18]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	N	N	Y	Y	N	Low
de Mello et al.[19]	Y	Y	Y	PY	N	Y	N	PY	Y	N	Y	N	Y	Y	Y	N	Moderate
Feng et al.[32]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	Y	Y	Y	Y	Y	Moderate
Liu et al.[33]	Y	N	Y	PY	N	Y	N	PY	Y	N	Y	N	Y	Y	Y	Y	Low
Liubaoerjijin et al.[34]	Y	N	Y	PY	Y	N	N	PY	Y	N	Y	Y	Y	Y	Y	Y	Low
Mateo-Gallego et al.[20]	Y	N	Y	PY	Y	Y	N	PY	Y	N	Y	N	N	Y	Y	Y	Critically low
Qiu et al.[17]	Y	Y	Y	PY	N	N	N	PY	Y	N	Y	N	N	Y	Y	Y	Low
Qiu et al.[35]	Y	Y	Y	PY	Y	Y	N	PY	Y	N	Y	Y	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.

Regarding other parameters of cardiometabolic health, the findings were generally equivocal, with most reviews reporting a lack of significant effects between HIIT and MICT (Table 4). The only exception was CRF, where HIIT consistently demonstrated superior enhancement compared with MICT in six reviews (WMD: 1.68–4.12 mL/kg/min; SMD: 0.04–2.83; Figure 3B).

4 | DISCUSSION

To the best of our knowledge, this is the first umbrella review comparing the effectiveness of HIIT with both non-exercising CON and with traditional MICT in individuals with T2DM. Our study identified 10 systematic reviews with meta-analyses that examined the effect of HIIT on glycaemic control and other clinically relevant cardiometabolic health outcomes, involving 76 primary studies and 2954 unique participants with T2DM. The findings underscore the potential of HIIT as an efficacious exercise modality for managing T2DM and highlight the importance of exercise intensity in influencing metabolic outcomes.

4.1 | Effects of HIIT on glycaemic control and overall cardiometabolic health

The primary finding of the current umbrella review is that all included systematic reviews consistently reported superior effects of HIIT on glycaemic control parameters, such as HbA1c, FBG, FBI and HOMA-IR, when compared with non-exercise CON conditions. Additionally, other clinically relevant cardiometabolic health parameters, including CRF, body composition, lipid profiles and blood pressure, exhibited general improvements following HIIT interventions. The significance of these findings lies in their implications for clinical practice and public health. Improved glycaemic control is crucial for reducing the risk of diabetes-related complications, including cardiovascular diseases and metabolic syndrome.[27] Specifically, improving HbA1c levels is crucial for the management of T2DM; it has been associated with reduced risk of microvascular complications, such as nephropathy, retinopathy and neuropathy, as well as macrovascular complications, such as cardiovascular disease and stroke.[27] Previous studies have shown that each 1% reduction in HbA1c levels is associated with a 37% decrease in the risk of microvascular complications and a 21% reduction in the risk of any diabetes-related endpoint or death.[36] The proposed physiological mechanisms underlying the glycaemic control and cardiometabolic health benefits of HIIT have been outlined in detail elsewhere.[13] These mechanisms broadly include enhanced mitochondrial function, increased insulin sensitivity and reduced oxidative stress, all of which contribute to better glucose metabolism and overall metabolic health.[37–39] Additionally, HIIT may promote greater recruitment of muscle fibres and more substantial depletion of muscle glycogen, leading to improved insulin sensitivity and glucose uptake by skeletal muscles following each bout of exercise.[40]

Another highlighted aspect of the present umbrella review was the comparative analysis of HIIT's efficacy against traditional training protocols, particularly MICT. The included reviews consistently indicated that HIIT resulted in more significant improvements in HbA1c levels, as well as CRF, when compared with MICT. These findings

TABLE 3 Summary of meta-analyses on high-intensity interval training versus control group.

