Effect of exercise on endothelial function among non-communicable diseases adults with overweight or obese: a systematic review and meta-analysis

Efecto del ejercicio sobre la función endotelial en adultos con enfermedades no transmisibles con sobrepeso u obesidad: una revisión sistemática y metaanálisis

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Abstract

Introduction: High-Intensity Interval Training (HIIT) and Moderate-Intensity Continuous Training (MICT) both provide notable benefits for endothelial function, metabolic health, and cardiovascular fitness in adults with non-communicable diseases who are overweight or obese. HIIT, due to its efficacy in enhancing VO_2 max and vascular function, may offer significant benefits in mitigating cardiovascular risk. This study underscores the need of structured exercise training in the management of vascular health, considering the growing prevalence of non-communicable diseases (NCDs).
Objective: To identify the effect of exercise on endothelial function among NCDs adults with overweight or obese.
Methods: A literature search was conducted using the internet database PubMed to compare HIIT and MICT studies focused on endothelial function, specifically assessed by FMD, in adults with NCDs with overweight or obese.
Results: HIIT led to a notable enhancement in FMD (0.48%; p=0.007) with a 41.14% increase, in contrast to 8.33% in MICT. VO_2 max showed a greater enhancement in HIIT (1.00%; p=0.003), with increases of 17.68 ml/kg/min (HIIT) compared to 13.17 ml/kg/min (MICT). HDL levels showed a modest increase in HIIT (5.61 mmol/L) compared to MICT (4.63 mmol/L) (p=0.022). Glucose results favor in HIIT than MICT. In contrast, LDL cholesterol exhibited a marginally greater decrease in MICT (-0.06; p=0.12). However, results suggest no clear advantages on neither HIIT nor MICT in reducing triglycerides. The results indicate that high-intensity interval training is more effective for improving vascular health and aerobic capacity, whereas moderate-intensity continuous training may be more beneficial for reducing LDL cholesterol levels.
Conclusion: HIIT demonstrates greater effectiveness for improving FMD and VO_2 max, HDL, and glucose whereas MICT is more effective for reducing LDL. A 12-week HIIT program (4×4 min at 85–95% HR max, 3 times/week) has the potential to greatly improve vascular health and overall fitness levels.

Keywords

High-intensity interval training; moderate-intensity continuous training; flow-mediated dilation; non-communicable disease; obese.

Resumen

Introducción: El entrenamiento a intervalos de alta intensidad (HIIT) y el entrenamiento continuo de intensidad moderada (MICT) proporcionan beneficios notables para la función endotelial, la salud metabólica y la aptitud cardiovascular en adultos con enfermedades no transmisibles (ENT) que presentan sobrepeso u obesidad. El HIIT, debido a su eficacia en mejorar el VO_2 máx y la función vascular, puede ofrecer beneficios significativos en la mitigación del riesgo cardiovascular. Este estudio destaca la necesidad de programas de ejercicio estructurado en el manejo de la salud vascular, considerando la creciente prevalencia de las ENT. Objetivo: Identificar el efecto del ejercicio sobre la función endotelial en adultos con ENT con sobrepeso u obesidad.
Metodología: Se realizó una búsqueda bibliográfica en la base de datos PubMed para comparar estudios sobre HIIT y MICT enfocados en la función endotelial, evaluada específicamente mediante dilatación mediada por flujo (FMD), en adultos con ENT con sobrepeso u obesidad.
Resultados: El HIIT produjo una mejora notable en la FMD (0,48%; p=0,007) con un aumento del 41,14%, en contraste con el 8,33% del MICT. El VO_2 máx mostró una mejora mayor con HIIT (1,00%; p=0,003), con aumentos de 17,68 ml/kg/min (HIIT) frente a 13,17 ml/kg/min (MICT). Los niveles de HDL aumentaron modestamente con HIIT (5,61 mmol/L) frente a MICT (4,63 mmol/L) (p=0,022). Los resultados de glucosa favorecieron al HIIT en comparación con el MICT. En contraste, el colesterol LDL mostró una disminución ligeramente mayor con MICT (-0,06; p=0,12). Sin embargo, los resultados no sugieren ventajas claras de ninguno de los dos métodos en la reducción de triglicéridos. Los resultados indican que el HIIT es más eficaz para mejorar la salud vascular y la capacidad aeróbica, mientras que el MICT puede ser más beneficioso para reducir los niveles de colesterol LDL. Conclusiones: El HIIT demuestra una mayor efectividad para mejorar la FMD, el VO_2 máx, el HDL y la glucosa, mientras que el MICT es más eficaz en la reducción del LDL. Un programa de HIIT de 12 semanas (4×4 minutos al 85–95% de la frecuencia cardíaca máxima, 3 veces por semana) tiene el potencial de mejorar significativamente la salud vascular y los niveles generales de aptitud física.

Palabras clave

Dilatación mediada por flujo; entrenamiento a intervalos de alta intensidad; entrenamiento continuo de intensidad moderada; enfermedad no transmisible; obesidad.

Introduction

Regular exercise is crucial for promoting cardiovascular health and reducing the risk of cardiovascular disease (CVD), the primary cause of morbidity and mortality worldwide, with different training modalities offering variety physiological benefits (World Health Organisations, 2021). Exercise training, particularly high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT), is increasingly supported by research demonstrating its advantageous effects in mitigating the risk of non-communicable diseases (NCDs)(Gibala et al., 2012) . HIIT consists of short bursts of intense exercise alternated with recovery periods, while MICT involves sustained moderate-intensity exercise over a longer duration (Gibala et al., 2012). Continuous training can be beneficial. However, participation may be restricted by time limitations, poor adherence, and diminished motivation. High-intensity exercise provides greater benefits, although may be difficult for certain persons to maintain. Both methods have been shown to enhance cardiorespiratory fitness, metabolic function, and vascular health. However, their comparative effects on endothelial function, particularly in individuals with NCDs who are overweight or obese, remain a topic of ongoing research.

