©Journal of Sports Science and Medicine (2024) **23**, 690-706
http://www.jssm.org DOI: https://doi.org/10.52082/jssm.2024.690

Review article

The Effects of High-Intensity Interval Training on Cardiometabolic Health in Children and Adolescents: A Systematic Review and Meta-Analysis

Yuan Song [1,2] and Huihui Lan [2] ✉
[1] Physical Education Department, Chongqing University of Technology, Chongqing, China
[2] Faculty of Social Sciences and Liberal Arts, UCSI University, Kuala Lumpur, Malaysia

Abstract

High-intensity interval training (HIIT) interventions are typically prescribed according to several laboratory-based parameters and fixed reference intensities to accurately calibrate exercise intensity. Repeated *all-out* printing efforts, or sprint interval training, is another form of HIIT that is prescribed without individual reference intensity as it is performed in maximal intensities. No previous study has performed a systematic review and meta-analysis to investigate the effect of HIIT and SIT on cardiometabolic health markers in children and adolescents. Moreover, previous studies have focused on single risk factors and exercise modalities, which may restrict their ability to capture a complete picture of the factors that could be affected by different interval interventions. The present study aimed to conduct a novel meta-analysis on the effects of HIIT and SIT on multiple cardiometabolic health markers in children and adolescents. An electronic search was conducted in three main online databases including PubMed, Web of Science, and Scopus were searched from inception to July 2024 to identify randomized and non-randomized control trials comparing HIIT and SIT versus the non-exercise control group in children and adolescents with mean age ranges from 6 to 18 years old on cardiometabolic health markers including fasting glucose and insulin, insulin resistance, triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), systolic blood (SBP) and diastolic blood (DBP) pressures. Standardized mean differences (SMD), weighted mean differences (WMD), and confidence were calculated using a random effect model. HIIT decreased insulin, insulin resistance, TG, TC, LDL, and SBP and increased HDL but did not decrease glucose and DBP. Furthermore, subgroup analyses show that insulin and insulin resistance were decreased by sprint interval training (SIT) and in those with obesity. Lipid profile mainly is improved by SIT and in those with obesity. Also, SBP was decreased by SIT and in those with obesity. Our results prove that HIIT is an effective intervention for improving cardiometabolic health in children and adolescents, mainly those with obesity. Specifically, SIT is an effective interval training mode in children and adolescents.

Key words: Lipid profile, blood pressure, insulin resistance, exercise, sprint interval training.

Introduction

Physical activity and organized exercise regimens are widely acknowledged as fundamental approaches to managing cardiometabolic health, irrespective of additional lifestyle considerations (Edwards et al., 2023). An extensive body of empirical research spanning the last decade has consistently documented notable enhancements in diverse cardiometabolic fitness parameters and health indicators after exercise interventions, including glycemic markers (Boer et al., 2014; Martin et al., 2015; Dias et al., 2018; Kranen et al., 2023), blood lipid profile (Ahmadi et al., 2020; Paahoo et al., 2021; Khaliltahmasebi et al., 2022), and blood pressure (Espinoza-Silva et al., 2019; Ketelhut et al., 2020; Oliveira et al., 2021; Salus et al., 2022a; 2022b). Ultimately, these cumulative effects diminish the overall risk of cardiovascular disease within the broader population (Kranen et al., 2023; Bond et al., 2015).

Cardiovascular disease stands as the primary etiology of noncommunicable mortality globally and is projected to endure as an enduring and ubiquitous threat internationally (Kranen et al., 2023). A seemingly inevitable escalation in obesity and diabetes presently constitutes the foremost obstacle in the ongoing endeavor to diminish the burden of cardiovascular disease worldwide, and cholesterol, especially low-density lipoprotein cholesterol, is considered the primary determinant of cardiovascular disease (Timmis et al., 2020; Sayevand et al., 2022). Blood pressure also has a linear correlation with the incidence of stroke and myocardial infarction (Prospective Studies Collaboration, 2002), and treatment aimed at reducing blood pressure levels protects patients against cardiovascular events (Xie et al., 2016).

Different exercise interventions have traditionally been prescribed to diminish the abovementioned factors, with the majority focusing on moderate-intensity training, generally completed by running (Edwards et al., 2023). However, despite the indisputable advantages of global exercise training guidelines (Bull et al., 2020), adopting and complying with the existing guidelines remain inadequate (Edwards et al., 2023), with the "insufficient time" as a primary hindrance to their consistent involvement regularly (Gillen and Gibala, 2014). Hence, it seems sensible to investigate innovative exercise training methods that could enhance the acceptance and commitment of the general public.

High-intensity interval training (HIIT), characterized by repeated bouts of intensive work interspersed by periods of low-intensity exercise or complete rest (Gillen and Gibala, 2014), has been introduced as an alternative to moderate-intensity training. Despite a lower time commitment, HIIT induces numerous adaptations resembling moderate-intensity training (Little et al., 2010). HIIT may also have superior effects on modification of cardiometabolic risk in youth than moderate-intensity training (Hay et al., 2012; Carson et al., 2014). Adolescents also indicated

Received: 05 March 2024 / Accepted: 21 August 2024 / Published (online): 01 December 2024

higher enjoyment during HIIT than moderate-intensity training suggesting HIIT as a useful approach for preventing cardiovascular disease (Kranen et al., 2023). Several methods for prescribing HIIT have been created to assist athletes in reaching targeted exercise intensities during their training sessions in a structured and individualized way. These methods may include using a rating of perceived exertion (RPE) to guide intensity, utilizing maximal aerobic speed and power metrics, which are thought to be critical prescription components for many categories; anaerobic speed/power reserve measures; and the upper limits of high-intensity performance above the velocity or power linked to maximal oxygen uptake [$\dot{V}O_{2max}$ ($v/p\dot{V}O_{2max}$). Repeated *all-out* sprinting efforts or sprint interval training (SIT) is another form of HIIT performed at *all-out* or maximal intensities over a given distance or duration. Since such exercise is consistently performed *all-out*, it can be prescribed without pretesting individual reference intensities (i.e., $v/p\dot{V}O_{2max}$) (Laursen and Buchheit, 2019).

A wide range of HIIT studies have shown significant impacts on different cardiometabolic risk factors (Fereshtian et al., 2017; Costa et al., 2018; Sheykhlouvand et al., 2018; 2022; 2024; Campbell et al., 2019; Reljic et al., 2020; Edwards et al., 2022; 2023; Gharaat et al., 2024; Tao et al., 2024; Song and Sheykhlouvand, 2024). Although these studies provide invaluable information regarding the effects of HIIT on different cardiometabolic risk factors, the studies' variables are limited to single risk factors and exercise modalities, which may restrict their ability to capture a complete picture of the factors that could be affected by different type of interval interventions. Moreover, studies regarding children and adolescents are limited. Over the past two decades, childhood obesity has escalated to epidemic levels globally (Grossman et al., 2017). An epidemiological study conducted in 2017 revealed that there are approximately 107.7 million obese children in 195 countries, and the prevalence of obesity among children is higher compared to adults (GBD 2015 Obesity Collaborators, 2017). A recent update by the World Health Organization (WHO, www.who.int) indicates that over 390 million children and adolescents aged 5–19 years were overweight in 2022, including 160 million who were living with obesity. Childhood obesity not only raises the risk of cardiovascular disease but also leads to conditions such as adult coronary heart disease, hypertension, metabolic syndrome, and type II diabetes mellitus (Cole and Lobstein, 2012). Studies showed that disorders of glycolipid metabolism may originate from childhood; obesity can accelerate this situation (Cao et al., 2021). Hence, identifying the effective interventions in modulating the mentioned risk factors would be of value. Although some studies have been dedicated to these age categories, no previous study has performed a systematic review and meta-analysis to investigate the effect of HIIT and SIT on cardiometabolic health markers in children and adolescents. Hence, the present study aimed to conduct a novel meta-analysis on the effects of different intensive interval interventions (HIIT and SIT) on multiple cardiometabolic health indicators in children and adolescents.

Methods

This systematic review and meta-analysis are reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline.

Search

Three electronic databases, including PubMed, Web of Science, and Scopus, were searched. The search strategy was performed on July 2024 using the following keywords: "high intensity interval training" OR "high-intensity interval training" OR "high intensity interval exercise" OR "high-intensity interval exercise" OR "high-intensity intermittent training" OR "high intensity intermittent training" OR "high intensity intermittent exercise" OR "high-intensity intermittent exercise" OR "aerobic interval training" OR "aerobic-interval training" OR "aerobic interval exercise" OR "aerobic-interval exercise" OR "interval training" OR "interval exercise" OR "sprint interval training" OR "sprint interval exercise" OR "sprint training" AND children OR childhood OR child* OR adolescent OR youth OR pediatrics (Table 1). In addition, the search was updated up to July 2024. Also, the references list of applicable articles and Google Scholar were manually searched to find other relevant articles. The search terms and strategies were performed in consultation with information specialists to ensure comprehensiveness and rigor in conducting the literature search.

Study selection, inclusion and exclusion criteria

Articles were included if they met the following criteria: (1) peer-reviewed and English languages published articles, (2) randomized and non-randomized control trials comparing HIIT versus non-exercise control groups, (3) studies involving children and adolescents with mean age ranges from 6 to 18 years, (4) studies involving exercise training with intervention duration ≥ two weeks, (5) outcomes measures including glycemia markers including fasting glucose and insulin and insulin resistance, lipid profiles including triglyceride, total cholesterol, low-density lipoprotein cholesterol and high-density lipoprotein cholesterol, and blood pressure including systolic blood pressure and diastolic blood pressures. Studies were excluded if participants were≥ 18 years old, articles were published in non-English-language journals, studies included a single-arm trial (without a control group), and studies included exercise training combined with other interventions, such as caloric restriction. In addition, non-original studies, such as reviews, were excluded. Two reviewers independently selected and identified studies according to inclusion and exclusion criteria, and disagreements were resolved by discussion. All articles were included in EndNote software, and after removing duplicates, a screen was conducted based on the title and abstract. Subsequently, the remaining articles were screened based on their full text.

Data extraction

Two reviewers independently conducted data extractions on a pre-designed template. Data retrieved from each study included study design, participants' characteristics,

Table 1. Search strategy.

PubMed	(("high-intensity interval training"[All Fields] OR "high-intensity interval training"[All Fields] OR "high-intensity interval exercise"[All Fields] OR "high-intensity interval exercise"[All Fields] OR "high-intensity intermittent training"[All Fields] OR "high-intensity intermittent training"[All Fields] OR "high-intensity intermittent exercise"[All Fields] OR "high-intensity intermittent exercise"[All Fields] OR "aerobic-interval training"[All Fields] OR "aerobic-interval training"[All Fields] OR "aerobic-interval exercise"[All Fields] OR "aerobic-interval exercise"[All Fields] OR "interval training"[All Fields] OR "interval exercise"[All Fields] OR "sprint interval training"[All Fields] OR "sprint interval exercise"[All Fields] OR "sprint training"[All Fields]) AND ("child"[MeSH Terms] OR "child"[All Fields] OR "children"[All Fields] OR "child s"[All Fields] OR "children s"[All Fields] OR "childrens"[All Fields] OR "childs"[All Fields] OR ("childhood"[All Fields] OR "childhoods"[All Fields]) OR "child*"[All Fields] OR ("adolescences"[All Fields] OR "adolescency"[All Fields] OR "adolescent"[MeSH Terms] OR "adolescent"[All Fields] OR "adolescence"[All Fields] OR "adolescents"[All Fields] OR "adolescent s"[All Fields]) OR ("adolescent"[MeSH Terms] OR "adolescent"[All Fields] OR "youth"[All Fields] OR "youths"[All Fields] OR "youth s"[All Fields]) OR ("paediatrics"[All Fields] OR "pediatrics"[MeSH Terms] OR "pediatrics"[All Fields] OR "paediatric"[All Fields] OR "pediatric"[All Fields]))) AND ((humans[Filter]) AND (english[Filter]))
Scopus	(TITLE-ABS-KEY ("high intensity interval training" OR "high-intensity interval training" OR "high intensity interval exercise" OR "high-intensity interval exercise" OR "high-intensity intermittent training" OR "high intensity intermittent training" OR "high intensity intermittent exercise" OR "high-intensity intermittent exercise" OR "aerobic interval training" OR "aerobic-interval training" OR "aerobic interval exercise" OR "aerobic-interval exercise" OR "interval training" OR "interval exercise" OR "sprint interval training" OR "sprint interval exercise" OR "sprint training") AND TITLE-ABS-KEY (children OR childhood OR child* OR adolescent OR youth OR pediatrics)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
Web of science	Results for (ALL=("high intensity interval training" OR "high-intensity interval training" OR "high intensity interval exercise" OR "high-intensity interval exercise" OR "high-intensity intermittent training" OR "high intensity intermittent training" OR "high intensity intermittent exercise" OR "high-intensity intermittent exercise" OR "aerobic interval training" OR "aerobic-interval training" OR "aerobic interval exercise" OR "aerobic-interval exercise" OR "interval training" OR "interval exercise" OR "sprint interval training" OR "sprint interval exercise" OR "sprint training")) AND ALL=(children OR childhood OR child* OR adolescent OR youth OR pediatrics) and English (Languages)

including sample size, body mass index, age, sex, and health status, HIIT characteristics, including program description, intensity, duration, frequency, and numbers of sets, and outcomes data. To calculate the effect size, mean and standard deviation (SD) or mean changes and their SDs in the training and control groups were extracted. When required, these data were extracted from the figure using Getdata or were calculated from other data such as median and data range or standard errors (Reeves et al., 2008; Wan et al., 2014). In addition, if a study had more than one intervention arm, all were included as a separated trial.