References	No. of studies (participants)	SMD/WMD	Mean change	95% CI	
				Lower limit	Upper limit
Outcome: glycosylated haemoglobin					
Arrieta-Leandro et al.[31]	16 ($n = 444$)	SMD	−0.62	−0.87	−0.37
Cavalli et al.[18]	17 ($n = 502$)	WMD (%)	−0.75	−0.97	−0.53
de Mello et al.[19]	10 ($n = 300$)	WMD (%)	−0.80	−1.06	−0.49
Liu et al.[33]	3 ($n = 63$)	WMD (%)	−0.39	−0.81	0.02
Mateo-Gallego et al.[20]	5 ($n = 161$)	WMD (%)	−0.34	−0.52	−0.16
Qiu et al.[17]	4 ($n = 95$)	WMD (%)	−0.83	−1.39	−0.27
Outcome: fasting blood glucose					
Arrieta-Leandro et al.[31]	22 ($n = 637$)	SMD	−1.04	−1.71	−0.38
Cavalli et al.[18]	14 ($n = 375$)	WMD (mmol/L)	−1.15	−1.44	−0.86
Liu et al.[33]	5 ($n = NR$)	SMD	−0.31	−0.69	0.06
Mateo-Gallego et al.[20]	8 ($n = 253$)	WMD (mmol/L)	−0.74	−1.10	−0.38
Outcome: fasting blood insulin					
Arrieta-Leandro et al.[31]	16 ($n = 488$)	SMD	−2.07	−3.14	−1.00
Liu et al.[33]	5 ($n = NR$)	SMD	−0.46	−0.91	0.02
Mateo-Gallego et al.[20]	4 ($n = 109$)	WMD (μIU/mL)	−2.27	−3.78	−0.75
Outcome: homeostatic model assessment for insulin resistance					
Arrieta-Leandro et al.[31]	17 ($n = 535$)	SMD	−1.60	−2.42	−0.77
Liu et al.[33]	4 ($n = NR$)	WMD (unit)	−0.18	−0.79	0.42
Mateo-Gallego et al.[20]	7 ($n = 227$)	WMD (unit)	−0.88	−1.49	−0.26
Outcome: cardiorespiratory fitness					
Arrieta-Leandro et al.[31]	3 ($n = 79$)	SMD (VO_2max)	5.63	0.73	10.53
Arrieta-Leandro et al.[31]	11 ($n = 325$)	SMD (VO_2peak)	4.03	2.21	5.86
de Mello et al.[19]	9 ($n = 299$)	WMD (mL/kg/min)	5.09	2.99	7.19
Liu et al.[33]	2 ($n = 40$)	WMD (mL/kg/min)	4.12	2.66	5.57
Mateo-Gallego et al.[20]	6 ($n = 198$)	WMD (mL/kg/min)	3.35	1.50	5.21
Qiu et al.[17]	2 ($n = 49$)	WMD (mL/kg/min)	6.38	3.66	9.10
Outcome: total cholesterol					
Cavalli et al.[18]	13 ($n = 356$)	WMD (mmol/L)	−0.31	−0.49	−0.12
Liu et al.[33]	6 ($n = NR$)	SMD	0.02	−0.32	0.37
Qiu et al.[17]	4 ($n = NR$)	WMD (mmol/L)	−0.64	−1.05	−0.23
Outcome: high-density lipoprotein cholesterol					
Cavalli et al.[18]	12 ($n = 333$)	WMD (mmol/L)	0.24	0.06	0.42
Liu et al.[33]	5 ($n = NR$)	SMD	0.60	−0.26	1.45
Qiu et al.[17]	3 ($n = NR$)	WMD (mmol/L)	0.20	−0.08	0.47
Outcome: low-density lipoprotein cholesterol					
Cavalli et al.[18]	12 ($n = 333$)	WMD (mmol/L)	−0.31	−0.49	−0.12
Liu et al.[33]	5 ($n = NR$)	WMD (mmol/L)	−0.60	−1.74	0.54
Qiu et al.[17]	3 ($n = NR$)	WMD (mmol/L)	−0.55	−1.01	−0.09
Outcome: triglyceride					
Cavalli et al.[18]	13 ($n = 356$)	WMD (mmol/L)	−0.27	−0.33	−0.2
Qiu et al.[17]	4 ($n = NR$)	WMD (mmol/L)	−0.22	−0.47	0.03
Outcome: body fat percentage					
Arrieta-Leandro et al.[31]	15 ($n = 377$)	SMD	−2.67	−4.40	−0.94

(Continues)

TABLE 3 (Continued)