The functionality of the endothelium is a crucial factor in vascular health, since it regulates blood flow, vascular tone, and inflammatory responses (Green & Smith, 2018). Flow-mediated dilation (FMD) is a prevalent non-invasive assessment of endothelial function, evaluating the capacity of blood arteries to dilate in reaction to enhanced shear stress (Thijssen et al., 2019). An enhanced FMD response correlates with a lower risk of CVD and superior vascular health. Besides FMD, cardiorespiratory fitness, assessed through maximal oxygen uptake (VO_2 max), and blood lipid indicators including high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides, and glucose levels, are crucial for metabolic and vascular function (Ross et al., 2016). VO_2 max is prevalent for cardiovascular health which are closely linked to NCDs prevention. An increase in VO_2 max is associated with a reduction in mortality risk. The study shows that each 1-MET improvement in exercise capacity reduces the risk of death by 10-14%, depending on individual factors (Kokkinos et al., 2010). Elevated HDL is advantageous for cardiovascular protection, whereas increased LDL, triglycerides, and glucose levels promote atherosclerosis and metabolic diseases. Exercise therapies, including HIIT and MICT, have demonstrated beneficial effects on these biomarkers, therefore improving endothelial function and overall vascular health.

Individuals with NCDs who are overweight or obese face a significantly higher risk of vascular dysfunction, metabolic disorders, and cardiovascular complications due to excess body fat, chronic inflammation, and insulin resistance. Given that endothelial dysfunction is a major contributor to hypertension, type 2 diabetes, and atherosclerosis, effective exercise strategies are essential for reducing disease burden in this population (Pedersen & Saltin, 2015) . This meta-analysis is particularly relevant as it aims to determine whether HIIT or MICT provides superior benefits for endothelial function, metabolic health, and overall cardiovascular risk reduction in individuals with NCDs and obesity. The findings could contribute to public health strategies aimed at developing personalized exercise programs, improving long-term adherence, and enhancing quality of life in overweight and obese populations at risk for NCD-related complications.

Method

Search Strategy

This review will adhere to the Preferred Reporting Items for Systematic Reviews and Meta-analyses: The PRISMA statement guideline (Moher et al., 2009). A thorough literature search will be conducted utilizing the internet database: PubMed. The search phrase will be formulated using keywords established by our research team. The search word will be broadened by consulting the list of synonyms, and suitable search notation will be employed. The Boolean format will be employed, incorporating AND, OR, and NOT in conjunction with the keywords. This method will expand and contract the scope of the search. Furthermore, researchers will consult the prior relevant meta-analysis to identify associated papers. Additionally, a reference list of the included papers will be scrutinized for potential articles. A researcher will seek to obtain unpublished data by contacting the author via email. Refer Table 1. This study will employ several search strategies to guarantee the inclusion of all pertinent papers for comprehensive result interpretation.

Table 1.

No.	Search method	Combination terms
1.	Online database: PubMed	#1 "High intensity interval training" OR "Aerobic interval training" #2 "Moderate intensity continuous training" OR "continuous training" #3 "endothelial function" OR "flow-mediated dilation" OR "vascular function" #4 "coronary artery disease" OR "obese" OR "overweight" OR "non-communicable disease" #5 search #1 AND #4 #6 search #2 AND #4 #7 search #3 AND #4 #8 search #1 AND #2 AND #3 AND #4
2.	Previous Related SR and MA	Cross check previous related systematic review and meta-analysis
3.	Reference list	Cross check reference list in the selected article
4.	Author	

Inclusion and Exclusion Criteria

Articles selections were restricted to randomized control trial (RCT) with English full-text articles that included participants diagnosed with NCDs and overweight or obese. NCDs are chronic conditions that are not transmitted between individuals and are the leading cause of death globally. NCDs, mainly type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVDs), and chronic respiratory diseases (CRDs) are the biggest cause of death worldwide (Hasanzad et al., 2019). Articles selection need to investigate the pre and post effect of an aerobic exercise as an intervention for management of NCDs risk factors. Studies should conduct any form of aerobic exercise such as walking, running, cycling, elliptical, as well as swimming. Exercise intervention requires a minimum training duration of 4 weeks and the sessions need to be either supervised or non-supervised with follow-up. The selected studies will then be divided into 2 groups based on the intensity reported by the author. Intensity will be standardized and classified based on heart rate maximum (HR max), heart rate reverse (HRR) or peak power methods. The highest point of intensity reported by the author will be considered as the training intensity. This is important to avoid misinterpretation of intensity prescribed in the training. This study will compare HIIT also known as aerobic interval training (AIT) with MICT.