Quality of assessment

Study quality was assessed using the Physiotherapy Evidence Database (PEDro) which contains 11 items. Two items, including blinding of participants and intervention, were excluded from the scale (De Morton, 2009). Finally, the quality of the included studies was assessed using 9 items that were performed by two independent reviewers. Details are provided in Table 2.

Data analysis

The meta-analysis of the included studies was conducted using comprehensive meta-analysis software version 3 (CMA3). To calculate effect size, standardized mean differences (SMD), weighted mean differences (WMD), and confidence intervals were calculated using a random effect model. The effect size was expressed as WMD when all studies reported the outcome in the same unit and was expressed as SMD when all studies reported the outcomes in the same units. For SMD, SMD of 0.2 to 0.49, 0.5 to 0.79, and > 0.8 were considered to represent small, medium, and large effect sizes, respectively (Cohen, 2013). Heterogeneity was assessed using Q statistics and I^2 values, where I^2 values of 25%, 50% and 70% were considered to represent low, moderate and high heterogeneity, respectively (Reeves et al., 2008). Publication bias was assessed using visual interpretation of a funnel plot and the Egger test (Sterne and Egger, 2001). In addition, several subgroup analyses were performed based on age (children: age < 12 years and adolescents: age ≥ 12 years), obesity (obese and non-obese), and mode of interval training (SIT and HIIT). The sensitivity of the analysis was determined by removing individual studies to ensure that individual results do not influence the results. In addition, analysis sensitivity was performed by removing non-randomized trials and studies with a high risk of bias.

Results

The database searches yielded 948 articles from Scopus, 829 articles from PubMed, and 662 articles from Web of Science, of which 1529 articles remained after removing duplicate records. Then, 1398 articles were eliminated based on titles and abstracts and subsequently 131 articles were removed based on the full-text screen as presented in Figure 1. In addition, one study was added after search updates (R). Finally, 31 articles met all inclusion criteria and were included in the meta-analysis (R)(Tjønna et al., 2009; Rosenkranz et al., 2012; Racil et al., 2013; 2016a; 2016b; Boer et al., 2014; Martin et al., 2015; Chuensiri et al., 2018; Cvetković et al., 2018; van Biljon et al., 2018; Delgado-Floody et al., 2018; Dias et al., 2018; Espinoza-Silva et al., 2019; 2023; Taylor et al., 2019; Ahmadi et al., 2020; Ketelhut et al., 2020; Plavsic et al., 2020; McNarry et al., 2021; Oliveira et al., 2021; Paahoo et al., 2021;

Khaliltahmasebi et al., 2022; Abassi et al., 2022; Meng et al., 2022; Martínez-Vizcaíno et al., 2022; Williams et al., 2022; Salus et al., 2022a; 2022b; Kranen et al., 2023; Tadiotto et al., 2023). Among the included studies, 23 were randomized control trials, and the remaining eight were non-randomized control trials (Espinoza-Silva et al., 2019; 2023; Salus et al., 2022a; 2022b; Delgado-Floody et al., 2018; Tadiotto et al., 2023; Taylor et al., 2019; van Biljon et al., 2018). Thirty-one studies included 2,496 children and adolescents with sample sizes ranging from16 (Rosenkranz et al., 2012) to 562 (Martínez-Vizcaíno et al., 2022) and mean ages ranging from 6.4 (Espinoza Silva et al., 2023) to 17.7 (Boer et al., 2014) years old. Table 3 presents more details of participants' characteristics. Of the included studies, 17 used SIT (Tjønna et al., 2009; Rosenkranz et al., 2012; Racil et al., 2013; 2016a, 2016b; Boer et al., 2014; Martin et al., 2015; Cvetković et al., 2018; van Biljon et al., 2018; Taylor et al., 2019; Ketelhut et al., 2020; Paahoo et al., 2021; Meng et al., 2022; Williams et al., 2022; Abassi et al., 2022; Khaliltahmasebi et al., 2022; Tadiotto et al., 2023), and 14 studies used HIIT (R) (Dias et al., 2018; Ahmadi et al., 2020; Kranen et al., 2023; Espinoza-Silva et al., 2019; 2023; Oliveira et al., 2021; Chuensiri et al., 2018; Delgado-Floody et al., 2018; Martínez-Vizcaíno et al., 2022; McNarry et al., 2021; Plavsic et al., 2020; Tjønna et al., 2009; van Biljon et al., 2018), of which intervention duration ranged from two weeks (Williams et al., 2022) to 12 months (Meng et al., 2022; Tjønna et al., 2009). Twelve weeks were most relevant. More details of HIIT characteristics are presented in Table 3.

Meta-Analysis

Glycemic markers

Figures 2 to 4 depict the change in fasting glucose, insulin, and insulin resistance following HIIT compared to the control group. Overall, HIIT significantly decreased insulin [SMD: –0.78 (CI: –1.41 to –0.15), p = 0.01, 13 trials] and insulin resistance [SMD: –1.01 (CI: –1.64 to –0.39), p = 0.002, 12 trials], but not glucose [WMD: –0.07 mmol/l (CI: –0.18 to 0.03), p = 0.18, 18 trials]. There were significant heterogeneities between studies for insulin (I^2 = 87.81, p = 0.001), glucose (I^2 = 54.44, p = 0.005), and insulin resistance (I^2 = 86.46, p = 0.001). Visual interpretation of funnel plot and Egger's test suggested publication bias for insulin resistance (p = 0.04) and only Egger's test showed publication bias for insulin (p = 0.07).

Table 2. Risk of bias assessment.

Authors & Year	Eligibility Criteria specified	Random allocation of participants	Allocation concealed	Groups similar at base-line	Assessors blinded	Outcome measures assessed in 85% of participants	Intention to treat analysis	Reporting of between group statistical comparison	Point measures and measures of variability reported for main effects	Total
Abassi et al. 2022	✓	✓	×	✓	×	✓	×	✓	✓	6
Ahmadi et al. 2020	✓	✓	✓	×	×	✓	×	✓	✓	6
Boer et al. 2014	✓	✓	×	✓	✓	✓	×	✓	✓	7
Chuensiri et al. 2017	✓	✓	×	✓	×	×	×	✓	✓	5
Cvetković et al. 2018	✓	✓	×	?	?	✓	×	✓	✓	5
Delgado-Floody et al. 2018	✓	×	×	✓	×	✓	×	✓	✓	5
Dias et al. 2018	✓	✓	✓	✓	?	×	✓	✓	✓	7
Espinoza Silva et al. 2023	✓	×	×	?	×	✓	×	✓	✓	4
Espinoza Silva et al. 2019	✓	×	×	✓	×	✓	×	✓	✓	5
Ketelhut et al. 2020	✓	✓	×	✓	×	✓	×	✓	✓	6
Khaliltahmasebi et al. 2022	✓	✓	×	✓	×	×	×	✓	✓	5
Kranen et al. 2023	✓	✓	?	✓	✓	✓	×	✓	✓	7
Martin et al. 2015	?	✓	×	✓	×	✓	×	✓	✓	5
Martínez-Vizcaíno et al. 2022	×	✓	×	?	?	✓	✓	✓	✓	5
Meng et al. 2022	✓	✓	✓	✓	?	×	×	✓	✓	6
McNarry et al. 2021	?	✓	×	✓	×	✓	×	✓	✓	5
Oliveira et al. 2022	?	✓	×	✓	×	✓	×	✓	✓	5
Paahoo et al. 2021	✓	✓	×	✓	×	✓	×	✓	✓	6
Plavsic et al. 2020	✓	✓	✓	✓	×	✓	×	✓	✓	7
Racil et al. 2013	?	✓	×	✓	×	✓	×	✓	✓	5
Racil et al. 2016a	?	✓	×	?	×	✓	×	✓	✓	4
Racil et al. 2016b	?	✓	×	?	×	✓	×	✓	✓	4
Rosenkranz et al. 2012	?	✓	×	✓	×	✓	×	✓	✓	5
Salus et al. 2022a	✓	×	×	×	×	×	×	✓	✓	3
Salus et al. 2022b	✓	×	×	✓	×	×	×	✓	✓	4
Tadiotto et al. 2023	✓	×	×	✓	×	✓	×	✓	✓	5
Tas et al. 2023	✓	✓	×	✓	?	✓	×	✓	✓	6
Taylor et al. 2019	✓	×	×	✓	×	✓	×	✓	✓	5
Tjønna et al. 2009	?	✓	✓	✓	✓	✓	×	✓	✓	7
van Biljon et al. 2018	×	×	×	✓	×	✓	×	✓	✓	4
Williams et al. 2022	✓	✓	×	✓	×	×	×	✓	✓	5

'low (✓), 'high (x) and unclear (?)

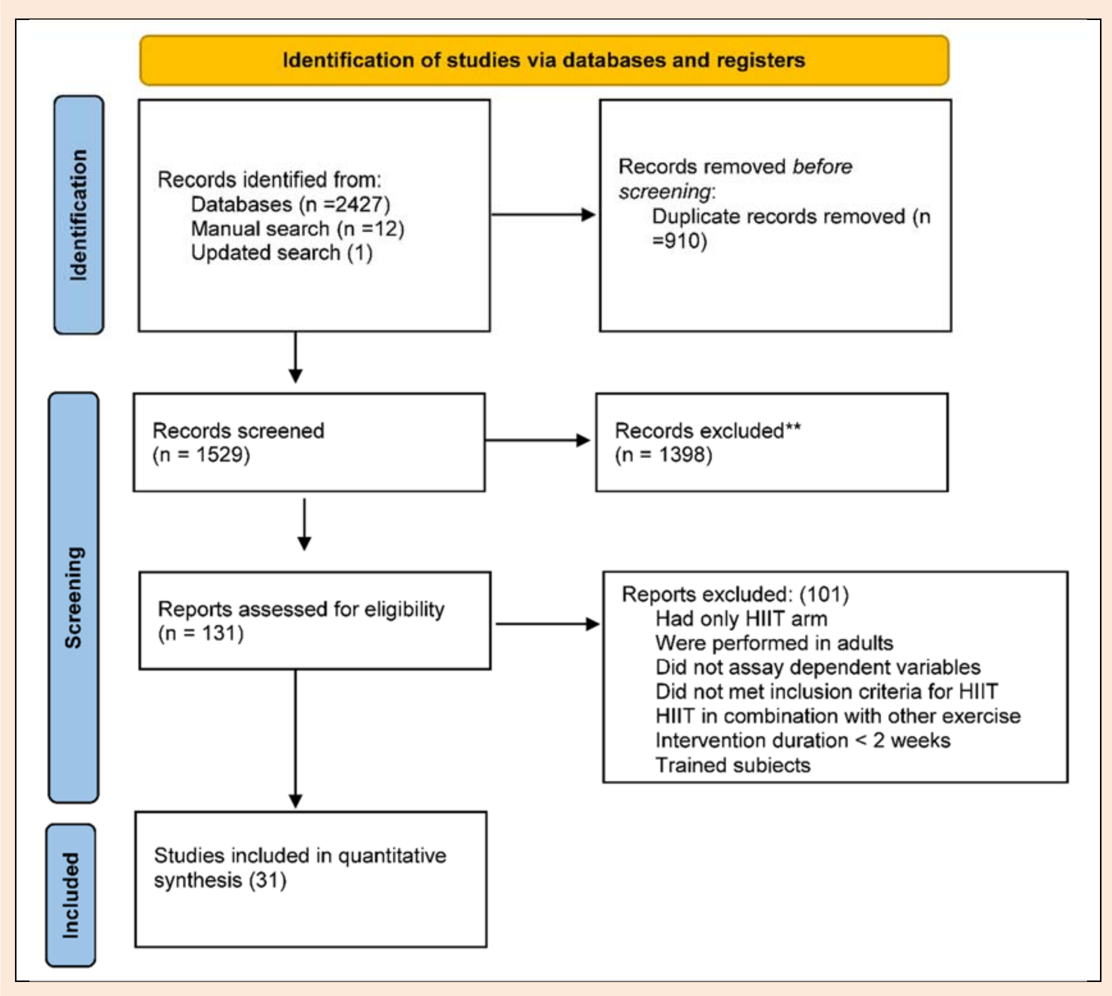

Figure 1. Follow diagram of literature search based on PRISMA.

Both Visual interpretation of the funnel plot, and Egger's test did not show publication bias for glucose (p = 0.10). The sensitivity of analyses shows that excluding non-randomized studies on overall effect sizes was insignificant. In addition, the sensitivity of analyses by removing studies with a high risk of bias did not change the significance.