References	No. of studies (participants)	SMD/WMD	Mean change	95% CI	
				Lower limit	Upper limit
Outcome: fat-free mass					
Arrieta-Leandro et al.[31]	5 (n = 137)	SMD	0.19	−1.20	1.59
Outcome: waist circumference					
Arrieta-Leandro et al.[31]	5 (n = 165)	SMD	−2.90	−4.82	−0.98
Outcome: body weight					
Liu et al.[33]	6 (n = NR)	WMD (kg)	−0.78	−2.36	0.80
Qiu et al.[17]	4 (n = NR)	WMD (kg)	−3.36	−7.24	0.52
Outcome: body mass index					
Liu et al.[33]	4 (n = NR)	WMD (kg/m^2)	−0.80	−1.86	0.27
Mateo-Gallego et al.[20]	5 (n = 172)	WMD (kg/m^2)	−0.31	−0.85	0.24
Qiu et al.[17]	3 (n = NR)	WMD (kg/m^2)	−0.90	−2.00	0.21
Outcome: fat mass					
Qiu et al.[17]	3 (n = NR)	SMD	−0.49	−0.96	−0.01
Outcome: systolic blood pressure					
Qiu et al.[17]	4 (n = NR)	WMD (mmHg)	−2.23	−4.37	−0.10
Outcome: diastolic blood pressure					
Qiu et al.[17]	4 (n = NR)	WMD (mmHg)	−0.64	−2.00	0.71
Outcome: flow-mediated dilation					
Qiu et al.[35]	5 (n = 149)	WMD (%)	2.62	1.42	3.82

Abbreviations: CI, confidence interval; SMD, standardised mean difference; VO_{2max}, maximal oxygen uptake; VO_{2peak}, peak oxygen uptake; WMD, weighted mean difference.

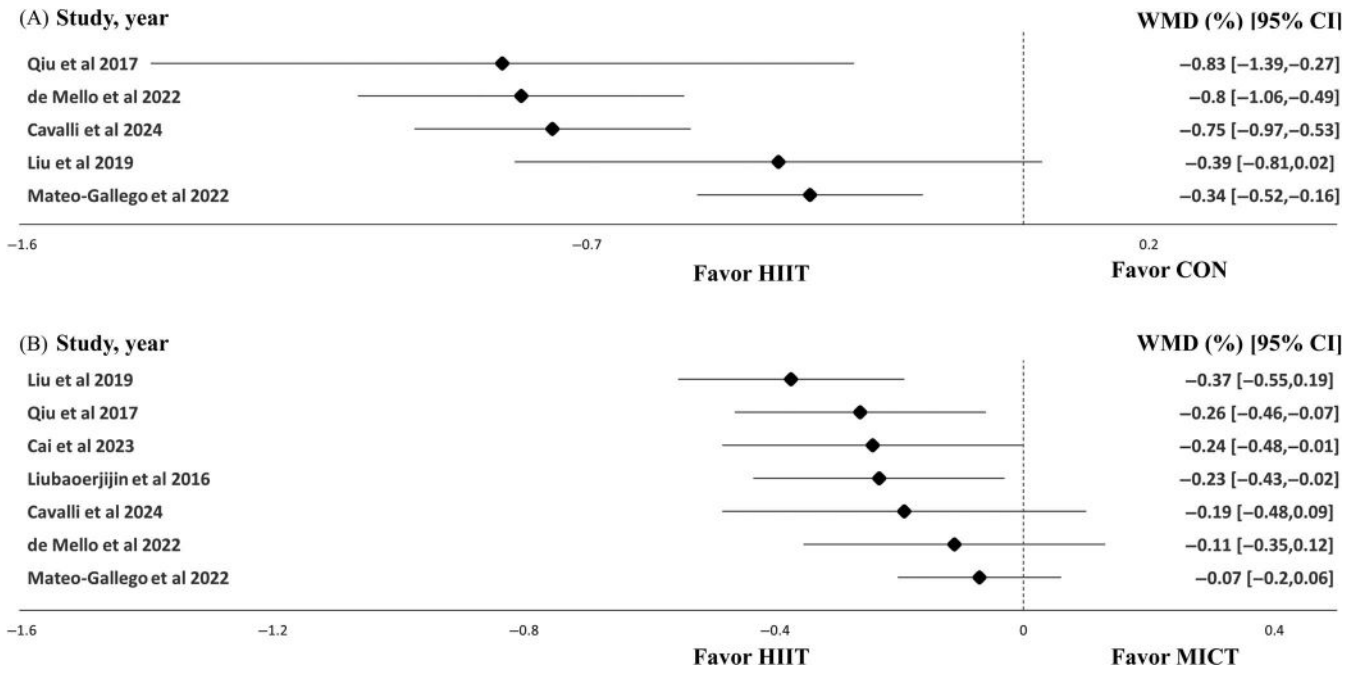

FIGURE 2 Results of meta-analyses that compared high-intensity interval training (HIIT) with (A) control group (CON) and (B) moderate-intensity continuous training for glycosylated haemoglobin improvements using weighted mean difference (%). WMD, weighted mean difference.