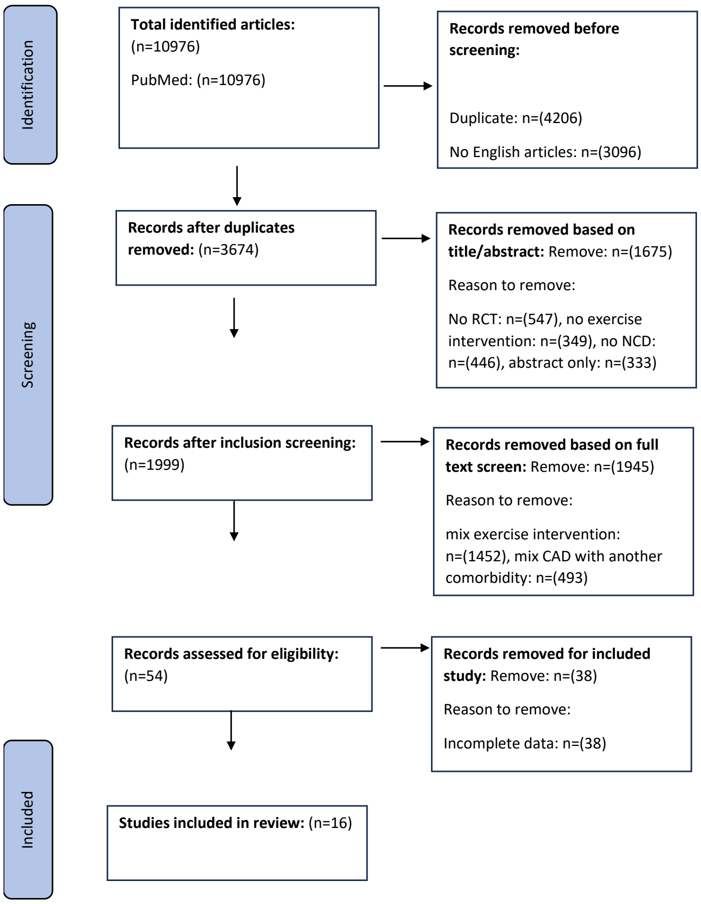
HIIT training was limited to interval durations, with the intensity classified as being 70 – 85% VO_2 max or 75 - 90% HR max or > 70 - 85% of HRR or >14-16 RPE, 20 Borg scale (Hansen et al., 2022). Meanwhile, MICT program included continuous aerobic exercise which was classified as 40 – 69% VO_2 max or 55 - 74% HR max or > 40 - 69% of HRR or >12-13 RPE, 20 Borg scale (Hansen et al., 2022). Sprint interval training (SIT) was included as HIIT if exercise was characterized by "all-out" or "supramaximal" efforts (≥100% of maximal work rate or VO_2 max) that was interspersed with recovery periods.

Exclusion criteria will be reviewing article, systematic-review and meta-analysis, acute study effect, case study, combined aerobic with resistant training, combined HIIT and MICT in the same group, combined NCDs with others comorbidity such as CAD with kidney failure, valvular heart disease and animal study.

Study Selection

The selection of studies will adhere to the PRISMA method, encompassing three distinct stages. The initial step involves gathering all relevant articles from the online database into a single folder, followed by the elimination of any duplicate entries. The second stage involves screening, where articles chosen after eliminating duplicates will be evaluated based on their titles and abstracts. Articles will be excluded if they do not satisfy this research's inclusion criteria. The subsequent step involves the screening of the full text, which will be conducted by two individuals independently. This will utilize a standardized form to ensure consistency and minimize the risk of bias throughout the entire screening stage. The subsequent step involves evaluating the report for eligibility. Articles that contain incomplete data or that combine aerobic and resistance training will be excluded next. The articles that are left will be incorporated into this study for examination. See figure 1.

Figure 1. Study selection flow diagram



Data Extraction

Participant's characteristic, exercise intervention characteristic, endothelial function, cardiorespiratory (CRP) function, body composition and blood biomarkers will be extracted from the included studies. If the data is unclear or incomplete, the study author will be contacted for clarification. If the study author did not respond to the email, this paper will be excluded from this study. Endothelial function included flow-mediated dilation (FMD) will be analyzed. In addition, cardiorespiratory data included peak VO2, will be analyzed. For body composition data including weight (kg) and height (cm) also will be analyzed. Finally, blood biomarkers, low density lipoprotein (LDL), high density lipoprotein (HDL), triglyceride, and glucose will be analyzed and extracted for this study.

Quality Assessment

Study quality will be assessed using tool for the assessment of study quality and reporting in exercise (TESTEX), that was designed specifically for use in exercise training studies by (Smart et al., 2015). This tool consists of a 15-point scale which is 5 points for study quality and 10 points scale for reporting. TESTEX is a comprehensive tool to assess the quality of the study thus qualifying inferences and conclusion in the exercise science study. The higher score reflects the high quality of study and vice versa. In all 16 studies, the TESTEX score was recorded as 13 medians out of 15, demonstrating consistently good methodological quality. This indicates that the studies were meticulously executed, with negligible chance of bias, hence providing dependable evidence for analysis. The uniformity in scoring demonstrates a robust compliance with study norms, hence enhancing the reliability of the findings. Refer Table 2.

Table 2. TESTEX

Author, year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Anggadi et.al 2014	/	/	×	/	/	/	/	/	/	/	/	/	/	/	/	14
Baekkrud et. al 2016	/	/	×	/	×	/	/	/	/	/	/	/	/	/	/	13
Conraads et. Al 2014	/	/	×	/	/	/	/	/	/	/	/	/	/	/	/	14
Currie et. Al 2013	/	/	×	/	×	/	/	/	/	/	/	/	/	×	/	12
Jo et. Al. 2020	/	/	×	/	×	/	/	/	/	/	/	/	/	×	×	11
Klonizakis et. Al 2014	/	/	×	/	/	/	/	/	/	/	/	/	/	/	/	14
Malin et. Al 2012	/	/	×	/	/	/	/	/	/	/	/	/	/	/	/	14
Moholdt et. Al 2012	/	/	/	/	×	/	/	/	/	/	/	/	/	/	/	14
Petrick et. Al 2021	/	/	×	/	×	/	/	×	/	/	/	/	/	/	/	12
Ramirez et. Al 2019	/	/	×	/	/	/	/	/	/	/	/	/	/	/	×	13
Sarvasti et. Al 2020	/	/	×	/	/	/	/	/	/	/	/	/	/	/	×	13
Sawyer et. Al 2016	/	/	×	/	/	/	×	/	/	/	/	/	/	/	/	13
Schjerve et. Al 2008	/	/	×	/	/	/	/	/	/	/	/	/	/	×	/	13
Scott et. Al 2019	/	×	×	/	×	/	/	/	/	/	/	×	/	/	/	12
Taylor et. Al 2021	/	/	×	/	/	/	×	/	×	/	/	/	/	/	×	11
Thijssen et. Al 2019	/	/	×	/	/	/	/	/	/	/	/	/	/	/	×	13