Subgroup analysis. After analyzing the different subgroup analyses, insulin was decreased by SIT [SMD: –1.21 (CI: –1.94 to –0.48), p = 0.001, 9 trials] and in those with obesity [SMD: –1.12 (CI: –1.81 to –0.42), p = 0.002, 9 trials] and adolescents [SMD: –1.00 (CI: –1.70 to –0.29), p = 0.005, 10 trials]. Subgroup analyses for insulin resistance indicate that SIT decreased insulin resistance [SMD: –1.30 (CI: –2.12 to –0.48), p = 0.002, 9 trials] and in those with obesity [SMD: –0.84 (CI: –1.35 to –0.32), p = 0.001, 10 trials] and adolescents [SMD: –1.25 (CI: –2.01 to –0.48), p = 0.001, 9 trials]. Glucose was decreased by SIT [WMD: –0.11 mmol/l (CI: -0.22 to –0.00), p = 0.03, 10 trials]

Lipid profiles

Figures 5 to 8 depict the changes in triglyceride, total cholesterol, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol following HIIT compared to the control group. Overall, HIIT significantly decreased triglyceride [WMD: –0.12 mmol/l (CI: –0.21 to –0.04), p = 0.004, 18 trials], total cholesterol [WMD: –0.23 mmol/l (CI: –0.37 to –0.08), p = 0.002, 17 trials] and low-density lipoprotein cholesterol [WMD: –0.23 mmol/l (CI: –0.35 to –0.11), p = 0.001, 17 trials] and increased high-density lipoprotein cholesterol [WMD: 0.07 mmol/l (CI: 0.02 to 0.12), p = 0.004, 18 trials]. There were significant heterogeneities between studies for triglyceride (I^2 = 44.82, p = 0.02), total cholesterol (I^2 = 57.72, p = 0.002), low-density lipoprotein cholesterol (I^2 = 57.29, p = 0.002) and high-density lipoprotein cholesterol (I^2 = 56.40, p = 0.001). Visual interpretation of the funnel plot suggested publication bias for triglyceride, total cholesterol, and high-density lipoprotein cholesterol, but Egger's test did not show publication bias for triglyceride (p = 0.13), total cholesterol (p = 0.70), and high-density lipoprotein cholesterol (p = 0.96). In addition, both visual interpretation of funnel plot and Egger's test did not suggest publication bias for low-density lipoprotein cholesterol (p = 0.33). Sensitivity of analyses shows that the either exclusion of studies and non-randomized studies on overall effect sizes were not significant. In addition, the visual interpretation of the funnel plot and Egger's test did not suggest publication bias for low-density lipoprotein cholesterol (p = 0.33).

Subgroup analysis. After analyzing the different subgroups, total cholesterol was decreased by SIT [WMD: –0.26 mmol/l (CI: –0.47 to –0.04), p = 0.01, 10 trials] and tended to decrease by HIIT [WMD: –0.17 mmol/l (CI: –0.34 to –0.00), p = 0.05, 7 trials], in those with obesity

[WMD: –0.28 mmol/l (CI: –0.41 to –0.16), p = 0.001, 14 trials], adolescent [WMD: –0.19 mmol/l (CI: –0.31 to –0.06), p = 0.003, 9 trials] and children [WMD: –0.30 mmol/l (CI: –0.60 to –0.01), p = 0.04, 8 trials]. HIIT [WMD: –0.15 mmol/l (CI: –0.29 to –0.01), p = 0.03, 8 trials] and SIT [WMD: –0.11 mmol/l (CI: –0.22 to –0.002), p = 0.04, 10 trials] decreased triglyceride, in those with obesity [WMD: –0.15 mmol/l (CI: –0.35 to –0.05), p = 0.003, 15 trials], adolescents [WMD: –0.06 mmol/l (CI: –0.12 to –0.00), p = 0.03, 10 trials], and children [WMD: –0.27 mmol/l (CI: –0.47 to –0.08), p = 0.005, 8 trials]. SIT decreased low-density lipoprotein cholesterol [WMD: –0.38 mmol/l (CI: –0.49 to –0.26), p=0.001, 9 trials] in those with obesity [WMD: –0.28 mmol/l (CI: –0.39 to –0.16), p = 0.001, 13 trials], adolescent [WMD: –0.15 mmol/l (CI: –0.26 to –0.04), p = 0.005, 10 trials] and children [WMD: –0.37 mmol/l (CI: –0.59 to –0.15), p = 0.001, 7 trials]. High-density lipoprotein cholesterol was increased by SIT [WMD: 0.06 mmol/l (CI: 0.04 to 0.09), p = 0.001, 9 trials], in those with obesity [WMD: 0.06 mmol/l (CI: 0.04 to 0.08), p = 0.001, 14 trials], adolescent [WMD: 0.09 mmol/l (CI: 0.008 to 0.18), p = 0.03, 11 trials] and children [WMD: 0.07 mmol/l (CI: 0.05 to 0.10), p = 0.001, 7 trials].

Table 3. Characteristics of participants and exercises.

Source, year	Sample size; sex; allocation	Age (BMI kg/m^2)	HIIT mode	Intervention protocol (HIIT or SIT vs. MICT and CON)	Outcomes
Abassi et al. (2022)	28 overweight and obesity; females; RCT	HIIT:16.4±1.0; (32.6±3.6) CON:16.4±1.0; (33.2±5.7)	SIT	HIIT: 2 × six to eight sets of 30-s at 100-110% of maximal aerobic speed by 30-s recovery at 50% of maximal aerobic speed; 12 weeks treadmill running; supervised 3 d/week. CON: without any structure program	SBP, DBP
Ahmadi et al. (2020)	60 overweight and obesity; males and females; RCT	HIIT:14.6±2.6; (30.0±5.2) CON:12.7±2.6; (28.5±6.0)	HIIT	HIIT: 30-min body weight training by 20-s rest intervals between each item; 8 weeks body weight; supervised 3 d/week. CON: without any structure program	TG, TC, LDL, HDL
Boer et al. (2014)	36 intellectual disabilities with overweight and obesity; males and females; RCT	HIIT:18.0±3.2; (28.4±4.7) CON:17.4±2.4; (26.9±3.2)	SIT	HIIT: ten sets of 15-s at all-out effort by 45-s recovery +10 min continuous training + ten sets of 15-s at all-out effort by 45-s recovery; 15 weeks cycling/running; supervised 2 d/week. CON: participated in usual everyday scholar activities without supervised exercise training	Glucose, insulin, HOMA-IR, SBP, DBP, TG, TC, LDL, HDL
Chuensiri et al. (2018)	48 overweight and obesity; males and females; RCT	HIIT$_1$:11.0±1.0; (24.2±3.3) HIIT$_2$:11.1±0.8; (26.5±3.5) CON:10.6±1.0; (26.1±3.3)	SIT & HIIT	HIIT$_1$: eight sets of 2-min at 90% of peak power output by 1-min recovery. HIIT$_2$: eight sets of 20-s at 170% of peak power output by 10-s recovery; 12 weeks cycling; supervised 3 d/week CON: without any structure program	SBP, DBP, TG, TC, LDL, HDL
Cvetković et al. (2018)	28 overweight and obesity; males; RCT	HIIT:11.0-13.0; (26.6±3.4) CON:11.0-13.0; (25.3±4.8)	SIT	HIIT: 3 × five to ten sets of 10-20-s 100% of maximal aerobic speed by 3-min recovery; 12 weeks running; supervised 3 d/week. CON: their normal physical education classes	SBP, DBP
Delgado-Floody et al. (2018)	179 overweight and obesity; males and females; NRCT	HIIT:8.4±1.2; (19.6-23.4) CON:8.4±1.2; (19.3-23.7)	HIIT	HIIT: four to five sets of 4-6-min at 80-95% of HR_{max} by 1-2-min recovery, and running, jumping, throwing 30-60-s by 30-60-s recovery; 28 weeks running; supervised 2 d/week CON: 35-min class with group relay exercises, pre-sports games, dances, and coordination exercises	SBP, DBP
Dias et al. (2018)	67 overweight and obesity; males and females; RCT	HIIT:7.0-16.0; (28.8±3.8) CON:7.0-16.0; (29.6±4.3)	HIIT	HIIT: four sets of 4-min at 85-95% of HR_{max} by 3-min recovery at 50-70% of HR_{max}; 12 weeks cycling; supervised 3 d/week CON: nutrition advice only	Glucose, HOMA-IR, TG, TC, LDL, HDL
Espinoza Silva et al. (2023)	443 overweight and obesity; males and females; NRCT	HIIT:6.4±0.6; (20.3±2.8) CON:6.3±0.7; (16.2±0.9)	HIIT	HIIT: 30-s high intensity activities by 1-min recovery until 15-20 min; three to four sets of 4-min activities by 1-2 recovery; 28 weeks activities; supervised 2 d/week CON: their normal physical education classes based on the national curriculum	SBP, DBP
Espinoza-Silva et al. (2019)	274 overweight and obesity; males and females; NRCT	HIIT:8.1±1.5; (22.7±3.2) CON:8.1±1.5; (22.7±3.2)	HIIT	HIIT: 30-60-s high intensity activities at a rating of 8-10 BRPE by 1-min recovery until 15-20 min; three to four sets of 4-min activities by 1-2 recovery; 28 weeks activities; supervised 2 d/week CON: performed the traditional activities of the official physical education program	SBP, DBP
Ketelhut et al. (2020)	46 normal weights; males and females; RCT	HIIT:10.8±0.6; (19.6±4.6) CON:10.7±0.7; (19.7±4.0)	SIT	HIIT: 2 × 6-min blocks including 20-120-s at maximal efforts by 30-90-s recovery; 12 weeks running; supervised 2 d/week CON: maintained daily activities	SBP, DBP

Abbreviations: **HIIT** (high intensity interval training), **MICT** (moderate intensity continuous training), **CON** (control), **$VO_{2max/peak}$** (maximal or peak oxygen uptake), **$HR_{max/peak}$** (maximal or peak heart rate), **HOMA-IR** (homeostatic model assessment for insulin resistance), **SBP** (systolic blood pressure), **DBP** (systolic blood pressure), **TG** (triglyceride), **TC** (total cholesterol), **LDL** (low density lipoprotein), **HDL** (high density lipoprotein), **NRCT** (nonrandomized controlled trial), **RCT** (randomized controlled trial), **ND** (not-defined)

Table 3. Continue…

Source, year	Sample size; sex; allocation	Age (BMI kg/m^2)	HIIT mode	Intervention protocol (HIIT or SIT vs. MICT and CON)	Outcomes
Khaliltah-masebi et al. (2022)	38 overweight and obesity; males; RCT	HIIT:12.0±1.0; (26.2±2.3) CON:12.0±1.0; (26.2±2.5)	SIT	HIIT: 2-4 × five sets of 30-s at 85-100% of maximal aerobic speed by 30-s recovery at 50% of maximal aerobic speed; 12 weeks running; supervised 3 d/week CON: maintained daily activities	TG, TC, LDL, HDL
Kranen et al. (2023)	19 normal weights; males; RCT	HIIT:13.3±0.6; (17.4±0.9) CON:13.3±0.5; (18.6±2.5)	HIIT	HIIT: eight sets of 1-min at 90% of maximal aerobic speed by 75-s recovery; 4 weeks running; supervised 3 d/week CON: maintained daily activities	Glucose, insulin, TG, TC, LDL, HDL
Martin et al. (2015)	49 normal weights; males and females; RCT	HIIT:16.9±0.4; (22.2±2.3) CON:16.8±0.5; (22.3±3.2)	SIT	HIIT: four to six sprints by 30-s recovery; 7 weeks running; supervised 3 d/week CON: standard physical education	Glucose, insulin, HOMA-IR
Martínez-Vizcaíno et al. (2022)	562 normal, over-weight and obe-sity; males and fe-males; RCT	$HIIT_{girl}$:10.0±0.7; (18.5±3.8) $HIIT_{boy}$:9.9±0.7; (18.5±3.8) CON_{girl}:10.0±0.7 ; (17.9±3.6) CON_{boy}:10.1±0.7 ; (17.9±3.6)	HIIT	HIIT: four sets of 4-min traditional games at 85-90% of HR_{max} by 3-min recovery at 65-75% of HR_{max}; 12 months playground games; supervised 4 d/week CON: continued with their standard physical education cur-riculum throughout the intervention period	Glucose, SBP, DBP, TG, TC, LDL, HDL
Meng et al. (2022)	30 overweight and obesity; males; RCT	HIIT:11.4±0.8; (24.5±1.1) CON:11.0±0.7; (23.8±0.8)	SIT	HIIT: eight sets of 15-s at 90-100% of maximal aerobic speed by 15-s recovery at 50% of maximal aerobic speed; 12 weeks running; supervised 3 d/week CON: maintained daily activities	Glucose, insulin, HOMA-IR, SBP, DBP, TG, TC, LDL, HDL
McNarry et al. (2021)	69 normal weight healthy and asthma; males and females; RCT	HIIT:13.6±0.9; (21.1±3.3) CON:13.6±0.9; (21.1±3.3)	HIIT	HIIT: 10-30 s activities over 90% of HR_{max} by 10-30 s re-covery; 6 months circuits and game-based activities; super-vised 3 d/week CON: engaged in their usual day-to-day activities	SBP, DBP, TG, TC, LDL, HDL
Oliveira et al. (2021)	19 normal weights; males; RCT	HIIT:13.3±0.5; (ND) CON:13.2±0.5; (ND)	HIIT	HIIT: eight to twelve sets of 1-min at 90% of maximal aero-bic speed by 75-s recovery; 4 weeks running; supervised 3 d/week CON: maintained daily activities	SBP, DBP
Paahoo et al. (2021)	30 overweight and obesity; males; RCT	HIIT:11.1±1.0; (25.3±1.0) CON:11.2±0.9; (25.0±1.9)	SIT	HIIT: 3 × ten sets of 10-s 100-110% of maximal aerobic speed by 3-min recovery; 12 weeks running; supervised 3 d/week CON: without any structure program	TG, TC, LDL, HDL
Plavsic et al. (2020)	44 overweight and obesity; females; RCT	HIIT:16.2±1.3; (32.6±2.7) CON:15.5±1.5; (33.2±3.5)	HIIT	HIIT: four sets of 4-min at 85-90% of HR_{max} by 3-min re-covery at 70% of HR_{max} and they were instructed to reduce their caloric intake; 12 weeks uphill treadmill walking/run-ning; supervised 2 d/week CON: they were instructed to reduce their caloric intake	HOMA-IR, SBP, DBP, TG, TC, LDL, HDL
Racil et al. (2013)	23 overweight and obesity; females; RCT	HIIT:15.6±0.7; (2.9±0.2) CON:15.9±1.2; (2.9±0.2) (Z-score)	SIT	HIIT: 2 × six to eight sets of 30-s at 100-110% of maximal aerobic speed by 30-s recovery at 50% of maximal aerobic speed; 12 weeks running; supervised 3 d/week CON: without any structure program	Glucose, insulin, HOMA-IR, TG, TC, LDL, HDL
Racil et al. (2016a)	31 overweight and obesity; females; RCT	HIIT:14.2±1.2; (3.4±0.4) CON:14.2±1.2; (3.3±0.5) (Z-score)	SIT	HIIT: 15-s at 100% of maximal aerobic speed by 15-s re-covery at 50% of maximal aerobic speed until 4-8 min; 12 weeks running; supervised 3 d/week recovery at 50% of maximal aerobic speed until 4-8 min CON: without any structure program	Glucose, insulin, HOMA-IR, SBP, DBP
Racil et al. (2016b)	42 overweight and obesity; females; RCT	HIIT:16.6±1.3; (2.6±0.2) CON:16.6±1.3; (2.6±0.2) (Z-score)	SIT	HIIT: 2 × six to eight sets of 30-s at 100% velocity at VO_{2peak} by 30-s recovery at 50% velocity at VO_{2peak}; 12 weeks running; supervised 3 d/week CON: without any structure program	Glucose, insulin, HOMA-IR
Rosenkranz et al. (2012)	16 normal weights; males and females; RCT	HIIT:8.6±0.6; (19.5±5.3) CON:9.6±1.4; (18.3±2.2)	SIT	HIIT: 4 × five to ten sets of 10-20-s at 100-130% maximal aerobic speed by 10-20-s recovery; 8 weeks running; super-vised 2 d/week CON: without any structure program	Glucose, SBP, DBP, TG, TC, LDL, HDL

