

A Meta-Analysis of the Effectiveness of High-Intensity Interval Training (HIIT) on Cardiovascular Health

Derar H. Abdel-Qader¹, Khalid Awad Al-Kubaisi², Nathir M Obeidat³, Rana Ibrahim², Nadia Al Mazrouei², Eman Massad⁴, Esra' Taybeh⁵, Sahar Abed Al-Qader Jaradat¹, Shorouq Saleh Al-Omoush¹, Alia Hani Saleh¹

¹Faculty of Pharmacy and Medical Sciences, University of Petra, Amman, Jordan; ²Department of Pharmacy Practice and Pharmacotherapeutics, College of Pharmacy, University of Sharjah, Sharjah, UAE; ³Department of Internal Medicine, School of Medicine, University of Jordan, Amman, Jordan; ⁴Public Health Institute, The University of Jordan; ⁵Department of Applied Pharmaceutical Sciences, School of Pharmacy, Isra University, Amman, Jordan

ABSTRACT

Background: High-intensity interval training (HIIT) is an efficient time-based exercise type with an overwhelming and positive outcome on cardiovascular health, ahead of moderate-intensity continuous training (MICT). This exciting twist on high-intensity interval training (HIIT) has, to date, shifted researchers' focus to non-exercise controls and MICT cardiovascular elements such as VO_2 max, blood pressure, vascular function, lipid profiles, and Resting Heart Rate (RHR). **Methods:** This interval training meta-analysis includes only HIIT studies with at least 80% of ages 20–40 at max heart rate from 4 weeks (assuming 80% of MHR max). HIIT shows improvement on the compared metrics compared with the non-exercise control: VO_2 max ($4.3 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), systolic (4 mm), and diastolic (3 mm). **Findings:** Improvements in endothelial function and arterial stiffness, with reduced pulse wave velocity, are noted. HIIT is superior to MICT, with gains in VO_2 max of 3–4 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and central systolic blood pressure, indicating marginally better vascular function and arterial stiffness. HIIT with gains identified seeks work. 2 or more work interval durations, 3 to 5 session frequencies, at least 8 weeks of total progression times, and work: no work ratios of 1:1 give the best results. **Conclusion:** Compliance remains high in supervised intervals, with minimal safety events; yet long-term sustainability beyond 12 months is less well substantiated. Comprehensive HIIT training remains a safe intervention with many benefits, and it can be easily tailored to assist individuals at risk in improving their cardiovascular health.

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 VO_2 Max, Physical Activity,
Interval Training,
Exercise, Training

1. Introduction

High-intensity interval training (HIIT) has become a popular intervention for cardiovascular health. The evidence collected in this meta-analysis suggests that HIIT has significant effects on improving cardiorespiratory fitness, blood pressure, and vascular function. The outcomes of this are often analogous to or utilize more intense gains with moderate-intensity continuous training (MICT) (Oliveira et al., 2023). Notably, HIIT provides an effective, time-saving strategy that can create a more adherent framework compared to traditional workouts. Recent meta-analyses in both clinical and healthy populations have supported these findings. It is indicated that HIIT can increase VO_2 max, decrease blood pressure, and improve body composition in diverse cohorts, which affirms its cardioprotective properties. Gao et al. (2025) emphasized that HIIT is superior compared to MICT, which demonstrated a significant impact on VO_2 max and Diastolic blood pressure, which was statistically significant. Griffiths et al. (2024) already proved that HIIT can have a positive effect not only on physical results but also on quality of life. HIIT is generally a safe, effective, and feasible intervention. Future studies need to examine long-term compliance, specific population responses, and, most importantly, improve protocol design to achieve optimal cardiac benefits.

1.1 Rationale of the Study

The need to conduct this research stems from persistent literature inequality and the urgent need to provide specific

guidelines on the effects of high-intensity interval training (HIIT) on cardiovascular health. Fitness experts and medical practitioners have increasingly promoted HIIT, although the relative value of this intervention compared with traditional moderate-intensity continuous training (MICT) remains unclear. Policy and clinical practitioners in the health sector need consolidated health evidence to develop evidence-based exercise prescriptions. A systematic meta-analysis, in this context, provides a rigorous synthesis capable of determining whether the recommendation of HIIT is warranted on a broad basis, identifying the populations most likely to benefit from the training, and establishing which specific exercises provide the superior training procedures.