1- Eligibility criteria specified, 2 - Randomization specified, 3 - Allocation concealment, 4 -Groups similar at baseline, 5 - Blinding of assessor, 6 - Outcome measures assessed in 85% of patient, if adherence > 85%, 7 - Outcome measures assessed in 85% of patient, if adverse events are reported, 8 - Outcome measures assessed in 85% of patient, if exercise attended is reported, 9 - Intention-to-treat analysis, 10 - Between-group statistical comparisons reported, primary outcome measure 11 – Between-group statistical comparisons reported, secondary outcome measure 12 - Point measures and measures of variability for all reported outcome measures, 13 - Activity monitoring in control groups, 14 - Relative exercise intensity remained constant, 15 - Exercise volume and energy expenditure

Statistical Analysis

The changes pre and post or mean difference will be calculated using random-effect model in the Review Manager 5 (REVMAN 5; version 5.4, The Cochrane Collaboration, Copenhagen, Denmark). An estimate of the mean summary weighted effect will be analyzed using random-effect model (REM). This is because, REM allows variation in characteristic of participants, intervention comparison outcome and design of the study, which mean REM is used in the analysis in case of heterogeneity designed (Pathak et al., 2020). Since this study is pooled of various exercise characteristics designed, therefore the use of REM seems applicable.

Since systematic review is the best available evidence regarding the benefit and risk in the medical intervention that the result is being used in decision making, reporting publication bias in systematic review and meta-analysis is important. This is because high publication bias is more likely, the result does not reflect the objective of the study. The funnel plot is a visual estimation method that looks at the equal numbers of study from left and right side of funnel plot, if the numbers is equal, then the plot is considered as symmetry, indicating no publication bias detected (Tawfik et al., 2019). Besides, from the funnel plot as well, standard error (SE) will be presented. High SE indicates less reliability and less precision study which likely the result is considered as premature. SE is highly associated with numbers of participants and the effect size in the study.

Once there is a presence of publication bias, researchers need to assess the magnitude of bias or degree of heterogeneity. In this study, heterogeneity will be reported using I2 statistics. High I2 value indicates that studies in meta-analysis are highly heterogenous and that observed differences between the studies are likely due to true differences between the studies rather than sampling error. The result should be interpreted cautiously. Heterogeneity of 25% is considered as low, 50% is considered as moderate and 75% is considered as high (Du et al., 2021). Large value of I2 (> 75%) indicates inconsistency in the result of the underlying studies (Kraal et al., 2017). In case of high heterogeneity found, cause of high I2 should be investigated and sub-group analysis without outlier should be conducted (Pathak et al., 2020). If heterogeneity is small, the results can be interpreted as the objective of the study. Researcher is advisable to consistently use multiple publication bias detection methods (Murad et al., 2018) to reduce misinterpretation of the results that can affect the decision making the medical intervention.

The standardized mean difference and 95% confidence interval (CI) will be used to report changes in the outcome measure. The threshold for significance will set to $p < 0.05$. Figure will be produced by Comprehensive Meta Analysis tool.

Results

Included Studies

Our initial search strategy revealed that 10976 records were from PubMed. After eliminating duplicates and screening titles and abstracts, 199 articles were included in the full-text analysis based on inclusion and exclusion criteria. After reviewing the full-texts, 54 studies were excluded according to the reasons presented in Figure 1. Finally, 16 studies met all eligibility criteria and were included in the meta-analysis, of which 16 studies compared HIIT vs. MICT.

Participant Characteristics

A total of 625 participants participated in the 16 articles. One study recruited exclusively female participant (Klonizakis et al., 2014)while another one study included only male participants (Petrick et al., 2021) and the rest 14 studies recruited both male and female. The mean age and BMI of participants are 51 years, and 30.0 kg/m2, respectively, indicating that the participants were overweight or obese. Additional demographic such as gender and health status are presented in Table 3.

Intervention Characteristics

The interventions across the included studies varied significantly in terms of training protocols, intensity, duration, frequency, and training modes, as detailed in Table 3. Of the 16 studies included, the duration of exercise intervention ranges from two to 12 weeks, with the majority being 12 weeks. The frequency is two to five sessions with the majority is three sessions per week.

Table 3. Characteristics of the participants and interventions.