Abbreviations: **HIIT** (high intensity interval training), **MICT** (moderate intensity continuous training), **CON** (control), **$VO_{2max/peak}$** (maximal or peak oxygen uptake), **$HR_{max/peak}$** (maximal or peak heart rate), **HOMA-IR** (homeostatic model assessment for insulin resistance), **SBP** (systolic blood pressure), **DBP** (systolic blood pressure), **TG** (triglyceride), **TC** (total cholesterol), **LDL** (low density lipoprotein), **HDL** (high density lipoprotein), **NRCT** (nonrandomized controlled trial), **RCT** (randomized controlled trial), **ND** (not-defined)

Table 3. Continue…

Source, year	Sample size; sex; allocation	Age (BMI kg/m^2)	HIIT mode	Intervention protocol (HIIT or SIT vs. MICT and CON)	Outcomes
Salus et al. (2022a)	37 overweight and obesity; males; NRCT	HIIT:13.1±1.7; (30.3±3.2) CON:13.7±1.6; (32.6±5.9)	SIT	HIIT: four to six sets of 30-s sprint by 4-min recovery; 12 weeks cycling; supervised 3 d/week CON: maintained their habitual lifestyle	Glucose, insulin, HOMA-IR, TG, HDL, TC, LDL
Salus et al. (2022b)	37 overweight and obesity; males; NRCT	HIIT:13.1±1.7; (30.3±3.2) CON:13.7±1.6; (32.6±5.9)	SIT	HIIT: four to six sets of 30-s sprint by 4-min recovery; 12 weeks cycling; supervised 3 d/week CON: maintained their habitual lifestyle	SBP, DBP
Tadiotto et al. (2023)	37 overweights; males and females; NRCT	HIIT:11-16; (2.4±1.0) CON:11-16; (2.1±0.8) (Z-score)	SIT	HIIT: 3 × four sets of 30-s at 80-100% of HRR by 1-min recovery; 12 weeks running; supervised 3 d/week CON: maintain their usual activities	Glucose, insulin, HOMA-IR, SBP, DBP, TG, TC, LDL, HDL
Tas et al. (2023)	42 overweight and obesity; males and females; RCT	HIIT:15.2±1.5; (36.9±6.0) CON:15.4±1.0; (34.9±5.9)	HIIT	HIIT: ten sets of 1-min at 80-90% of HR_{max} by 2-min recovery; 4 weeks running; supervised 3 d/week CON: maintain their usual activities	Glucose, insulin, HOMA-IR, HDL, LDL, TG, TC
Taylor et al. (2019)	30 overweight and obesity with Serious mental illness; males and females; NRCT	HIIT:16.1±1.3; (26.0±7.0) CON:15.9±1.1; (25.4±5.5)	SIT	HIIT: four sets of 30-s at maximal cycling sprints by 4-min recovery; 8 weeks cycling; supervised 3 d/week CON: Treatment included medication, psychiatry sessions, art/music therapy, and group talk-therapy	SBP, DBP
Tjønna et al. (2009)	54 overweight and obesity; males and females; RCT	HIIT:13.9±0.3; (33.2±6.1) CON:14.2±0.3; (33.3±4.5)	HIIT	HIIT: four sets of 4-min at 90-90% of HR_{max} by 3-min recovery at 70% of HR_{max}; 12 months running; supervised 2 d/week CON: exercise, dietary and psychological advice, twice a month	Glucose, insulin, SBP, DBP, TG, HDL
van Biljon et al. (2018)	58 normal weights; males and females; NRCT	HIIT:11.1±0.8; (18.5±3.2) CON:11.1±0.8; (20.3±3.7)	HIIT	HIIT: ten sets of 1-min over 80% of HR_{max} by 75-s recovery under 70% of HR_{max}; 5 weeks running; supervised 3 d/week CON: was not exposed to any exercise intervention	Glucose, insulin, SBP, DBP,
Williams et al. (2022)	20 normal weights; females; RCT	HIIT:11.8±0.2; (17.8±2.2) CON:11.6±0.4; (18.5±3.0)	SIT	HIIT: six to eight sets of 10-s sprint by 50-s recovery; 2 weeks running; supervised 3 d/week CON: maintained their habitual lifestyle	Glucose, insulin, HOMA-IR

Abbreviations: **HIIT** (high intensity interval training), **MICT** (moderate intensity continuous training), **CON** (control), **$VO_{2max/peak}$** (maximal or peak oxygen uptake), **$HR_{max/peak}$** (maximal or peak heart rate), **HOMA-IR** (homeostatic model assessment for insulin resistance), **SBP** (systolic blood pressure), **DBP** (systolic blood pressure), **TG** (triglyceride), **TC** (total cholesterol), **LDL** (low density lipoprotein), **HDL** (high density lipoprotein), **NRCT** (nonrandomized controlled trial), **RCT** (randomized controlled trial), **ND** (not-defined)

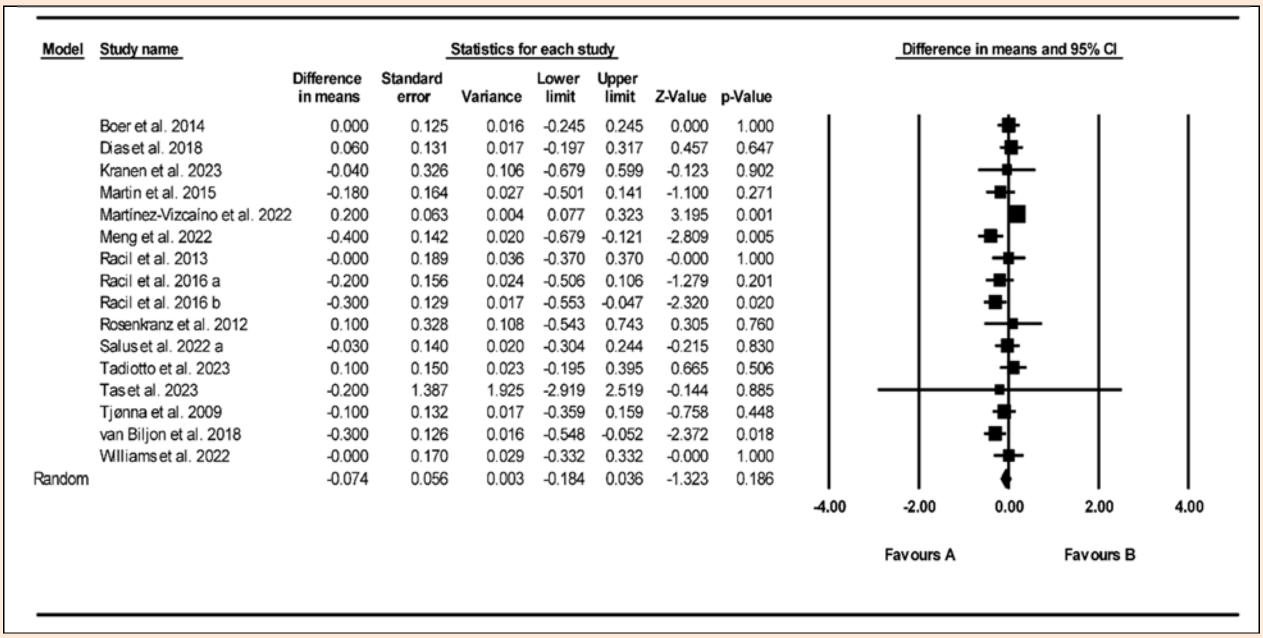

Figure 2. Forest plots of the effect of high intensity interval training versus Control group on fasting glucose.

Model	Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Boer et al. 2014	-0.873	0.378	0.143	-1.613	-0.133	-2.313	0.021
	Kranen et al. 2023	0.677	0.472	0.223	-0.249	1.603	1.433	0.152
	Martin et al. 2015	-1.708	0.384	0.148	-2.461	-0.955	-4.445	0.000
	Meng et al. 2022	-1.210	0.435	0.190	-2.063	-0.357	-2.779	0.005
	Racil et al. 2013	-2.434	0.550	0.303	-3.513	-1.355	-4.422	0.000
	Racil et al. 2016 a	-2.700	0.498	0.248	-3.676	-1.724	-5.424	0.000
	Racil et al. 2016 b	-2.485	0.412	0.170	-3.292	-1.678	-6.034	0.000
	Saluset al. 2022 a	0.142	0.378	0.143	-0.599	0.884	0.376	0.707
	Tadiotto et al. 2023	-0.149	0.345	0.119	-0.825	0.526	-0.433	0.665
	Taset al. 2023	-0.287	0.444	0.197	-1.157	0.583	-0.646	0.518
	Tjønna et al. 2009	-0.422	0.389	0.152	-1.185	0.342	-1.083	0.279
	van Biljon et al. 2018	0.711	0.284	0.081	0.154	1.269	2.500	0.012
	Williamset al. 2022	0.274	0.502	0.252	-0.711	1.258	0.545	0.586
Random		-0.784	0.324	0.105	-1.419	-0.150	-2.423	0.015

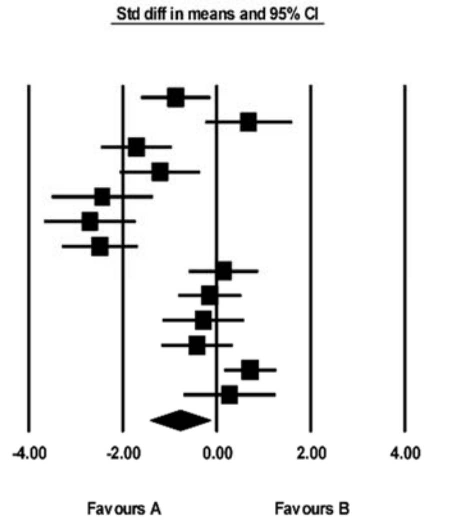

Figure 3. **Forest plots of the effect of high intensity interval training versus control group on fasting insulin.**