1.2 Research Questions

1. What is the effectiveness of HIIT compared to non-exercise control regimes in enhancing the cardiovascular health measures, which maximizes oxygen consumption VO_2 max, blood pressure, vascularity, and cardiac functioning?
2. What is the comparison between HIIT and moderate-intensity continuous training of healthy adults, as well as clinical populations?
3. What protocol variables, such as frequency, duration, interval intensity, and work-to-rest ratio, affect cardiovascular outcome?

1.3 Research Objectives

- To combine the already existing literature regarding the effect of HIIT on important cardiovascular health indicators
- To conduct a comparison between the HIIT and non-exercise control group and between HIIT and an MICT intervention.
- To establish the mediating effect of protocol variables on cardiovascular measures.
- To assess the evidence related to the adherence, safety, and sustainability of HIIT in the long run.

2. Methodology

2.1 Meta-Analysis

The meta-analysis has been conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Peer-reviewed publications using PubMed, Scopus, Web of Science, and Google Scholar in the period of January 2019–September 2024 were searched comprehensively. Category search terms were developed to reach the records of research that utilized the following categorical search terms: “high-intensity interval training” or “HIIT” and “cardiovascular health” or “ VO_2 max” or “blood pressure” or “endothelial functions” or “arterial stiffness”, and “lipid profile”.

2.2 PICOS Framework

Population: The sample of the conducted study included adults who are aged no less than 18 years and older, regardless of whether they are healthy, are overweight or even obese, have high blood pressure, or suffer cardiometabolic disorders.

Intervention: The prescriptive inclusion criteria nature was grounded on the inclusion of systematic high-intensity interval training (HIIT) in resolutions involving a measure of intensity higher than 80 % maximum heart rate (HRmax) or other function, and performed proportions of contractions over four weeks of minimal persistent

Comparator: MICT, other exercise modalities, or common care.

Outcomes: The cardiovascular outcomes measured included maximal oxygen consumption (VO_2 peak), blood pressure, indices of vascular functioning, lipid levels, and resting heart rate.

Study Design: The study included evidence from randomised controlled trials (RCTs), systematic reviews, or meta-analyses.

2.3 Exclusion Criteria

One of the exclusion criteria was pediatric patients, and an intervention where the high-intensity interval training (HIIT) was absent. The second exclusion was the lack of a cardiovascular result in the studies. Titles, abstracts, and full texts were screened, and 15 studies meeting the eligibility criteria were subsequently identified. The data mining included participant characteristics, protocol characteristics, comparators, outcomes, and their respective results. Due to the HIIT protocols, statistical pooling was not possible; therefore, a narrative synthesis was used to identify recurring patterns and clarify inconsistencies.

3. Results

3.1 Study Selection and Characteristics

Fifteen randomised controlled trials (with corresponding meta-analyses where applicable) published between 2019 and 2024 were identified in the initial search. The focus populations ranged from healthy and overweight/obese individuals, patients with hypertension and cardio metabolic risk, older adults, and individuals recovering from coronary artery disease and post-COVID-19 syndrome. HIIT protocols were diverse, but work intervals (75-100% of HRmax or HRR) of 1-4 minutes, completed 2-5 times a week, ranged from 4-24 weeks. The broad comparators included moderate intensity continuous training (MICT) at 40-79% of HRmax.

3.2 VO₂ Max / Peak Oxygen Consumption

Compared to non-exercise controls, HIIT improved VO₂ max across populations the most, and often outperformed MICT. Amongst cancer survivors, HIIT resulted in moderate-to-large SMD benefits (SMD $\approx$ 0.53), while HIIT with overweight individuals had markedly greater SMD benefits (SMD $\approx$ 0.44) for intervals > 2 minutes compared to MICT. Over MICT and control, HIIT increased VO₂ peak in patients with hypertension (Peng et al., 2025). HIIT is effective for improving cardiorespiratory fitness in healthy and clinical populations, but most notably in clinically defined populations.