Author, year	BMI (kg/m2)	Participants Characteristics	Frequency (days)	Exercise Characteristics
Anggadi et. Al, 2014	HIIT: 29.8 MICT: 29.3	Heart failure and overweight	3	HIIT: 4 x 2-4 min I, 2-3 min RI at 80-90% HR peak MICT: 15 - 30 min at 50-60% HR peak
Baekkrud et. Al, 2016	HIIT: 31.1 MICT: 29.0	Overweight and obese only	3	HIIT: 4 x 4min I, 3 min RI / 10 x 1 min I at 85-95% of HR max MICT: 45 min at 70% of HR max
Conraads et. Al, 2014	HIIT: 28.0 MICT: 28.5	Coronary Artery Disease and overweight	3	HIIT: 4 x 4 min I, 3 min RI at 90-95% of HR peak, MICT: 47 min at 65-75% of HR peak
Currie et. Al, 2013	HIIT: 27.9 MICT: 27.3	Coronary Artery Disease and overweight	2	HIIT: 10 x 1 min I, 1min RI at 89% of PPO MICT: 30 - 50 min at 58% of PPO
Jo et. Al, 2020	HIIT: 24.9 MICT: 24.9	Hypertensive, metabolic syndrome and overweight	3	HIIT: 3 x 3 min I, 3 min RI at 80% of HRR MICT: 35 min at 60% of HRR
Klonizakis et. Al, 2014	ND	Postmenopausal only	3	HIIT: 10 x 1 min I, 1min RI at 100% of PPO MICT: 40 min at 65% of PPO
Malin et. Al, 2019	HIIT: 30.9 MICT:35.6	Prediabetes and obese	6	HIIT: 10 x 3 min I, 3 min RI at 90% HR peak MICT: 60 min at 70% of HR peak
Moholdt et. Al, 2012	HIIT: 26.8 MICT: 27.2	Myocardial infarction and overweight	3	HIIT: 4 x 4 min I, 3 min RI at 85-95 of HR max MICT: 35 min walking, jogging, lunges and squat
Ramirez et. Al, 2019	HIIT: 25.5 MICT: 23.6	Sedentary adults only	3	HIIT: 4 x 4 min I, 4 min RI at 85-95% of HRR MICT: 30 - 35 min at 60-75% at HRR
Sarvasti et. Al, 2020	HIIT: 27.0 MICT: 27.0	Coronary Artery Disease and overweight	3	HIIT: 4 x 4 min I, 3 min RI at 60-80% HRR MICT: 29 min at 40-60% of HRR
Sawyer et. Al, 2016	HIIT: 37.4 MICT: 34.5	Obese only	3	HIIT: 10 x 1 min I, 1 min RI at 90-95% of HR max MICT: 30 min at 70-75% of HR max
Schejerv et. Al, 2008	HIIT: 36.6 MICT: 36.7	Obese only	3	HIIT: 4 x 4min I, 3 min RI at 85-95% of HR max MICT: 47 min at 60-70% of HR max
Scott et. Al, 2019	HIIT: 34.2 MICT: 33.3	Obese only	3	HIIT: 4 - 8 x 1 min I, 1 min RI at 80% - 90% of HRmax MICT: 30 -50 min at 65% HR max
Taylor et. Al, 2021	HIIT: 28.7 MICT: 29.5	Coronary Artery Disease and overweight	3	HIIT: 4 × 4-min I, 3 min RI at 85-95 of HR peak MICT: 40 min at 65-75% of HR peak
Thijssen et. Al, 2019	HIIT: 28.1 MICT: 28.9	Heart failure and overweight	3	HIIT: 10 x 1 min I, 2.5 min RI at 90% of maximal workload MICT: 30 min at 60-75% of maximal workload

Abbreviation: HIIT: High Intensity Interval Training, MICT: Moderate Intensity Continuous Training, M: Male, F: Female, I: Interval, RI: Rest Interval, HR peak: Heart Rate peak, HR max: Heart Rate max, HRR: Heart Rate Reserve, PPO: Peak Power Output.

Outcomes Measure

1 HIIT vs MICT on FMD

Two study have been contacted for their incomplete data. However, the authors did not respond to our email. Thus, we need to exclude both studies. As shown in Figure 2, a significant improvement was observed after HIIT compared to MICT in the total group (0.48 %; 95% CI 0.13 – 0.83; p=0.007) with weighted mean changes of 41.14% in HIIT and 8.33% in MICT. From a clinical perspective, the findings indicate that HIIT elicited a substantial and clinically significant enhancement in endothelial function, whereas the improvement observed with MICT was relatively modest. This interpretation is consistent with prior research demonstrating that a 1% absolute increase in FMD correlates with a 12–13% reduction in the risk of future cardiovascular events (Green et al., 2011) . Consequently, the marked improvement associated with HIIT underscores its potential as the more effective intervention for promoting vascular health compared to MICT, suggesting engaging in HIIT experienced a notable enhancement in FMD. Figure 3 shows the funnel plot of FMD.

Figure 2. Forest plot of FMD

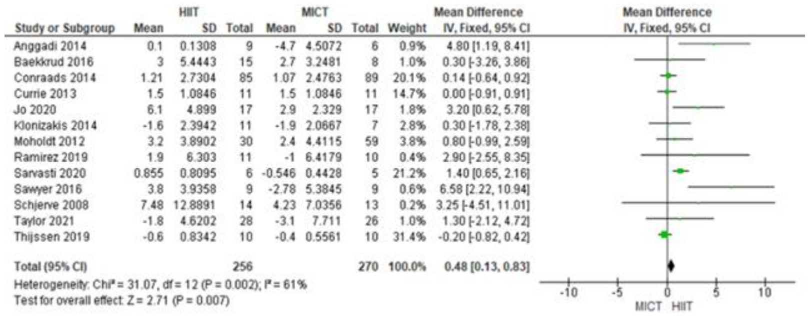
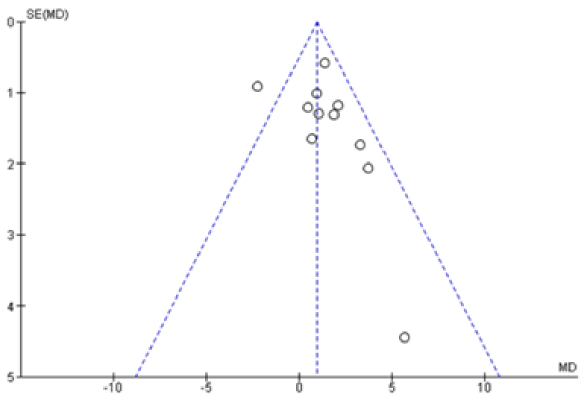


Figure 3. Funnel plot of FMD



2 HIIT vs MICT on VO_2 max

In addition, the secondary outcome for this study is maximal oxygen consumption (VO_2 max). Study reported on VO_2 max comparing HIIT and MICT among NCD's adults totaling 468 participants (n=227) for HIIT and (n=241) for MICT. As shown in Figure 4, a significant improvement was observed after HIIT compared to MICT in the total group (1.00 %; 95% CI 0.33 – 2.68; p=0.003). VO_2 max increased by 17.68 ml/kg/min in HIIT and 13.17 ml/kg/min in MICT. Figure 4 and Figure 5 demonstrate the result of this parameter.