suggest that the benefits of HIIT extend beyond glycaemic control, potentially offering additional clinical advantages. Notably, low CRF is a major predictor of mortality in individuals with diabetes,[41,42] while enhancing CRF can improve functional capacity, which is a crucial therapeutic goal in T2DM patients.[43] On the other hand, although most reviews indicated comparable or superior benefits of HIIT in

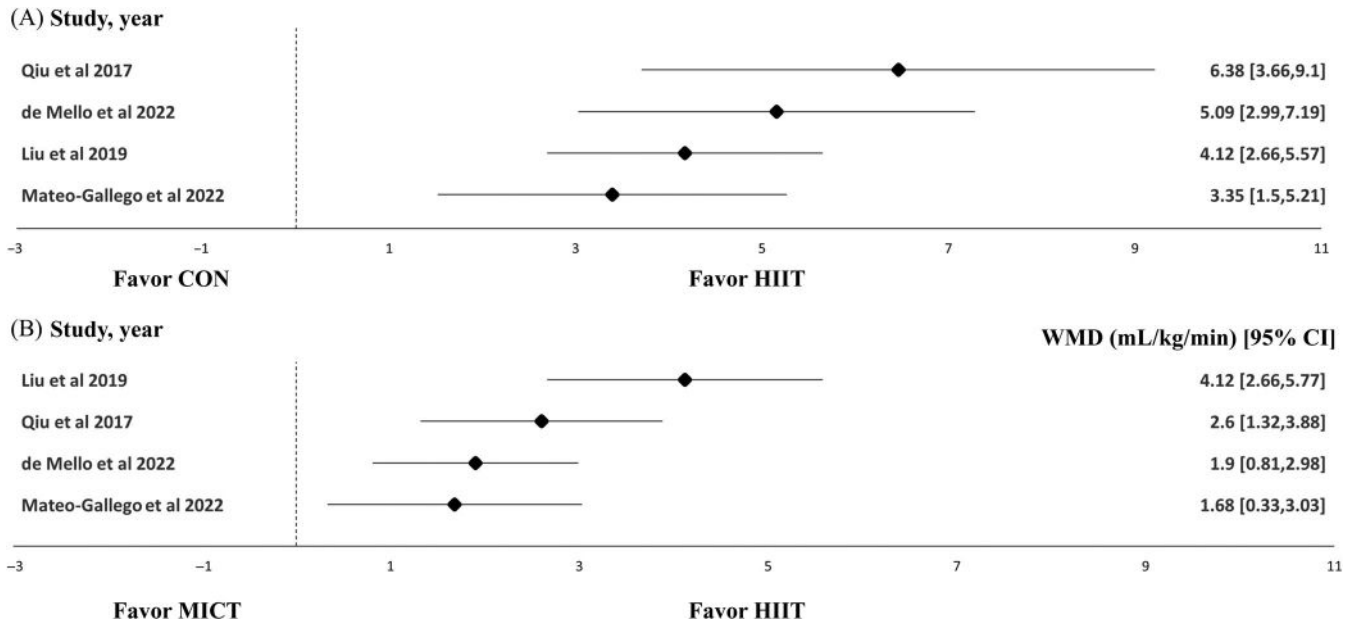

FIGURE 3 Results of meta-analyses that compared high-intensity interval training (HIIT) with (A) control group (CON) and (B) moderate-intensity continuous training (MICT) for cardiorespiratory fitness improvements using weighted mean difference (in milligram per kilogram per minute). WMD, weighted mean difference.

other glycaemic outcomes, such as FBI, FBG and HOMA-IR, the findings regarding other cardiometabolic health parameters, including body composition, lipid profiles and blood pressure, were less conclusive. This variability may be attributed to the limited number of systematic reviews addressing these specific outcomes. Nonetheless, the overall trend suggests that HIIT may be a more efficacious alternative to MICT for improving glycaemic control and certain aspects of cardiometabolic health in individuals with T2DM.