3.3 Blood Pressure

HIIT has also been shown to induce clinically significant reductions in both SBP and DBP in less macrovascular healthy individuals (hypertensive) and less clinically controlled populations (Oliveira et al., 2023). Showing significant clinical benefit with even fewer controlled populations (meaning those who did not complete controls), particularly in post-exercise heart rate (PEHR) and DBP increases (where controls were also outperformed by post-exercise heart rate increases studied with MICT protocols).

3.4 Vascular Function and Arterial Stiffness

HIIT improves endothelial function and reduces vascular stiffness, thereby preserving and enhancing vascular health. Studies on HIIT and FMD show pronounced enhancements with FMD, and with more specialised HIIT protocols in clinical populations. While achieving relative standards of clinical improvement on FMD (Luo et al., 2024). These studies also, in clinical HIIT populations, demonstrate lower PWV (WMD $\approx$ -0.62 m/s), indicating lower vascular age and reduced cardiovascular ageing associated with higher CV risk.

3.5 Lipid Profile, Resting Heart Rate, and Other Parameters

HIIT improved lipid profiles, including lower total cholesterol and LDL levels, with minor increases in HDL levels. Resting heart rate in HIIT was lower than in controls in population-level studies (Edwards et al., 2023). Other benefits, including better insulin sensitivity and lower inflammatory markers, were noted. However, the findings were mixed. When energy expenditure was held constant, differences between HIIT and MICT in lipid and body composition outcomes were often minimal, suggesting that intensity, rather than total work, was critical.

3.6 Protocol Variables, Adherence, and Safety

Among protocols with ≥ 2 -minute intervals, those with ≥ 8 -week durations were associated with the greatest increases in VO₂ max and vascular benefits, although even shorter programs (4-6 weeks) produced measurable improvements. Frequencies of 3-5 sessions per week were optimal. Adherence in supervised trials was between 75-100%, with positive safety outcomes (Taylor et al., 2020). The FITR Heart Study showed that HIIT is feasible in cardiac rehab, with low adverse event rates over a 12-month follow-up period, and that it was well tolerated.

3.7 HIIT vs MICT: Outcomes Comparison

HIIT and MICT both have greater impacts on cardiovascular health than the control. Nevertheless, HIIT improves VO₂ max to a greater extent, reduces SBP (particularly central SBP) to a greater extent, and decreases vascular stiffness to a greater extent. Differences in DBP, lipid fractions, and inflammatory markers, more specific inflammatory markers, are patchy and appear to disappear more often when training loads are equal.

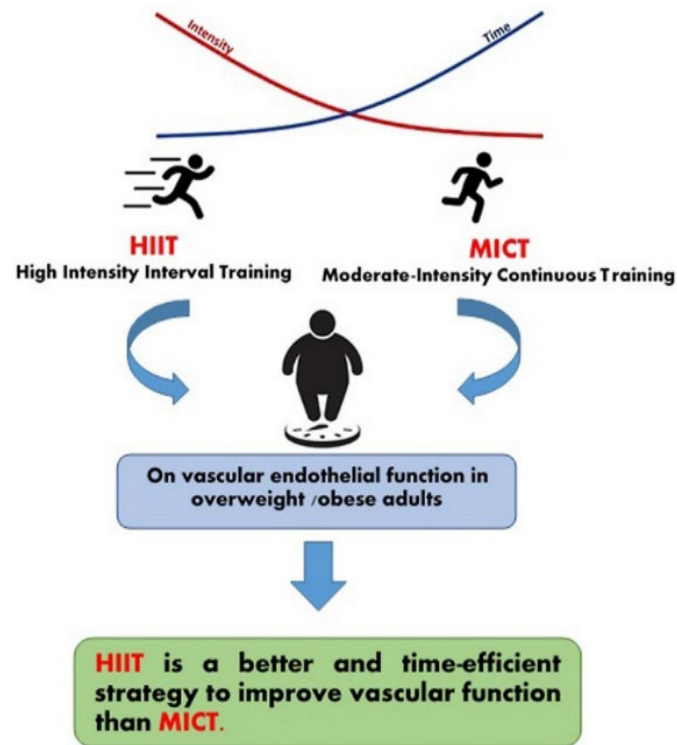


Figure 1: HIIT vs MICT (Sabouri et al., 2023)