Model	Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Boer et al. 2014	-0.883	0.378	0.143	-1.624	-0.142	-2.336	0.019
	Dias et al. 2018	0.039	0.345	0.119	-0.638	0.716	0.112	0.911
	Martin et al. 2015	-4.426	0.611	0.373	-5.623	-3.229	-7.248	0.000
	Meng et al. 2022	-1.354	0.444	0.197	-2.224	-0.485	-3.052	0.002
	Plavsic et al. 2020	-0.461	0.305	0.093	-1.060	0.137	-1.510	0.131
	Racil et al. 2013	-1.710	0.488	0.238	-2.666	-0.754	-3.506	0.000
	Racil et al. 2016 a	-1.985	0.440	0.194	-2.848	-1.122	-4.509	0.000
	Racil et al. 2016 b	-2.049	0.382	0.146	-2.798	-1.300	-5.361	0.000
	Saluset al. 2022 a	0.134	0.378	0.143	-0.608	0.876	0.354	0.723
	Tadiotto et al. 2023	-0.138	0.345	0.119	-0.813	0.538	-0.399	0.690
	Taset al. 2023	-0.278	0.444	0.197	-1.148	0.592	-0.627	0.531
	Williamset al. 2022	0.296	0.503	0.253	-0.689	1.281	0.588	0.556
Random		-1.019	0.319	0.102	-1.645	-0.394	-3.196	0.001

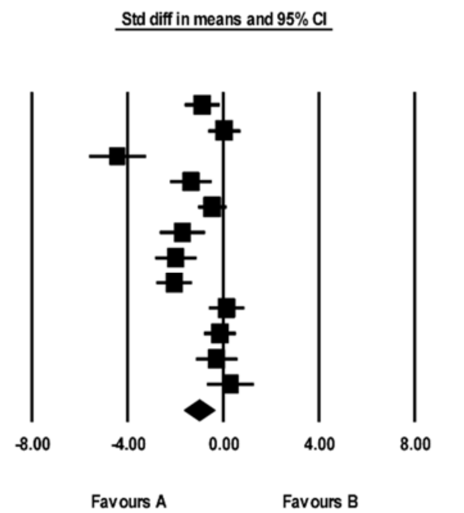

Figure 4. **Forest plots of the effect of high intensity interval training versus control group on insulin resistance.**

Blood pressure

Figures 9 and 10 depict the changes in systolic blood pressure and diastolic blood pressures following HIIT compared to the control group. Overall, HIIT significantly decreased systolic blood pressure [WMD: –2.35mm Hg (CI: –3.79 to –0.91), p = 0.001, 24 trials], but not diastolic blood pressures [WMD: –0.92 mm Hg (CI: –2.31 to 0.47), p = 0.19, 24 trials]. Significant heterogeneities existed between systolic blood pressure studies (I2=40.68, p = 0.02) and diastolic blood pressures (I^2 = 60.11, p = 0.001). Visual interpretation of the funnel plot and Egger's test did not suggest publication bias for systolic blood pressure (p=0.74), and only Visual interpretation of the funnel plot showed publication bias for diastolic blood pressures (Egger's test p = 0.90). The sensitivity of analyses shows that the exclusion of studies on overall effect sizes was not significant. However, removing non-randomized studies led to a significant effect size for diastolic blood pressures [WMD: –1.90 mm Hg (CI: –3.71 to –0.10), p=0.03, 14 trials]. The sensitivity of analyses shows that excluding non-randomized studies on overall effect sizes was insignificant. In addition, the sensitivity of analyses by removing studies with a high risk of bias did not change the significance.

Subgroup analysis. After analyzing the different subgroup analyses, systolic blood pressure was decreased by SIT [WMD: –3.97 mm Hg (CI: –6.33 to –1.61), p = 0.001, 11 trials] and in those with obesity [WMD: –3.30 mm Hg (CI: –4.79 to –1.81), p = 0.001, 18 trials] and children [WMD: -1.79 mm Hg (CI: –3.13 to –0.45), p = 0.008, 13 trials] and tended to significant in adolescents [WMD: –2.69 mm Hg (CI: –5.53 to 0.14), p = 0.06, 11 trials]. Subgroup analyses show that diastolic blood pressure only was decreased by SIT [WMD: –2.22 mm Hg (CI: –3.97 to –0.47), p = 0.01, 11 trials].

Discussion

The present meta-analysis analyzed glycemic markers, lipid profiles, and blood pressure to determine the impact of HIIT on cardiometabolic health in children and adolescents by analyzing glycemic markers, lipid profiles, and blood pressure. Our results demonstrated the broad efficacy of HIIT, with significant improvements in insulin and insulin resistance, triglyceride, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, systolic blood pressure, and diastolic blood pressure in the mentioned categories. Importantly, subgroup analysis revealed SIT as a highly effective modality of HIIT in modulating the mentioned variables. These findings reinforce the significance of HIIT in regulating cardiometabolic health.

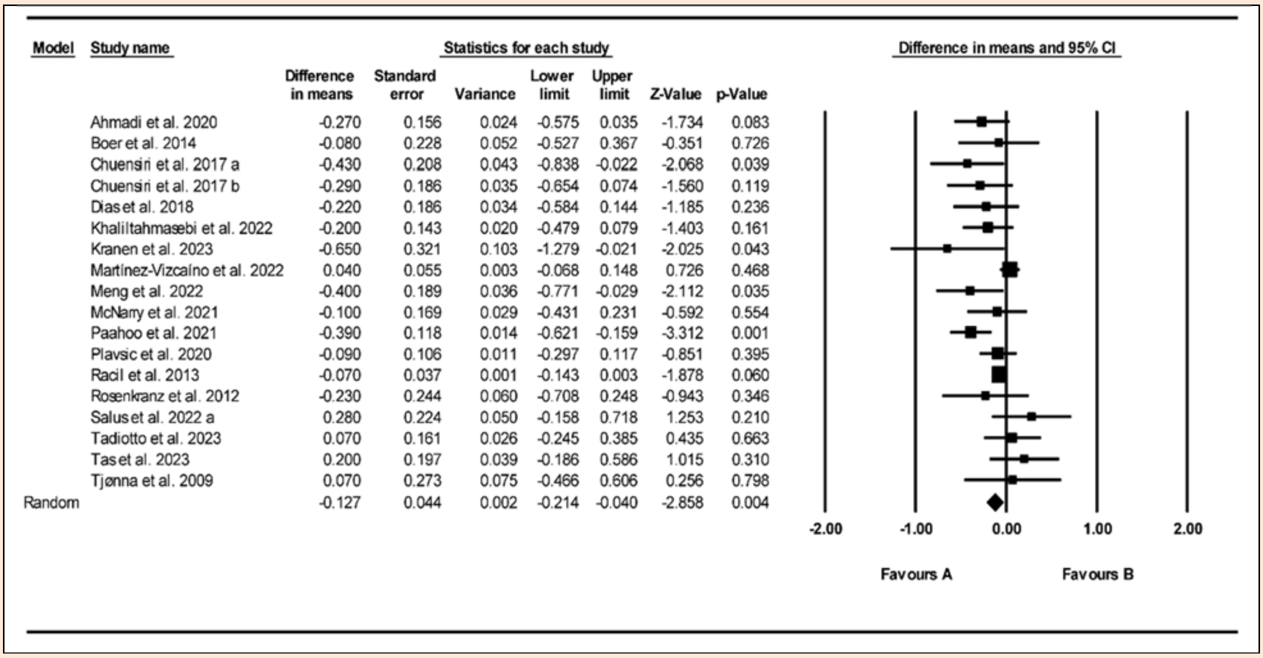

Figure 5. Forest plots of the effect of high intensity interval training versus control group on triglyceride.

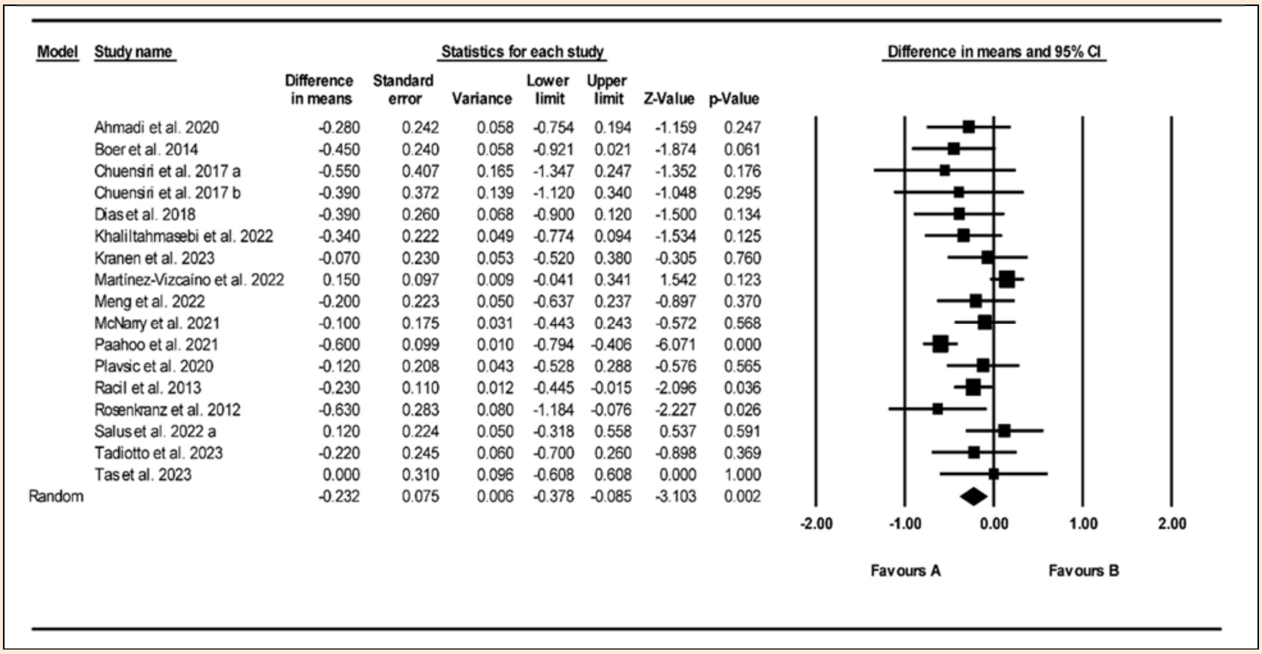

Figure 6. Forest plots of the effect of high intensity interval training versus control group on total cholesterol.

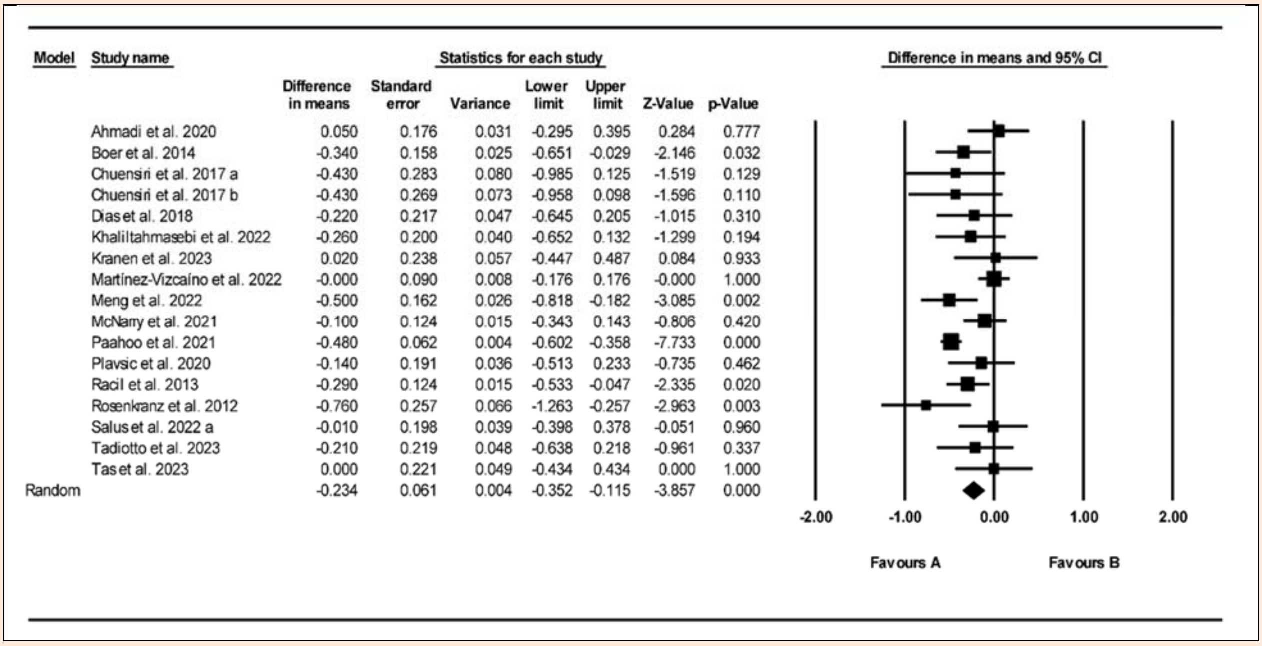

Figure 7. **Forest plots of the effect of high intensity interval training versus control group on low-density lipoprotein cholesterol.**