4.2 | Potential moderators of HIIT effects

Six out of 10 reviews 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 and methodological limitations in the original studies included, four systematic reviews were unable to perform quantitative analyses for potential moderators of HIIT effects.[17,33–35] Nonetheless, four systematic reviews suggested that interventions lasting ≥4–12 weeks may confer greater advantages in improving glycaemic control and/or other cardiometabolic health outcomes compared with shorter interventions.[16,18,19,32] Additionally, several reviews reported that other intervention components including interval intensity,[20,31,32] interval duration,[16,18,19,31] total session time[19] and frequency,[16] as well as participants' age[32] and duration of disease,[32] may moderate the effects of HIIT, 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 the key glycaemic control and cardiometabolic health outcomes, by employing additional high-quality RCTs. It is also important to recognise that health and fitness professionals may need to individualise HIIT program parameters to achieve the optimal stimulus for adaptations, particularly in individuals who were previously sedentary. Depending on participants' initial fitness levels and experience, it is advisable to implement a progression in interval duration, intensity or frequency.[8]

4.3 | Practicality and safety of implementing HIIT

There are understandable concerns regarding the practicality and safety of implementing HIIT as a health promotion strategy for individuals with T2DM. Some critics contend that HIIT is complex and aversive, necessitating a high degree of supervision and self-regulation.[44,45] Surprisingly, our umbrella review found that only three systematic reviews (30%) explicitly addressed safety-related matters. Notably, among the original studies included in the meta-analysis by Qiu et al.,[17] none reported potential harms such as hypoglycaemia, cardiovascular events or sport-related injuries associated with HIIT in patients with T2DM. Additionally, Mateo-Gallego et al.[20] reported no differences in safety, tolerability and compliance between the HIIT and MICT protocols. Similarly, Liubaoerjijin et al.[34] found that higher intensity exercise was not associated with lower adherence, greater dropouts or more adverse events compared with lower intensity protocols in individuals with T2DM. While large-scale studies assessing safety outcomes in the T2DM population are still 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.[46–50] This notion is also supported by a recent

TABLE 4 Summary of meta-analyses on high-intensity interval training versus moderate-intensity continuous training.