4. Discussion

The results from this meta-analysis reiterate that HIIT has favourable effects on cardiovascular health in various adult populations, even those who are overweight, hypertensive, or at risk for other cardiometabolic morbidities. As such, several implications, strengths, limitations, and domains for further inquiry emerge.

4.1 Key Implications

Greater VO_2 max Improvements: The increased VO_2 max improvements observed with HIIT relative to MICT or control conditions provide further justification for using HIIT to enhance cardiorespiratory fitness, given its significant role in the determinants of cardiovascular morbidity and mortality. As such, HIIT may be ideal for individuals who are pressed for time and need to achieve results quickly. In Blood Pressure and Vascular Health, the concomitant improvements in FMD and PWV, along with substantial reductions in central (and peripheral) SBP and DBP (albeit to a lesser extent), demonstrate that HIIT targets fitness components as well as vascular health, thereby mitigating cardiovascular risk.

Specifics of a given protocol can affect the amount of benefit achieved, depending on the interval duration, session frequency, total intervention duration, rest period effects, and session intensity. Protocols with ≥ 8 -week sessions of 3-5 weekly ≥ 2 -minute work bouts tend to demonstrate the greatest effectiveness. The work-rest ratio, total volume of HIIT, and level of supervision also matter. First, there is the matter of the feasibility, safety, and adherence to the protocol. HIIT is effective in improving outcomes in adult and clinical populations, with adverse effects very low. High compliance with the protocol under supervision suggests that HIIT is safe, enhancing its potential translational value in public health and clinical practice.

4.2 Comparison with Existing Literature

The results from this work add to those of other recent meta-analyses. In the general population, large meta-analyses report an average VO_2 max increase of 3.9 mL/kg/min, resting SBP decreases of ~ 3 mmHg, and increases in lipids, resting heart rate, and other parameters (Al-Mhanna et al., 2025). In overweight adults and those with obesity, the other HIIT-versus-MICT comparisons produced similar results, with increases in VO_2 max and improvements in cardiovascular health.

4.3 Limitations

Heterogeneity is a term used to capture differences in population characteristics across the reviewed studies. They

include healthy versus diseased individuals, HIIT protocol design, HIIT duration, and the type of comparator interventions. This heterogeneity reduces the precision of estimated effect sizes. Matching energy expenditure appears to be a discrepancy between studies that do and those that do not match energy output between HIIT and MICT, which may bias comparisons of outcomes. When energy expenditure is equated, some differences remain.

Short follow-up lengths: Most studies are of short durations, 4 to 12 weeks. Only a small number exceed the 12-month mark. Thus, the long-term sustainability, safety, and maintenance of cardiovascular benefits are not well defined. Inadequately studied groups are a gap in information for older adults with numerous comorbidities, specific ethnic groups, and individuals with severe cardiovascular disease. Differences in gender and age, and baseline fitness are not always reported despite their influence on responsiveness.

4.4 Future Directions

Conduct randomized controlled trials that are well powered with longer follow-ups (≥ 12 months) to evaluate the sustainability and safety of cardiovascular improvements. HIIT protocol reporting needs to be standardised to improve the synthesis of the literature and facilitate targeted guidelines (work interval duration, intensity, frequency, and work: rest ratio). Examine specific dose-response relationships in targeted populations, including and not limited to the elderly, post-myocardial infarction, hypertensive, and post-COVID-19. Behaviour changes and adherence strategies need to be investigated in unsupervised settings, as real-world practicality is crucial. Investigate mechanisms of vascular functional improvements induced by HIIT, such as endothelial and arterial stiffness, to better refine targeted interventions.