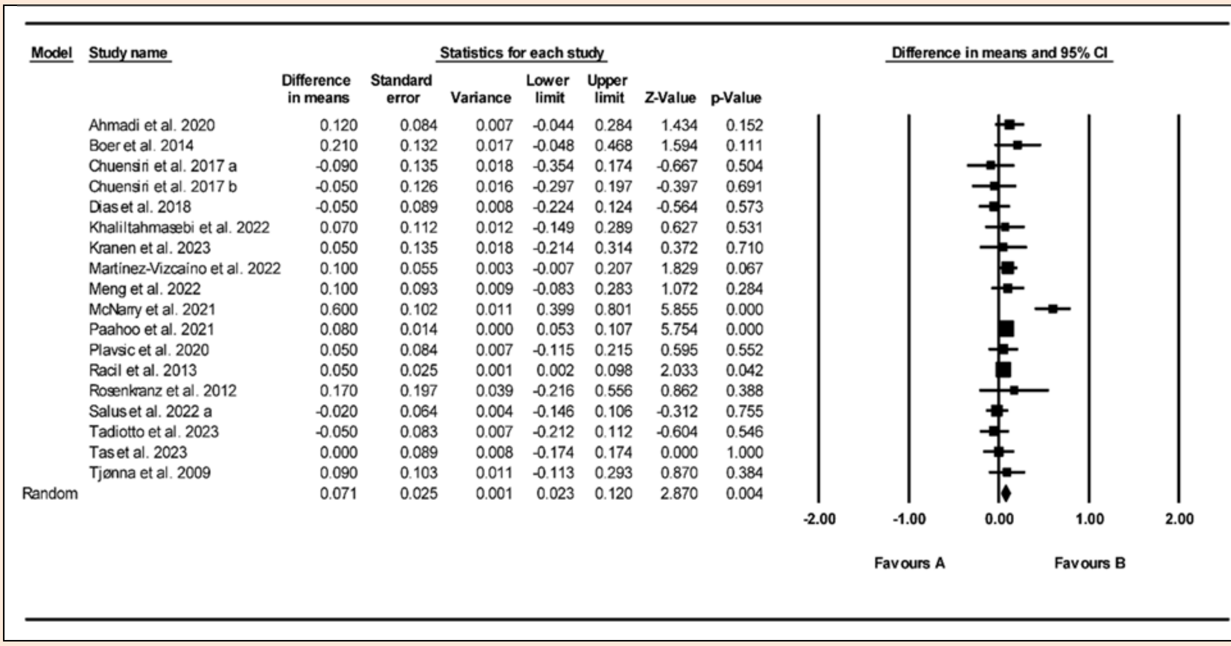

Figure 8. **Forest plots of the effect of high intensity interval training versus control group on high-density lipoprotein cholesterol.**

Elevated fasting blood glucose and insulin levels are widely recognized as established factors that increase the risk of developing metabolic disorders (Martin et al., 2015). Following analysis of randomized-controlled trials, our findings indicate a statistically significant decrease in insulin levels (12 studies) and insulin resistance (11 studies) in children and adolescents following HIIT. More importantly, the majority of these studies have employed SIT as an interval intervention, highlighting its strong influence in modulating these metabolic indicators. However, glucose levels only decreased in response to SIT and exhibited an unresponsiveness to HIIT, demonstrating the ineffectiveness of HIIT in targeting this metabolic marker. In a recent meta-analysis investigating the effects of HIIT on cardiometabolic risk factors in childhood obesity, Zhu and colleagues 2021) have reported that HIIT is effective in fasting Insulin and Insulin sensitivity. In another meta-analysis of randomized controlled trials, Cao and colleagues (2021) found no statistically significant difference between HIIT and moderate-intensity continuous training on in fasting Insulin and Insulin sensitivity in overweight and obese children. However, the mentioned studies haven't specified interval intervention modality (i.e., HIIT vs. SIT). Our results indicated that studies employing SIT interventions observed suitable modulation in metabolic biomarkers mentioned above. A growing body of studies exploring the effects of high-intensity interval interventions on improving metabolic health has argued the potential mechanism affecting insulin sensitivity following such interventions (Gillen and Gibala, 2014; Gibala, 2018; Ryan et al., 2020). In line with early studies (Fell et al., 1982; Bogardus et al., 1983), Ryan and colleagues (2020) recently indicated that the post-exercise decrease in muscle glycogen content could be considered the main contributor to the short-lived improvement in insulin sensitivity which could also be known as the acute effects of the most recent exercise training. This effect may persist for at least a few days after exercise. Long-term metabolic adaptations in skeletal muscles could result from enhanced oxidative capacity and mitochondrial respiratory protein abundance (Ryan et al., 2020; Kelley et al., 1999; Goodpaster et al., 2003; 2013; Holloszy, 2009; 2013; Muoio and Neufer, 2012). Research has indicated that insulin-sensitive populations possess higher mitochondrial density than insulin-resistant individuals, and a training-induced increase in this factor and oxidative capacity may influence insulin sensitivity (Goodpaster, 2013). According to proponents of this theory, high mitochondrial density may be associated with an increased fat-burning ratio at rest (Kelley et al., 1999; Goodpaster et al., 2003).

Model	Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Abassi et al. 2022	-3.000	1.228	1.508	-5.407	-0.593	-2.443	0.015
	Boer et al. 2014	-12.000	3.446	11.875	-18.754	-5.246	-3.482	0.000
	Chuensiri et al. 2017 a	-3.000	7.152	51.150	-17.017	11.017	-0.419	0.675
	Chuensiri et al. 2017 b	-11.000	6.656	44.304	-24.046	2.046	-1.653	0.098
	Cvetkovi? et al. 2018	-8.060	5.500	30.250	-18.840	2.720	-1.465	0.143
	Delgado-Floody et al. 2018 a	2.800	4.457	19.868	-5.936	11.536	0.628	0.530
	Delgado-Floody et al. 2018 b	3.150	5.052	25.520	-6.751	13.051	0.624	0.533
	Delgado-Floody et al. 2018 c	-2.390	2.858	8.167	-7.991	3.211	-0.836	0.403
	Delgado-Floody et al. 2018 d	-1.510	3.437	11.811	-8.246	5.226	-0.439	0.660
	Espinoza Silva et al. 2023	-2.150	1.287	1.656	-4.672	0.372	-1.671	0.095
	Espinoza Silva et al. 2019	-2.360	1.916	3.672	-6.116	1.396	-1.232	0.218
	Ketelhut et al. 2020	-5.200	3.222	10.382	-11.515	1.115	-1.614	0.107
	Martinez-Vizcaino et al. 2022	0.490	1.323	1.751	-2.104	3.084	0.370	0.711
	Meng et al. 2022	-6.000	2.178	4.745	-10.269	-1.731	-2.754	0.006
	McNarry et al. 2021	5.000	2.625	6.890	-0.145	10.145	1.905	0.057
	Oliveira et al. 2022	-0.300	3.879	15.049	-7.903	7.303	-0.077	0.938
	Plavsic et al. 2020	-5.500	2.334	5.448	-10.075	-0.925	-2.356	0.018
	Racil et al. 2016 a	-6.000	2.309	5.331	-10.526	-1.474	-2.599	0.009
	Rosenkranz et al. 2012	-0.300	1.947	3.793	-4.117	3.517	-0.154	0.878
	Salus et al. 2022 b	6.000	5.222	27.268	-4.235	16.235	1.149	0.251
	Tadiotto et al. 2023	1.500	3.939	15.517	-6.220	9.220	0.381	0.703
	Taylor et al. 2019	-2.160	3.825	14.628	-9.656	5.336	-0.565	0.572
	Tjønna et al. 2009	-2.700	4.606	21.216	-11.728	6.328	-0.586	0.558
	van Biljon et al. 2018	-3.370	3.461	11.979	-10.154	3.414	-0.974	0.330
Random		-2.354	0.733	0.538	-3.791	-0.916	-3.209	0.001

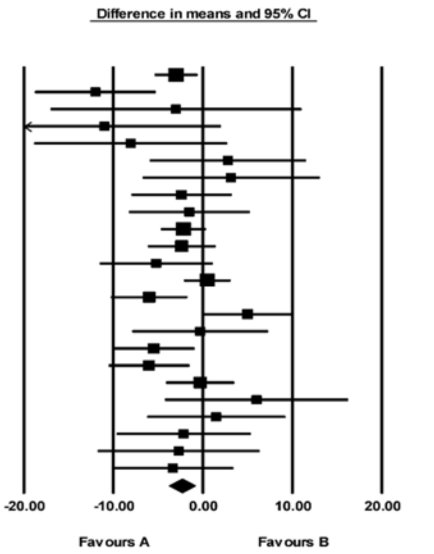

Figure 9. **Forest plots of the effect of high intensity interval training versus control group on systolic blood pressure.**

Model	Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Abassi et al. 2022	-0.900	1.651	2.727	-4.137	2.337	-0.545	0.586
	Boer et al. 2014	3.000	2.357	5.556	-1.620	7.620	1.273	0.203
	Chuensiri et al. 2017 a	-1.000	3.576	12.787	-8.009	6.009	-0.280	0.780
	Chuensiri et al. 2017 b	-6.000	3.605	12.999	-13.066	1.066	-1.664	0.096
	Cvetkovi? et al. 2018	-9.070	4.533	20.546	-17.954	-0.186	-2.001	0.045
	Delgado-Floody et al. 2018 a	-0.490	3.548	12.591	-7.445	6.465	-0.138	0.890
	Delgado-Floody et al. 2018 b	5.070	6.118	37.436	-6.922	17.062	0.829	0.407
	Delgado-Floody et al. 2018 c	3.720	2.431	5.908	-1.044	8.484	1.531	0.126
	Delgado-Floody et al. 2018 d	5.000	3.029	9.176	-0.937	10.937	1.651	0.099
	Espinoza Silva et al. 2023	-0.420	1.259	1.586	-2.889	2.049	-0.333	0.739
	Espinoza Silva et al. 2019	3.730	1.629	2.653	0.538	6.922	2.290	0.022
	Ketelhut et al. 2020	-2.700	2.117	4.481	-6.849	1.449	-1.275	0.202
	Martinez-Vizcaino et al. 2022	0.260	0.928	0.861	-1.559	2.079	0.280	0.779
	Meng et al. 2022	-2.000	1.644	2.701	-5.221	1.221	-1.217	0.224
	McNarry et al. 2021	5.000	2.157	4.652	0.773	9.227	2.318	0.020
	Oliveira et al. 2022	-3.900	4.105	16.852	-11.946	4.146	-0.950	0.342
	Plavsic et al. 2020	-4.800	2.014	4.058	-8.748	-0.852	-2.383	0.017
	Racil et al. 2016 a	-5.000	1.127	1.271	-7.210	-2.790	-4.435	0.000
	Rosenkranz et al. 2012	-0.800	2.293	5.256	-5.294	3.694	-0.349	0.727
	Salus et al. 2022 b	-5.000	4.589	21.059	-13.994	3.994	-1.090	0.276
	Tadiotto et al. 2023	-2.700	3.283	10.778	-9.135	3.735	-0.822	0.411
	Taylor et al. 2019	0.500	2.280	5.199	-3.969	4.969	0.219	0.826
	Tjønna et al. 2009	-5.600	2.806	7.875	-11.100	-0.100	-1.996	0.046
	van Biljon et al. 2018	-2.880	1.903	3.623	-6.611	0.851	-1.513	0.130
Random		-0.920	0.713	0.509	-2.318	0.478	-1.290	0.197

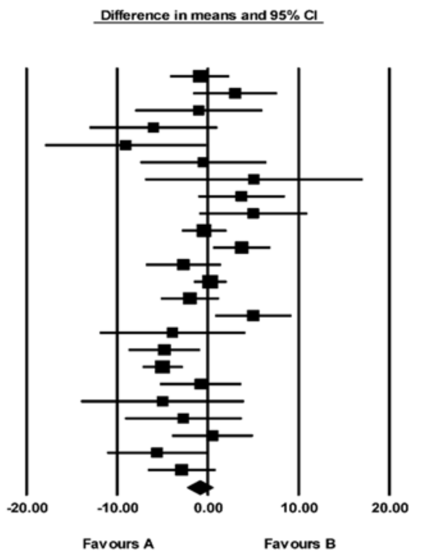

Figure 10. **Forest plots of the effect of high intensity interval training versus control group on diastolic blood pressure.**

Bioactive fatty acid metabolites can induce insulin resistance by activating proinflammatory pathways (Schenk and Horowitz, 2007). Enhanced fat oxidation could limit the accumulation of bioactive lipid species and prevent a direct hindrance to insulin signaling (Goodpaster, 2013). However, despite the positive effects of exercise on mitochondrial density, research indicates unaltered resting fat oxidation after the training (Kanaley et al., 2001; Van Aggel-Leijssen et al., 2002), making this hypothesis controversial (Ryan et al., 2020). Overall, the exact mechanisms underlying these effects still need to be fully understood, and further research is warranted to elucidate the relationship between HIIT and insulin sensitivity.