Figure 4. Funnel plot of VO_2 max

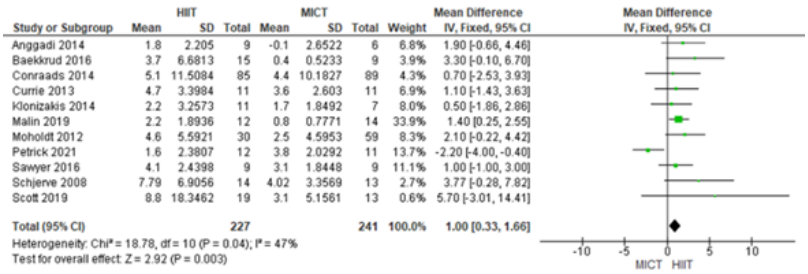
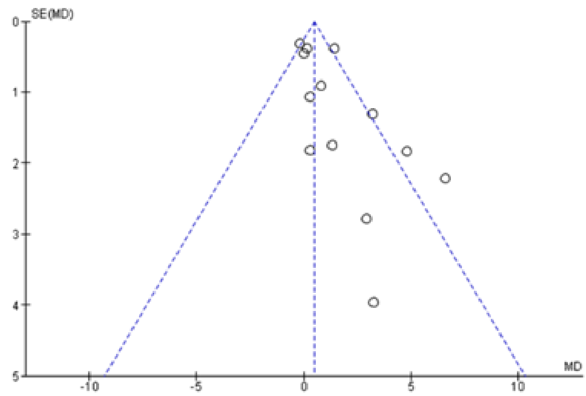


Figure 5. Funnel plot of VO_2 max



3 HIIT vs MICT on HDL

The study revealed a difference in HDL levels between HIIT and MICT group. An increase observed after HIIT compared to MICT in the total group (0.02 %; 95% CI -0.01 – 0.06; p=0.022) with weighted mean changes of 5.61 mmol/l in HIIT and 4.63 mmol/l in MICT. (Figure 6 and Figure 7).

Figure 6. Forest plot of HDL

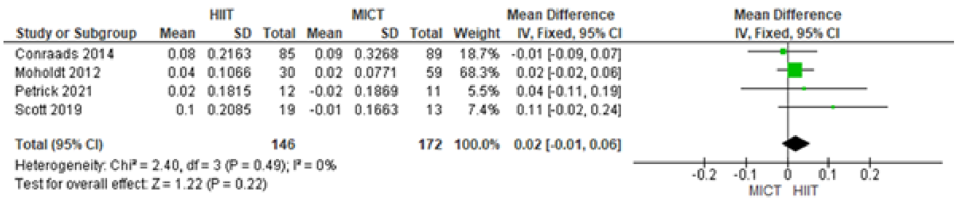
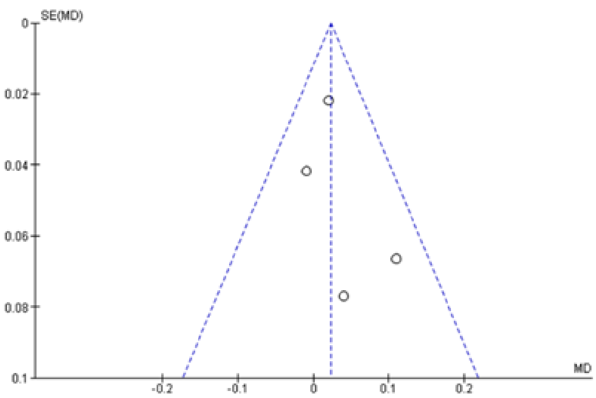


Figure 7. Funnel plot of HDL



4 HIIT vs MICT on LDL

Figure 8 presents the forest plot showing the pooled effect of HIIT compared to MICT on LDL. It revealed a reduction in the LDL parameter of 3 studies after HIIT compared to MICT in the total group (-0.06; 95% CI -0.12 – 0.01; p=0.12) following the interventions. This indicates a slight but significant decrease in LDL cholesterol in the MICT compared to the HIIT. Figure 9 shows the funnel plot used to evaluate publication bias among the included studies.