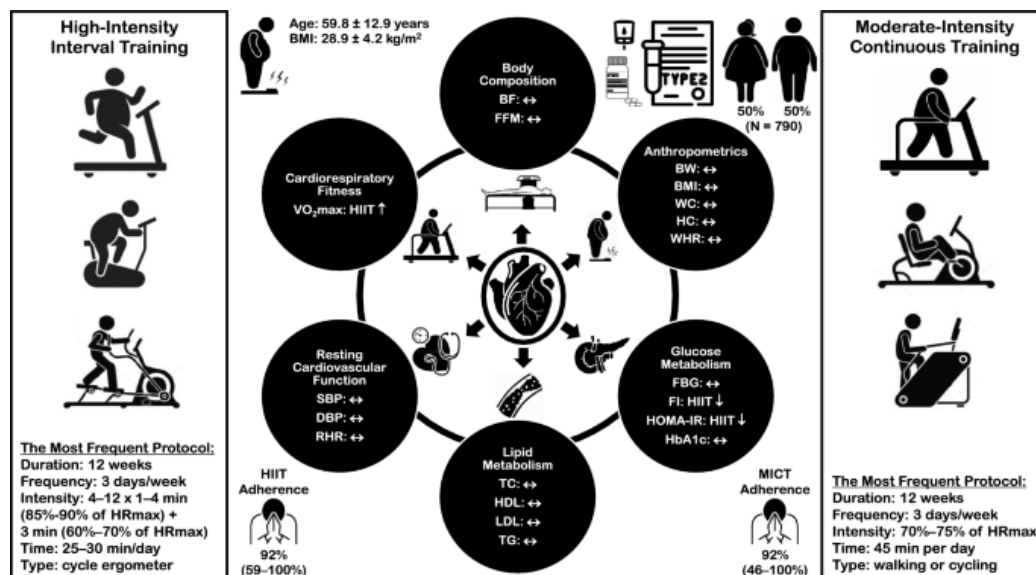


Figure 2: Potential of HIIT as an Efficacious Exercise (Al-Mhanna et al., 2025)

5. Conclusion

In conclusion, this meta-analysis underscores the efficacy and relative safety of high-intensity interval training (HIIT) in improving the multidimensional aspects of cardiovascular health in adult populations. Compared with rest control conditions, HIIT training increases cardiorespiratory fitness (VO₂ max) and blood pressure (both systolic and diastolic), and improves vascular endothelial function and arterial stiffness. Compared to moderate-intensity continuous training (MICT), HIIT training is more effective in improving VO₂ max, blood pressure (central systolic), and vascular function, and more effective in gaining maximal blood pressure (central systolic) and vascular function; for some cardiometabolic markers, HIIT (the difference) is matched (the difference) for energy expenditure.

HIIT is maximised by longer work intervals (≥ 2 minutes), total duration (≥ 8 weeks), 3–5 sessions per week, and supervision. In supervised settings, the risk of adverse events is low; hence, adherence tends to be good. However, concerns include adverse long-term effects (> 12 months), unsupervised settings, and a lack of evidence on protocol standardization.

To conclude, HIIT is an effective time-efficient strategy for improving cardiovascular health, especially for time-deprived individuals and those seeking rapid improvements in physical fitness. Health professionals and policymakers can include HIIT in their exercise recommendations, along with tailored guidance on protocol design to optimise safety and

effectiveness.