References	No. of studies (participants)	SMD/WMD	Mean change	95% CI	
				Lower limit	Upper limit
Outcome: glycosylated haemoglobin					
Arrieta-Leandro et al.[31]	13 ($n = 347$)	SMD	−0.12	−0.24	0.01
Cai et al.[16]	12 (n = NR)	SMD	−0.24	−0.48	−0.01
Cavalli et al.[18]	15 ($n = 523$)	WMD (%)	−0.19	−0.48	0.09
de Mello et al.[19]	8 ($n = 202$)	WMD (%)	−0.11	−0.35	0.12
Liu et al.[33]	9 ($n = 209$)	WMD (%)	−0.37	−0.55	0.19
Liubaoerjijin et al.[34]	3 ($n = 66$)	WMD (%)	−0.23	−0.43	−0.02
Mateo-Gallego et al.[20]	11 ($n = 300$)	WMD (%)	−0.07	−0.20	0.06
Qiu et al.[17]	5 ($n = 120$)	WMD (%)	−0.26	−0.46	−0.07
Outcome: fasting blood glucose					
Arrieta-Leandro et al.[31]	16 ($n = 379$)	SMD	−0.21	−0.40	−0.02
Cai et al.[16]	12 (n = NR)	SMD	0.05	−0.18	0.28
Cavalli et al.[18]	16 ($n = 523$)	WMD (mmol/L)	−0.19	−0.48	0.09
Liu et al.[33]	8 (n = NR)	WMD (mmol/L)	0.10	−0.84	0.65
Liubaoerjijin et al.[34]	3 ($n = 66$)	WMD (mmol/L)	0.07	−0.54	0.69
Mateo-Gallego et al.[20]	8 ($n = 265$)	WMD (mmol/L)	−0.21	−0.48	0.07
Outcome: fasting blood insulin					
Arrieta-Leandro et al.[31]	9 ($n = 250$)	SMD	−0.43	−1.57	0.71
Cai et al.[16]	9 (n = NR)	SMD	−0.18	−0.47	0.11
Liu et al.[33]	4 (n = NR)	SMD	−0.19	−0.58	0.20
Liubaoerjijin et al.[34]	1 ($n = 24$)	SMD	−0.58	−1.41	0.24
Mateo-Gallego et al.[20]	3 ($n = 132$)	WMD (μIU/mL)	−0.53	−2.14	1.08
Outcome: homeostatic model assessment for insulin resistance					
Arrieta-Leandro et al.[31]	12 ($n = 380$)	SMD	0.01	−0.45	0.46
Liu et al.[33]	6 (n = NR)	WMD (unit)	0.13	−0.10	0.36
Liubaoerjijin et al.[34]	2 ($n = 52$)	SMD	−0.31	−0.86	0.24
Mateo-Gallego et al.[20]	7 ($n = 304$)	WMD (unit)	−0.17	−0.57	0.22
Outcome: cardiorespiratory fitness					
Arrieta-Leandro et al.[31]	8 ($n = 246$)	SMD (VO_2max)	2.83	1.72	3.95
Arrieta-Leandro et al.[31]	11 ($n = 287$)	SMD (VO_2peak)	0.04	−0.97	1.06
Cai et al.[16]	11 (n = NR)	SMD	0.40	0.08	0.73
de Mello et al.[19]	11 ($n = 449$)	WMD (mL/kg/min)	1.90	0.81	2.98
Liu et al.[33]	7 ($n = 182$)	WMD (ml/kg/min)	4.12	2.66	5.77
Mateo-Gallego et al.[20]	11 ($n = 344$)	WMD (ml/kg/min)	1.68	0.33	3.03
Qiu et al.[17]	4 ($n = 104$)	WMD (ml/kg/min)	2.60	1.32	3.88
Outcome: total cholesterol					
Cavalli et al.[18]	16 ($n = 553$)	WMD (mmol/L)	−0.10	−0.27	0.06
Liu et al.[33]	7 (n = NR)	WMD (mmol/L)	−0.18	−0.44	0.07
Qiu et al.[17]	4 (n = NR)	WMD (mmol/L)	−0.11	−0.51	0.30
Outcome: high-density lipoprotein cholesterol					
Cavalli et al.[18]	18 ($n = 585$)	WMD (mmol/L)	−0.03	−0.16	0.10
Liu et al.[33]	9 (n = NR)	WMD (mmol/L)	−0.04	−0.10	0.02
Qiu et al.[17]	4 (n = NR)	WMD (mmol/L)	−0.11	−0.24	0.03
Outcome: low-density lipoprotein cholesterol					
Cavalli et al.[18]	15 ($n = 530$)	WMD (mmol/L)	0.01	−0.13	0.15

TABLE 4 (Continued)

References	No. of studies (participants)	SMD/WMD	Mean change	95% CI	
				Lower limit	Upper limit
Liu et al.[33]	6 (n = NR)	WMD (mmol/L)	−0.25	−0.46	−0.04
Qiu et al.[17]	4 (n = NR)	WMD (mmol/L)	−0.09	−0.52	0.35
Outcome: triglycerides					
Cavalli et al.[18]	18 (n = 592)	WMD (mmol/L)	−0.004	−0.11	0.03
Qiu et al.[17]	4 (n = NR)	WMD (mmol/L)	0.40	−0.18	0.97
Outcome: body fat percentage					
Arrieta-Leandro et al.[31]	13 (n = 362)	SMD	0.25	−0.47	0.97
Cai et al.[16]	8 (n = NR)	SMD	0.02	−0.27	0.32
Liu et al.[33]	5 (n = NR)	WMD (%)	−0.50	−1.18	0.19
Outcome: fat-free mass					
Arrieta-Leandro et al.[31]	9 (n = 240)	SMD	−0.70	−2.20	0.79
Cai et al.[16]	7 (n = NR)	SMD	−0.03	−0.33	0.28
Outcome: waist circumference					
Arrieta-Leandro et al.[31]	9 (n = 252)	SMD	−0.30	−1.69	1.09
Liu et al.[33]	6 (n = NR)	WMD (cm)	−0.15	−1.21	0.91
Outcome: body weight					
Cai et al.[16]	15 (n = NR)	SMD	0.06	−0.21	0.33
Liu et al.[33]	8 (n = NR)	WMD (kg)	−1.22	−2.23	−0.18
Qiu et al.[17]	4 (n = NR)	WMD (kg)	0.39	−1.33	2.11
Outcome: body mass index					
Cai et al.[16]	13 (n = NR)	SMD	0.05	−0.23	0.33
Liu et al.[33]	8 (n = NR)	WMD (kg/m^2)	−0.40	−0.78	−0.02
Mateo-Gallego et al.[20]	10 (n = 296)	WMD (kg/m^2)	−0.10	−0.54	0.35
Qiu et al.[17]	5 (n = NR)	WMD (kg/m^2)	−0.16	−0.57	0.24
Outcome: fat mass					
Cai et al.[16]	5 (n = NR)	SMD	0.04	−0.33	0.40
Qiu et al.[17]	5 (n = NR)	SMD	−0.15	−0.51	0.21
Outcome: systolic blood pressure					
Qiu et al.[17]	3 (n = NR)	WMD (mmHg)	−7.07	−17.31	3.17
Outcome: diastolic blood pressure					
Qiu et al.[17]	3 (n = NR)	WMD (mmHg)	−2.40	−5.71	0.91