Figure 8. Forest plot of LDL

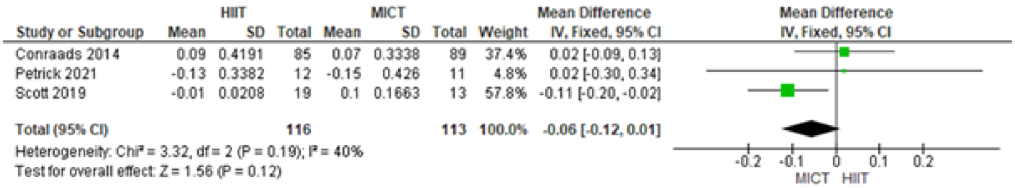
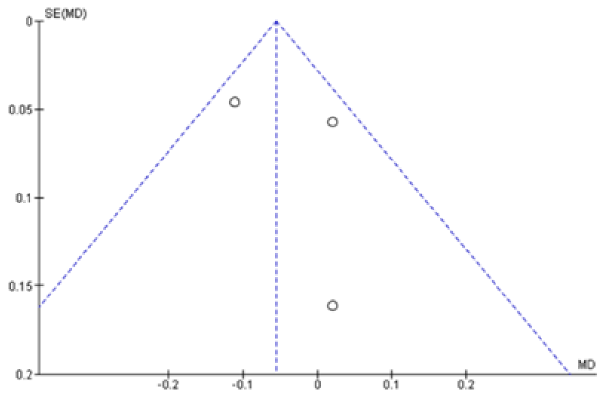


Figure 9. Funnel plot of LDL



5 HIIT vs MICT on Triglyceride

The mean differences in triglyceride levels between HIIT and MICT differ among research, with some supporting MICT (10,11) and others supporting HIIT (12). The aggregated mean difference is 0.01 [-0.02, 0.05], signifying no significant difference between the two training methodologies. (P = 0.49) indicates that the result lacks statistical significance. The high heterogeneity level (I^2 = 81%, P = 0.001) indicates considerable diversity among research, hence restricting the capacity to reach final conclusions. According to these data, both HIIT and MICT exhibit comparable effects on triglyceride levels, with insufficient evidence to support one method over the other. (Figure 10 and Figure 11).

Figure 10. Forest plot of Triglyceride

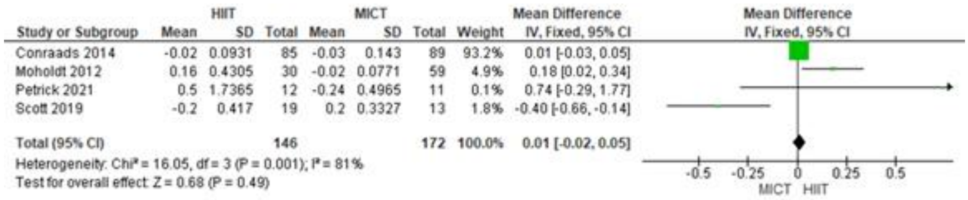
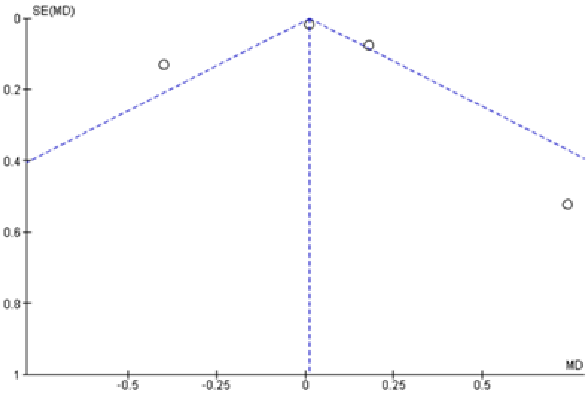


Figure 11. Funnel plot of Triglyceride



6 HIIT vs MICT on Glucose

As shown in Figure 12, glucose weighted mean was observed as 1.486 mmol/L for HIIT and 2.347 mmol/L for MICT group. The pooled analysis demonstrated a significant mean difference of -0.17 (95% CI: -0.30 to -0.03; p = 0.02). These results indicate that HIIT shows better outcomes compared to MICT. (Figure 13)

Figure 12. Forest plot of Glucose

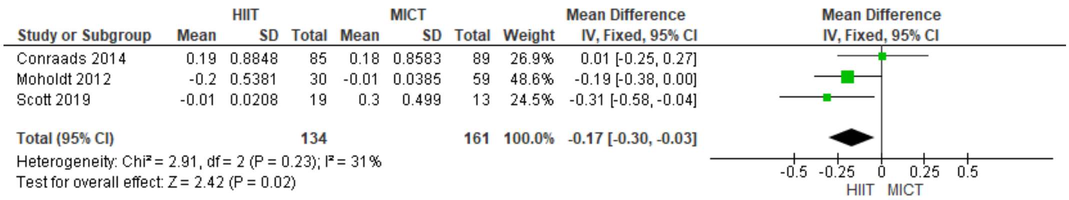
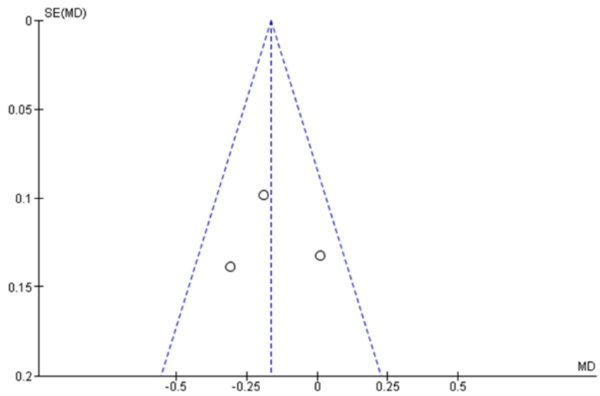


Figure 13. Funnel plot glucose



Discussion

This meta-analysis investigated the effect of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on flow-mediated dilation (FMD) in individuals with non-communicable diseases (NCDs) with overweight or obese, focusing on different parameters related to vascular health function. This study analyzed data from 16 studies to assess the effect of HIIT and MICT interventions on FMD, VO_2 max, and blood components, including high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), triglycerides, and glucose levels.