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Table 1(a): Meta-Analysis

Study (Author, Year)	Design	Population/ Sample Size	Intervention (HIIT)	Control	Duration	Outcomes	Key Findings	Conclusion
Sert et al. (2025)	Systematic review & meta-analysis of RCTs	Older adults ≥ 60 years (11 RCTs)	HIIT	No exercise / standard care	Varied across studies	Cardiometabolic health (6MWT, VO_2 peak, HR), QoL, gait speed	6MWT $\uparrow$ ($z=3.24$, $p=0.0002$), VO_2 peak $\uparrow$ ($z=3.74$, $p=0.0002$), QoL $\uparrow$ ($z=2.66$, $p=0.008$), gait speed NS ($p=0.15$)	HIIT improves cardiometabolic health and QoL in older adults; recommend implementation with multidisciplinary support
de Souza Mesquita et al. (2023)	Systematic review & meta-analysis of RCTs	Hypertensive patients (569 participants across 9 RCTs)	HIIT	Moderate-intensity continuous training (MICT) / Control	Varied across studies	VO_2 peak, BP, resting HR	HIIT significantly improved VO_2 peak versus MICT (MD 3.3) and control (MD 4.4), with additional BP and resting HR benefits.	HIIT is superior to MICT in improving VO_2 peak in hypertensive patients; safe when supervised in stage 1 hypertension
Yin et al. (2024)	Meta-analysis of RCTs	Adults (849 participants across 21 studies)	Low-volume HIIT (≤ 5 min high-intensity exercise within ≤ 15 min session)	Untrained control, MICT, HV-HIIT	Varied across studies	Cardiorespiratory fitness (CRF), systolic/diastolic BP, mean arterial pressure (MAP), MetS z-score, fat mass (kg and %), waist circumference	LV-HIIT improved CRF, BP, MAP, MetS z-score, fat mass, and waist circumference, with no significant differences versus MICT or HV-HIIT.	LV-HIIT is a time-efficient strategy to improve cardiometabolic health and body composition; higher intensity enhances CRF gain
Edwards et al. (2023)	Systematic review & meta-analysis of RCTs	General population (3399 participants across 97 RCTs)	HIIT	No exercise / standard care	Varied across studies	Cardiometabolic health parameters (VO_2 peak, BP, HR, stroke volume, body composition, insulin, lipids)	Exercise significantly improved VO_2 peak, LVEF, and stroke volume, and increased HDL, while reducing BP, resting HR, BMI, waist circumference, body fat, fasting insulin, hs-CRP, triglycerides, and LDL.	HIIT significantly improves multiple cardiometabolic risk factors in the general population; supports its inclusion in physical activity guidelines
Hong and Liu (2025)	Systematic review & meta-analysis of RCTs	CHD patients post-PCI or CABG (1455 HIIT, 1474 MICT)	HIIT	MICT	Varied across studies	VO_2 peak, LVEF, peak HR, resting HR, QoL	HIIT improved VO_2 peak, LVEF, peak HR, and QoL versus MICT, with no significant difference in resting HR.	HIIT effectively enhances cardiopulmonary function and quality of life in CHD post-surgery. HIIT may be a time-efficient alternative to MICT in cardiac rehabilitation programs. However, publication bias and high heterogeneity warrant caution in interpreting these results, indicating a need for further research
Liang et al. (2024)	Systematic review & meta-analysis of RCTs	Older adults (≥ 60 years)	HIIT	No exercise / other exercise interventions	Varied across studies	Resting heart rate (HR), systolic blood pressure (SBP), cardiorespiratory fitness (CRF), body fat percentage (BF%), muscular strength (MS), muscular endurance (ME), balance	HIIT improved HR, SBP, CRF, body composition, strength, endurance, and balance	HIIT is effective in improving various physical fitness and health parameters among older adults.