Abbreviations: CI, confidence interval; SMD, standardised mean difference; VO_{2max}, maximal oxygen uptake; VO_{2peak}, peak oxygen uptake; WMD, weighted mean difference.

systematic review that indicated high compliance to HIIT among insufficiently active adults and adults with a medical condition.[50] Among our included reviews that reported compliance,[16,18,19,32–34] the compliance level within HIIT programs was satisfactory (i.e., ≥80%) in general. Nevertheless, individuals with T2DM should undergo a thorough medical evaluation before initiating any exercise program, particularly to assess cardiovascular health and identify any contraindications to vigorous exercise.[5,51] All exercise programs should be delivered in a progressive manner with adequate supervision. Low-impact exercises, such as cycling or brisk walking, were commonly employed HIIT modalities in our included studies, which would appear to be suitable exercise options those who live with overweight/obesity or have medical conditions to reduce stress on joints and lower injury risk.[5] Additionally, regular monitoring of blood glucose levels before, during and after exercise is vital to prevent hypoglycaemia, and individuals who use insulin or sulphonylureas should have fast-acting carbohydrates readily available in case of low blood sugar.[3,4] By following these guidelines, individuals with T2DM can be more safely engage in HIIT and potentially improve their glycaemic control and overall metabolic health.

4.4 | Strengths and limitations

The strengths of this umbrella review include adherence to PRIOR guidelines and the use of widely recognised benchmarks

(e.g., AMSTAR-2) to assess the scientific rigour 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. We have also provided important clinical information and implications on the therapeutic magnitude of HIIT programmes on various glycaemic control and cardiometabolic health outcomes, thus clearly defining the novelty and significance of the work as the largest evaluation specific to T2DM.

However, this umbrella review had several limitations. First, some of the included systematic reviews were rated as low ($n = 5$) or critically low ($n = 1$), in quality based on the AMSTAR-2 rating. Specifically, only a small proportion of reviews 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 field. Moreover, the CCA of 14.3% in this umbrella review indicates a significant overlap of primary studies among the included systematic reviews. While high overlap may lead to inflated estimates of the effect sizes, it also reflects the growing interest in HIIT for T2DM management and interconnectedness of research in this area.[52] Future research can focus on diversifying study designs to ensure a more robust and comprehensive understanding of the effects of HIIT in individuals with T2DM. In addition, it is important to acknowledge that many participants in the included studies were on medications for T2DM or other complications that were not withdrawn or reduced during the intervention period. This raises the possibility of an interaction between the medication and the exercise training effect.

Despite these issues, from a practical perspective, our umbrella review findings can provide valuable insights to a wide range of interested parties involved in health and fitness promotion, including researchers, health organisations and government entities. These insights can support the ongoing advancement of existing physical activity guidelines aimed at improving T2DM management strategies.

5 | CONCLUSION

This novel umbrella review provides comprehensive and up-to-date evidence supporting the efficacy of HIIT in improving glycaemic control compared with non-active CON groups and conventional exercise regimens such as MICT in individuals with T2DM. Additionally, it demonstrates that HIIT can improve certain relevant cardiometabolic health outcomes when compared with non-active CON, but further research is needed to ascertain the additional cardiometabolic benefits of HIIT over MICT. Ongoing research and implementation efforts are also warranted to optimise the integration of HIIT into a comprehensive diabetes management plan and to evaluate the long-term impacts and safety outcomes of various HIIT interventions.

AUTHOR CONTRIBUTIONS

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

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

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

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