The results of this study indicated that both HIIT and MICT exercises significantly enhanced FMD. HIIT significantly enhanced FMD by 41.1% in contrast to MICT, which increased FMD by 8.3%. FMD is an assessment of endothelium-dependent dilation, evaluating the capacity of blood vessels to expand in response to enhanced flow, hence reflecting endothelial function essential for vascular health and overall cardiovascular resilience. HIIT significantly increases because it enhances the vascular function, doubling the End-Diastolic Volume Diameter (EDVD) from baseline, surpassing the improvements shown with MICT over the same training duration (Ko et al., 2025)This discovery indicates that HIIT may enhance cardiovascular health, especially in groups susceptible to endothelial dysfunction with overweight or obese.

Physiologically, HIIT can elevate oxidative stress and the production of reactive oxygen species (ROS), which momentarily stresses the body's cells while also eliciting an advantageous adaptive response. In reaction to this increase in oxidative stress, the body enhances its antioxidant mechanisms, including glutathione and superoxide dismutase, which assist in neutralizing reactive oxygen species (ROS) and safeguarding the endothelium, the inner lining of blood. The antioxidants facilitate the restoration of the endothelium, enhancing its elasticity and capacity to synthesize nitric oxide (NO), a chemical that encourages vasodilation and enhances blood circulation vessels (Wisløff et al., 2007). The rigorous exertion in HIIT elevates heart rate and blood circulation, resulting in shear stress on the endothelium walls, so promoting NO generation and improving vascular health. Conversely, MICT imposes reduced shear stress on the endothelium, resulting in a less significant impact on FMD and endothelial function. Consequently, although both forms of exercise enhance cardiovascular health, the intensity of HIIT results in a more significant enhancement of endothelial function and nitric oxide synthesis, thereby promoting improved vascular flexibility and overall cardiac health.

HIIT consists of alternating short bursts of vigorous activity with phases of lower intensity recovery or rest, so challenging both aerobic and anaerobic energy systems (Gibala et al., 2012). This training method increases cardiac output by boosting stroke volume and heart contractility, essential for optimizing oxygen transport to active muscles. Moreover, HIIT enhances mitochondrial biogenesis and improves the oxidative capacity of skeletal muscles, facilitating more efficient oxygen utilization during physical activity (Li et al., 2025). These adaptations are especially advantageous for populations with non-communicable diseases, such as individuals with cardiovascular disease or type 2 diabetes, as they frequently demonstrate impaired aerobic capacity and mitochondrial dysfunction. Moreover, HIIT has demonstrated efficacy in increasing endothelial function and reducing systemic inflammation, prevalent concerns in NCDs with overweight or obese, hence reinforcing its contribution to the improvement of VO_2 max. Consequently, these psychological changes facilitate the notable enhancements in VO_2 max reported in NCD adults with overweight or obese subsequent to HIIT.

Among the 16 studies in the meta-analysis, only four examined high-density lipoproteins (HDL) and three assessed low-density lipoproteins (LDL) levels. This may be due to the limitations of HDL and LDL, as their assessment is an intrusive technique necessitating specific laboratory protocols, potentially incurring additional costs. Nevertheless, no significant difference was identified due to the minimal mean difference and the limited number of trials considered. It was reported that no significant differences were detected in the lipid profile, as the studies analyzed failed to achieve the requisite minimum score of 18, which consists of four points for pre- and post-intervention changes and 14 points for the magnitude of changes (Ismail et al., 2025). The number of studies analyzing HDL and LDL was limited, and the results should be interpreted with caution—the conclusions in this area are overly assertive given the small number of analyzed studies.

The findings of this meta-analysis suggesting that neither HIIT nor MICT demonstrates a distinct benefit in lowering triglycerides. In contrast, the finding suggest HIIT is more effective than MICT in reducing glucose levels. The statistically significant MD suggests that this impact is improbable to be coincidental. The glucose reduction in the HIIT group may be ascribed to its elevated intensity, perhaps improving insulin sensitivity and glucose uptake more efficiently than MICT. Nevertheless, an increased sample size could alter the outcome, possibly indicating a difference, or it may persist unchanged. Moreover, adherence may be an issue, since persons within this demographic suffering from NCDs with obesity could find it challenging to completely comply with the intervention. Explicitly indicate that although beneficial changes in VO_2 max and FMD were observed following HIIT, the effects on glucose and lipid profiles require further investigation with larger sample sizes.

Improvements in cardiorespiratory fitness and decreases in body fat percentage were noted in obese people within both the HIIT and MICT groups; however, these changes lacked statistical significance (Mahzan et al., 2024). However, among persons with non-communicable diseases (NCDs) who are overweight or obese, high-intensity interval training (HIIT) may result in substantial enhancements in cardiorespiratory fitness.

Conclusions

This meta-analysis demonstrates that both HIIT and MICT significantly improve endothelial function, VO_2 max, and reduce glucose levels in individuals with non-communicable diseases (NCDs) who are overweight or obese. However, HIIT exhibits greater efficacy in enhancing VO_2 max, with both interventions improving FMD, although HIIT shows a stronger trend of improvement. This has established it as an effective intervention for advancing vascular health and cardiorespiratory fitness.

To achieve the best cardiovascular outcomes, the recommended HIIT protocol (4×4 minutes, 3 times per week, for 12 weeks) may be considered in physiotherapeutic practice, but the decision should be tailored to the patient's capabilities and clinical status. This structured regimen can significantly enhance vascular function, cardiorespiratory fitness, and overall health in NCD populations with overweight or obese. The findings of this meta-analysis may support the design of training programs for NCDs' patients with overweight or obese, particularly in the context of cardiac and metabolic rehabilitation. While the findings suggest that HIIT may offer greater benefits on FMD and VO2 max compared to other forms of exercise, the robustness of these conclusions is limited by methodological heterogeneity, the short duration of some interventions, and the small number of studies investigating metabolic parameters.

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