Table 1(b): Meta-Analysis

Study (Author, Year)	Design	Population/ Sample Size	Intervention (HIIT)	Control	Duration	Outcomes	Key Findings	Conclusion
Al-Mhanna et al. (2025)	Systematic review & meta-analysis of RCTs	Patients with diabetes (T2DM + overweight/obesity)	HIIT	MICT	Varied across studies	Insulin sensitivity (FI, HOMA-IR), aerobic capacity, body composition	HIIT significantly reduced fasting insulin (SMD = -0.43) and HOMA-IR (SMD = -0.52) compared to MICT.	HIIT is more effective than MICT in improving insulin sensitivity in patients with diabetes.
Yin et al. (2024)	Systematic review & meta-analysis of RCTs	Adults (849 participants)	Low-volume HIIT (≤ 5 min high-intensity exercise within a ≤ 15 -min session)	No exercise, MICT, or high-volume HIIT	Varied across studies	Cardiorespiratory fitness (CRF), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), MetS z-score, fat mass (kg & %), waist circumference	LV-HIIT improved CRF, BP, MetS z-score, fat mass, and waist circumference compared with no exercise, with no significant differences compared with MICT or high-volume HIIT; higher intensity boosted CRF gains.	LV-HIIT is a time-efficient strategy that can improve cardiometabolic health and body composition, offering benefits similar to those of MICT and high-volume HIIT when performed at higher intensities.
Sabouri et al. (2023)	Systematic review & meta-analysis of RCTs	Overweight/obese adults (208 participants)	HIIT	MICT / Control	Varied across studies	Flow-mediated dilation (FMD)	HIIT improved FMD by 2.6% compared to MICT (95% CI: 0.82–4.38, $P = 0.004$) and by 1.83% compared to control (95% CI: 0.48–3.19, $P = 0.008$).	HIIT is more effective than MICT and control in improving vascular endothelial function in overweight and obese adults.
Romero-Vera et al. (2024)	Systematic review & meta-analysis of RCTs	Hypertensive patients	HIIT	Control (no exercise)	Varied across studies	Systolic blood pressure (SBP), diastolic blood pressure (DBP)	HIIT interventions yielded small reductions in SBP, with minimal impact on DBP.	HIIT offers modest cardiovascular benefits, but its independent efficacy for managing hypertension is limited.
Carpes et al. (2022)	Systematic review & meta-analysis of RCTs	Older adults (≥ 60 years)	HIIT	No exercise / MICT	≥ 4 weeks	Systolic BP (SBP), Diastolic BP (DBP)	HIIT significantly reduced SBP (MD = -7.36 mmHg, $P < 0.01$) and DBP (MD = -5.48 mmHg, $P < 0.01$) compared to control. No significant difference in BP reduction between HIIT and MICT.	HIIT effectively reduces BP in older adults and is as effective as MICT.
Cuenca-Martínez et al. (2022)	Systematic review & meta-analysis with meta-regression	Patients with musculoskeletal disorders	HIIT	No exercise / other exercise modalities	Varied across studies	Pain intensity, VO_2 max, disability, quality of life	HIIT significantly reduced pain intensity (SMD = -0.73) and improved VO_2 max (SMD = 0.69). No significant effects on disability or quality of life.	HIIT is effective in reducing pain intensity and improving VO_2 max in patients with musculoskeletal disorders but does not significantly impact disability or quality of life.
Khalafi et al. (2022)	Systematic review & meta-analysis	Adults with or without cardiometabolic diseases (1,437 participants)	HIIT	MICT / Control	Varied across studies	Flow-mediated dilation (FMD)	HIIT significantly improved FMD compared with MICT and control, with benefits observed in participants with cardiovascular or metabolic diseases but not in healthy individuals.	HIIT is effective for improving vascular function in individuals with metabolic disorders and cardiovascular diseases and has a superior effect compared to MICT, demonstrating time efficiency.

Table 1(c): Meta-Analysis

Study (Author, Year)	Design	Population/ Sample Size	Intervention (HIIT)	Control	Duration	Outcomes	Key Findings	Conclusion
Li et al. (2022)	Systematic review & meta-analysis of RCTs	Hypertensive patients (442 participants)	HIIT	MICT / Control	Varied across studies	Systolic BP (SBP), Diastolic BP (DBP), Flow-mediated vasodilation (FMD)	HIIT and MICT similarly affected resting BP, but HIIT better reduced daytime SBP and improved FMD.	HIIT offers comparable benefits to MICT for overall BP reduction and superior improvements in daytime SBP and vascular function in hypertensive patients.
Poon et al. (2024)	Umbrella review of 18 systematic reviews (223 studies, 13,900 participants)	Children and adolescents	HIIT	Varied (No exercise, MICT, or other exercise)	Varied across studies	VO ₂ max, body fat %, waist circumference, cholesterol, LDL	HIIT improved VO ₂ max, reduced body fat %, waist circumference, and total cholesterol, LDL; benefits were stronger in overweight or metabolically at-risk youth	HIIT is an effective, time-efficient strategy to improve cardiometabolic health in youth; supports its inclusion in school and community programs