Modified lipid profile is another positive effect of HIIT, which our findings support. Statistically significant improvements in triglycerides, total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol in children and adolescents reinforce previous systematic review and meta-analysis of randomized controlled trials demonstrating HIIT's effects on the maintenance of optimal health (Edwards et al., 2023). However, our findings do not comply with Batacan and colleagues' study (2017), which could result from including recently published studies in our work and excluding non-randomized trials. The most remarkable effects of SIT on lipid profile highlight the effectiveness of this training modality, which hasn't been specified with the previous investigations. Previous meta-analyses have confirmed a dose-dependent association between elevated triglyceride (Liu et al., 2013), low-density lipoprotein cholesterol, and declined high-density lipoprotein cholesterol levels (Jung et al., 2022) with higher risks of cardiovascular disease and all-cause mortality. By enhancing catecholamines and growth hormone levels (Langin, 2006; Trapp et al., 2007), HIIT stimulates lipolysis of adipose and increases free fatty acid availability to be utilized by active muscles (Dias et al., 2018; Burguera et al., 2000). Enhanced the capacity of the skeletal muscles in utilizing lipids, reduces plasma lipid levels (Earnest et al., 2013) and improves lipid profile (Mann et al., 2014). The mechanism may also include an elevation in lecithin cholesterol acyltransferase (LCAT) (an enzyme transferring ester to high-density lipoprotein cholesterol [Calabresi and Franceschini, 2010]), which is increased in response to HIIT (Rahmati-Ahmadabad et al., 2018; Lira et al., 2019). "The cholesterol removal process is known as reverse cholesterol transport" (Mann et al., 2014). Cholesterol is removed from circulation through this process for disposal, which, in turn, is a result of an increase in LCAT and a decrease in cholesterol ester transferring protein (a responsible enzyme for transferring high-density lipoprotein cholesterol to other lipoproteins) in response to HIIT (Lira et al., 2019). The increased enzyme activity mentioned above following HIIT elevates the ability of active muscles in fatty acids oxidization originating from plasma, triglyceride, and low-density lipoprotein cholesterol (Mann et al., 2014; Shaw et al., 2009) and improves lipid profile.

Significant improvements were also observed in blood pressure after HIIT. Since hypertension remains the primary modifiable risk factor for cardiovascular disease and all-cause mortality (Lim et al., 2012), the significant decreases observed due to HIIT hold essential clinical significance (Edwards et al., 2023). Analyses of 24 randomized-controlled trials indicated that various HIIT forms significantly decrease systolic blood pressure. However, diastolic blood pressure only decreases with SIT, indicating the importance of this training modality on blood pressure. In line with our findings, other meta-analyses have shown the positive effects of interval interventions on lowering blood pressure (Cao et al., 2021; Zhu et al., 2021). However, our study specifically focused on the effects of different interval interventions (HIIT vs. SIT) on blood pressure in this category, and indicated the effects of SIT on diastolic blood pressure. Studies have indicated that the change in blood pressure in healthy individuals with normal blood pressure is short-lived and an acute effect of the most recent exercise training (Whyte et al., 2010; Rossow et al., 2010; Burns et al., 2012). By contrast, improved blood pressure following HIIT could be more long-lasting in hypertensive subjects (Chuensiri et al., 2018). Improved endothelial function by HIIT is one of the main contributing factors in chronically reducing blood pressure (Ciolac et al., 2010). Several HIIT studies have reported reduced arterial stiffness (AS) indicated by measuring brachial-ankle pulse wave velocity (Chuensiri et al., 2018; Ciolac et al., 2010; Guimarães et al., 2010). More intensive interventions may result in a greater effect on AS reduction in people already exhibiting some alterations in vascular elasticity (Ciolac et al., 2010). Mechanisms underpinning the reduction in AS by HIIT are not fully elucidated. However, such a change could be mediated by "the removal of chronic restraint on the arterial smooth muscle cells provided by the sympathetic adrenergic vasoconstrictor tone (Sugawara et al., 2009) as well as endothelin-1" (Maeda et al., 2009). Accumulative evidence indicated vascular reactivity through exercise-induced blood flow and shear stress (Ciolac et al., 2010; Niebauer and Cooke, 1996). Endothelium-dependent vasodilation is mediated by upregulated expression of mRNA for nitric oxide (NO) synthesis in endothelial cells exposed to laminar shear stress through long-term change in blood flow by HIIT (Sessa et al., 1992; Noris et al., 1995). Long-term change in flow could also mediate vascular remodeling by enlarging vessels, changing vascular structure (Niebauer and Cooke, 1996), and decreasing blood pressure.

Clinical implications

The clinical implications of our study underscore the transformative potential of high-intensity interval training in enhancing cardiometabolic health among children and adolescents. Through a comprehensive meta-analysis, we observed substantial improvements in insulin levels, insulin resistance, lipid profiles, and blood pressure, with sprint interval training emerging as particularly efficacious. These findings align with and bolster current guidelines advocating for vigorous physical activity to mitigate cardiometabolic risks in youth. Integrating HIIT, especially SIT, into pediatric exercise regimens can significantly improve metabolic markers, offering a promising strategy to reduce the long-term risk of cardiovascular diseases in this vulnerable population.

Limitations

Our study has several limitations that should be considered when interpreting results. There were significant heterogeneities for several outcomes. The HIIT type, age, and BMI of participants may be the source of heterogeneity. In addition, the present meta-analysis was not limited to non-randomized trials where these types of studies have less clinical value. However, we performed subgroup analysis based on the type of studies, and our result remained significant.

Conclusions

Our findings indicate the wide-ranging effectiveness of high-intensity interval training, resulting in significant enhancements in insulin levels, insulin resistance, triglycerides, total cholesterol, low-density lipoprotein, high-density lipoprotein, systolic blood pressure, and diastolic blood pressure within the specified categories. Sprint interval training emerged as an exceptionally potent form of HIIT for influencing these parameters when we analyzed subgroups. These results underscore the importance of HIIT in managing cardiovascular and metabolic health, highlighting its apparent potential for incorporation into guidelines and clinical practice.

Acknowledgements

The experiments comply with the current laws of the country in which they were performed. The authors have no conflict of interest to declare. The datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author who was an organizer of the study.

References

Abassi, W., Ouerghi, N., Nikolaidis, P.T., Hill, L., Racil, G., Knechtle, B., Feki, M. and Bouassida, A. (2022) Interval training with different intensities in overweight/obese adolescent females. *International Journal of Sports Medicine* **43(05)**, 434-443. https://doi.org/10.1055/a-1648-4653

Ahmadi, A., Moheb-Mohammadi, F., Navabi, Z.S., Dehghani, M., Heydari, H., Sajjadi, F. and Khodarahmi, S. (2020) The effects of aerobic training, resistance training, combined training, and healthy eating recommendations on lipid profile and body mass index in overweight and obese children and adolescents: A randomized clinical trial. *ARYA Atherosclerosis* **16(5)**, 226-234.

Batacan, R.B., Duncan, M.J., Dalbo, V.J., Tucker, P.S. and Fenning, A.S. (2017) Effects of high-intensity interval training on cardiometabolic health: a systematic review and meta-analysis of intervention studies. *British Journal of Sports Medicine* **51(6)**, 494-503. https://doi.org/10.1136/bjsports-2015-095841

Boer, P.H., Meeus, M., Terblanche, E., Rombaut, L., Wandele, I.D., Hermans, L., Gysel, T., Ruige, J. and Calders, P. (2014) The influence of sprint interval training on body composition, physical and metabolic fitness in adolescents and young adults with intellectual disability: a randomized controlled trial. *Clinical rehabilitation* **28(3)**, 221-231. https://doi.org/10.1177/0269215513498609

Bogardus, C., Thuillez, P., Ravussin, E., Vasquez, B., Narimiga, M. and Azhar, S. (1983) Effect of muscle glycogen depletion on in vivo insulin action in man. *The Journal of Clinical Investigation* **72(5)**, 1605-1610. https://doi.org/10.1172/JCI111119

Bond, B., Cockcroft, E.J., Williams, C.A., Harris, S., Gates, P.E., Jackman, S.R., Armstrong, N. and Barker, A.R. (2015) Two weeks of high-intensity interval training improves novel but not traditional cardiovascular disease risk factors in adolescents. *American Journal of Physiology-Heart and Circulatory Physiology* **309(6)**, 1039-1047. https://doi.org/10.1152/ajpheart.00360.2015

Bull, F.C., Al-Ansari, S.S., Biddle, S., Borodulin, K., Buman, M.P., Cardon, G., Carty, C., Chaput, J.P., Chastin, S., Chou, R. and Dempsey, P.C. (2020) World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine* **54(24)**, 1451-1462. https://doi.org/10.1136/bjsports-2020-102955

Burguera, B., Proctor, D., Dietz, N., Guo, Z., Joyner, M. and Jensen, M.D. (2000) Leg free fatty acid kinetics during exercise in men and women. *American Journal of Physiology-Endocrinology and Metabolism* **278(1)**, 113-117. https://doi.org/10.1152/ajpendo.2000.278.1.E113

Burns, S.F., Oo, H.H. and Tran, A.T.T. (2012) Effect of sprint interval exercise on postexercise metabolism and blood pressure in adolescents. *International journal of sport nutrition and exercise metabolism* **22(1)**, 47-54. https://doi.org/10.1123/ijsnem.22.1.47

Calabresi, L. and Franceschini, G. (2010) Lecithin: cholesterol acyltransferase, high-density lipoproteins, and atheroprotection in humans. *Trends in Cardiovascular Medicine* **20(2)**, 50-53. https://doi.org/10.1016/j.tcm.2010.03.007

Campbell, W.W., Kraus, W.E., Powell, K.E., Haskell, W.L., Janz, K.F., Jakicic, J.M., Troiano, R.P., Sprow, K., Torres, A., Piercy, K.L. and Bartlett, D.B. (2019) High-intensity interval training for cardiometabolic disease prevention. *Medicine and Science in Sports and Exercise* **51(6)**, 1220-1226. https://doi.org/10.1249/MSS.0000000000001934

Cao, M., Tang, Y., Li, S. and Zou, Y. (2021) Effects of high-intensity interval training and moderate-intensity continuous training on cardiometabolic risk factors in overweight and obesity children and adolescents: a meta-analysis of randomized controlled trials. *International Journal of Environmental Research and Public Health* **18(22)**, https://doi.org/11905. 10.3390/ijerph182211905

Carson, V., Rinaldi, R.L., Torrance, B., Maximova, K., Ball, G.D.C., Majumdar, S.R., Plotnikoff, R.C., Veugelers, P., Boulé, N.G., Wozny, P. and McCargar, L. (2014) Vigorous physical activity and longitudinal associations with cardiometabolic risk factors in youth. *International Journal of Obesity* **38(1)**, 16-21. https://doi.org/10.1038/ijo.2013.135

Chuensiri, N., Suksom, D. and Tanaka, H. (2018) Effects of high-intensity intermittent training on vascular function in obese preadolescent boys. *Childhood Obesity* **14(1)**, 41-49. https://doi.org/10.1089/chi.2017.0024

Ciolac, E.G., Bocchi, E.A., Bortolotto, L.A., Carvalho, V.O., Greve, J. and Guimaraes, G.V. (2010) Effects of high-intensity aerobic interval training vs. moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities of young normotensive women at high familial risk for hypertension. *Hypertension Research* **33(8)**, 836-843. https://doi.org/10.1038/hr.2010.72

Cohen, J. (2013) Statistical power analysis for the behavioral sciences. Academic press. https://doi.org/10.4324/9780203771587

Cole, T. J. and Lobstein, T. (2012) Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatric obesity* **7(4)**, 284-294. https://doi.org/10.1111/j.2047-6310.2012.00064.x

Costa, E.C., Hay, J.L., Kehler, D.S., Boreskie, K.F., Arora, R.C., Umpierre, D., Szwajcer, A. and Duhamel, T.A. (2018) Effects of high-intensity interval training versus moderate-intensity continuous training on blood pressure in adults with pre-to established hypertension: a systematic review and meta-analysis of randomized trials. *Sports Medicine* **48**, 2127-2142. https://doi.org/10.1007/s40279-018-0944-y

Cvetković, N., Stojanović, E., Stojiljković, N., Nikolić, D., Scanlan, A.T. and Milanović, Z. (2018) Exercise training in overweight and obese children: Recreational football and high-intensity interval training provide similar benefits to physical fitness. *Scandinavian Journal of Medicine & Science in Sports* **28**, 18-32. https://doi.org/10.1111/sms.13241

Delgado-Floody, P., Espinoza-Silva, M., García-Pinillos, F. and Latorre-Román, P. (2018) Effects of 28 weeks of high-intensity interval training during physical education classes on cardiometabolic risk factors in Chilean schoolchildren: a pilot trial. *European Journal of Pediatrics* **177**, 1019-1027. https://doi.org/10.1007/s00431-018-3149-3

De Morton, N.A. (2009) The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy* **55(2)**, 129-133. https://doi.org/10.1016/s0004-9514(09)70043-1

Dias, K.A., Ingul, C.B., Tjønna, A.E., Keating, S.E., Gomersall, S.R., Follestad, T., Hosseini, M.S., Hollekim-Strand, S.M., Ro, T.B., Haram, M. and Huuse, E.M. (2018) Effect of high-intensity interval training on fitness, fat mass and cardiometabolic biomarkers in children with obesity: a randomised controlled trial. *Sports Medicine* **48**, 733-746. https://doi.org/10.1177/0269215513498609

Earnest, C.P., Artero, E.G., Sui, X., Lee, D.C., Church, T.S. and Blair, S.N. (2013) Maximal estimated cardiorespiratory fitness, cardiometabolic risk factors, and metabolic syndrome in the aerobics center longitudinal study. *Mayo Clinic Proceedings* **88(3)**, 259-270. https://doi.org/10.1016/j.mayocp.2012.11.006

Edwards, J., De Caux, A., Donaldson, J., Wiles, J. and O'Driscoll, J. (2022) Isometric exercise versus high-intensity interval training for the management of blood pressure: a systematic review and meta-analysis. *British Journal of Sports Medicine* **56(9)**, 506-514. https://doi.org/10.1136/bjsports-2021-104642

Edwards, J.J., Griffiths, M., Deenmamode, A.H. and O'Driscoll, J.M. (2023). High-Intensity Interval Training and Cardiometabolic Health in the General Population: A Systematic Review and Meta-Analysis of Randomised Controlled Trials. *Sports Medicine* **53(9)**, 1753-1763. https://doi.org/10.1007/s40279-023-01863-8

Espinoza-Silva, M., Latorre-Román, P., Párraga-Montilla, J., Caamaño-Navarrete, F., Jerez-Mayorga, D. and Delgado-Floody, P. (2019) Response of obese schoolchildren to high-intensity interval training applied in the school context. *Endocrinología, Diabetes y Nutrición (English ed.)* **66(10)**, 611-619. https://doi.org/10.1016/j.endinu.2019.05.005

Espinoza Silva, J.M., Latorre Román, P.Á., Cabrera Linares, J.C., Párraga Montilla, J.A. and Martínez Salazar, C. (2023) Effects of a High Intensity Interval Training (HIIT) Program on Anthropomorphic and Cardiometabolic Variables in School Children with Overweight and Obesity. *Children* **10(2)**, 317. https://doi.org/10.3390/children10020317

Fell, R.D., Terblanche, S.E., Ivy, J.L., Young, J.C. and Holloszy, J.O. (1982) Effect of muscle glycogen content on glucose uptake following exercise. *Journal of Applied Physiology* **52(2)**, 434-437. https://doi.org/10.1152/jappl.1982.52.2.434

Fereshtian, S., Sheykhlouvand, M., Forbes, S., Agha-Alinejad, H. and Gharaat, M. (2017) Physiological and performance responses to high-intensity interval training in female inline speed skaters. *Apunts. Medicina de l'Esport* **52(196)**, 131-138. https://doi.org/10.1016/j.apunts.2017.06.003

GBD 2015 Obesity Collaborators. (2017) Health effects of overweight and obesity in 195 countries over 25 years. *New England Journal of Medicine* **377(1)**, 13-27. https://doi.org/10.1056/NEJMoa1614362

Gharaat, M.A., Choobdari, H.R. and Sheykhlouvand, M. (2024) Cardioprotective effects of aerobic training in diabetic rats: Reducing cardiac apoptotic indices and oxidative stress for a healthier heart. *ARYA Atherosclerosis* **20(2)**, 50-60. https://doi.org/10.48305/arya.2024.41976.2911

Gharaat, M. A., Kashef, M., Eidi Abarghani, L. and Sheykhlouvand, M. (2020) Effect of beta alanine on lactate level and Specific performance of elite male rowers. *Journal of Sabzevar University of Medical Sciences* **27(1)**, 73-81.

Gibala, M.J. (2018) Interval training for cardiometabolic health: why such a HIIT?. *Current Sports Medicine Reports* **17(5)**, 148-150. https://doi.org/10.1249/JSR.0000000000000483

Gillen, J.B. and Gibala, M.J. (2014) Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? *Applied Physiology, Nutrition, and Metabolism* **39(3)**, 409-412. https://doi.org/10.1139/apnm-2013-0187

Goodpaster, B.H., Katsiaras, A. and Kelley, D.E. (2003) Enhanced fat oxidation through physical activity is associated with improvements in insulin sensitivity in obesity. *Diabetes* **52(9)**, 2191-2197. https://doi.org/10.2337/diabetes.52.9.2191

Goodpaster, B.H. (2013) Mitochondrial deficiency is associated with insulin resistance. *Diabetes* **62(4)**, https://doi.org/1032-1035. 10.2337/db12-1612

Grossman, D.C., Bibbins-Domingo, K., Curry, S.J., Barry, M.J., Davidson, K.W., Doubeni, C.A., Epling, J.W., Kemper, A.R., Krist, A.H., Kurth, A.E. and Landefeld, C.S. and US Preventive Services Task Force. (2017) Screening for obesity in children and adolescents: US Preventive Services Task Force recommendation statement. *JAMA* **317(23)**, 2417-2426. https://doi.org/10.1001/jama.2017.6803

Guimarães, G.V., Ciolac, E.G., Carvalho, V.O., D'Avila, V.M., Bortolotto, L.A. and Bocchi, E.A. (2010) Effects of continuous vs. interval exercise training on blood pressure and arterial stiffness in treated hypertension. *Hypertension Research* **33(6)**, 627-632. https://doi.org/10.1038/hr.2010.42

Hay, J., Maximova, K., Durksen, A., Carson, V., Rinaldi, R.L., Torrance, B., Ball, G.D., Majumdar, S.R., Plotnikoff, R.C., Veugelers, P. and Boulé, N.G. (2012) Physical activity intensity and cardiometabolic risk in youth. *Archives of Pediatrics & Adolescent Medicine* **166(11)**, 1022-1029. https://doi.org/10.1001/archpediatrics.2012.1028

Holloszy, J.O. (2009) Skeletal muscle “mitochondrial deficiency” does not mediate insulin resistance. *The American Journal of Clinical Nutrition* **89(1)**, 463-466. https://doi.org/10.3945/ajcn.2008.26717C

Holloszy, J.O. (2013) “Deficiency” of mitochondria in muscle does not cause insulin resistance. *Diabetes* **62(4)**, 1036-1040. https://doi.org/10.2337/db12-1107

Jung, E., Kong, S.Y., Ro, Y.S., Ryu, H.H. and Shin, S.D. (2022) Serum cholesterol levels and risk of cardiovascular death: A systematic review and a dose-response meta-analysis of prospective cohort studies. *International Journal of Environmental Research and Public Health* **19(14)**, 8272. https://doi.org/10.3390/ijerph19148272

Kanaley, J., Weatherup-Dentes, M., Alvarado, C. and Whitehead, G. (2001) Substrate oxidation during acute exercise and with exercise training in lean and obese women. *European Journal of Applied Physiology* **85**, 68-73. https://doi.org/10.1007/s004210100404

Kelley, D.E., Goodpaster, B., Wing, R.R. and Simoneau, J.A. (1999) Skeletal muscle fatty acid metabolism in association with insulin resistance, obesity, and weight loss. *American Journal of Physiology-Endocrinology and Metabolism* **277(6)**, 1130-1141. https://doi.org/10.1152/ajpendo.1999.277.6.E1130

Ketelhut, S., Kircher, E., Ketelhut, S.R., Wehlan, E. and Ketelhut, K., (2020) Effectiveness of multi-activity, high-intensity interval training in school-aged children. *International Journal of Sports Medicine* **41(04)**, 227-232. https://doi.org/10.1055/a-1068-9331

Khaliltahmasebi, R., Minasian, V. and Hovsepian, S. (2022) Effects of two different school-based training on serum miR15b expression and lipid profile of adolescents with obesity. *International Journal of Preventive Medicine* **13**, 139. https://doi.org/10.4103/ijpvm.ijpvm_6_21

Kranen, S.H., Oliveira, R.S., Bond, B., Williams, C.A. and Barker, A.R. (2023) The effect of 4 weeks of high-intensity interval training and 2 weeks of detraining on cardiovascular disease risk factors in male adolescents. *Experimental Physiology* **108(4)**, 595-606. https://doi.org/10.1113/EP090340

Laursen, P.B. and Buchheit, M. (2019) in *Science and Application of High-Intensity Interval Training*, 1st Edn, Champaign: Human Kinetics. 17-26. https://doi.org/10.5040/9781492595830.ch-002

Langin, D. (2006) Adipose tissue lipolysis as a metabolic pathway to define pharmacological strategies against obesity and the metabolic syndrome. *Pharmacological Research* **53(6)**, 482-491. https://doi.org/10.1016/j.phrs.2006.03.009

Lira, F.S., Antunes, B.M., Figueiredo, C., Campos, E.Z., Panissa, V.L.G., St-Pierre, D.H., Lavoie, J.M. and Magri-Tomaz, L. (2019) Impact of 5-week high-intensity interval training on indices of cardio metabolic health in men. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* **13(2)**, 1359-1364. https://doi.org/10.1016/j.dsx.2019.02.006

Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., AlMazroa, M.A., Amann, M., Anderson, H.R., Andrews, K.G. and Aryee, M. (2012) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *The lancet* **380(9859)**, 2224-2260. https://doi.org/10.1016/S0140-6736(12)61766-8

Little, J.P., Safdar, A., Wilkin, G.P., Tarnopolsky, M.A. and Gibala, M.J. (2010) A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: potential mechanisms. *The Journal of physiology* **588(6)**, 1011-1022. https://doi.org/10.1113/jphysiol.2009.181743

Liu, J., Zeng, F.F., Liu, Z.M., Zhang, C.X., Ling, W.H. and Chen, Y.M. (2013) Effects of blood triglycerides on cardiovascular and all-cause mortality: a systematic review and meta-analysis of 61 prospective studies. *Lipids in Health and Disease* **12**, 1-11. https://doi.org/10.1186/1476-511X-12-159

Mann, S., Beedie, C. and Jimenez, A. (2014) Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations. *Sports Medicine* **44**, 211-221. https://doi.org/10.1007/s40279-013-0110-5

Maeda, S., Sugawara, J., Yoshizawa, M., Otsuki, T., Shimojo, N., Jesmin, S., Ajisaka, R., Miyauchi, T. and Tanaka, H. (2009) Involvement of endothelin-1 in habitual exercise-induced increase in arterial compliance. *Acta Physiologica* **196(2)**, 223-229. https://doi.org/10.1111/j.1748-1716.2008.01909.x

Martin, R., Buchan, D.S., Baker, J.S., Young, J., Sculthorpe, N. and Grace, F.M. (2015) Sprint interval training (SIT) is an effective method to maintain cardiorespiratory fitness (CRF) and glucose homeostasis in Scottish adolescents. *Biology of Sport* **32(4)**, 307-313. https://doi.org/10.5604/20831862.1173644

Martínez-Vizcaíno, V., Soriano-Cano, A., Garrido-Miguel, M., Cavero-Redondo, I., Medio, E.P.D., Madrid, V.M., Martínez-Hortelano, J.A., Berlanga-Macías, C. and Sánchez-López, M. (2022) The effectiveness of a high-intensity interval games intervention in schoolchildren: A cluster-randomized trial. *Scandinavian Journal of Medicine & Science in Sports* **32(4)**, 765-781. https://doi.org/10.1111/sms.14113

McNarry, M.A., Lester, L., Ellins, E.A., Halcox, J.P., Davies, G., Winn, C.O.N. and Mackintosh, K.A. (2021) Asthma and high-intensity interval training have no effect on clustered cardiometabolic risk or arterial stiffness in adolescents. *European Journal of Applied Physiology* **121**, 1967-1978. https://doi.org/10.1007/s00421-020-04590-4

Meng, C., Yucheng, T., Shu, L. and Yu, Z. (2022) Effects of school-based high-intensity interval training on body composition, cardiorespiratory fitness and cardiometabolic markers in adolescent boys with obesity: A randomized controlled trial. *BMC Pediatrics* **22(1)**, 1-11. https://doi.org/10.1186/s12887-021-03079-z

Muoio, D.M. and Neufer, P.D. (2012) Lipid-induced mitochondrial stress and insulin action in muscle. *Cell Metabolism* **15(5)**, 595-605. https://doi.org/10.1016/j.cmet.2012.04.010

Niebauer, J. and Cooke, J.P. (1996) Cardiovascular effects of exercise: role of endothelial shear stress. *Journal of the American College of Cardiology* **28(7)**, 1652-1660. https://doi.org/10.1016/S0735-1097(96)00393-2

Noris, M., Morigi, M., Donadelli, R., Aiello, S., Foppolo, M., Todeschini, M., Orisio, S., Remuzzi, G. and Remuzzi, A. (1995) Nitric oxide synthesis by cultured endothelial cells is modulated by flow conditions. *Circulation Research* **76(4)**, 536-543. https://doi.org/10.1161/01.res.76.4.536

Oliveira, R.S., Barker, A.R., Kranen, S.H., Debras, F. and Williams, C.A. (2021) Effects of High-Intensity Interval Training on the Vascular and Autonomic Components of the Baroreflex at Rest in Adolescents. *Pediatric Exercise Science* **34(1)**, 13-19. https://doi.org/10.1123/pes.2020-0220

Paahoo, A., Tadibi, V. and Behpoor, N. (2021) Effectiveness of continuous aerobic versus high-intensity interval training on atherosclerotic and inflammatory markers in boys with overweight/obesity. *Pediatric Exercise Science* **33(3)**, 132-138. https://doi.org/10.1123/pes.2020-0138

Plavsic, L., Knezevic, O.M., Sovtic, A., Minic, P., Vukovic, R., Mazibrada, I., Stanojlovic, O., Hrncic, D., Rasic-Markovic, A. and Macut, D. (2020) Effects of high-intensity interval training and nutrition advice on cardiometabolic markers and aerobic fitness in adolescent girls with obesity. *Applied Physiology, Nutrition, and Metabolism* **45(3)**, 294-300. https://doi.org/10.1139/apnm-2019-0137

Prospective Studies Collaboration (2002) Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *The Lancet* **360(9349)**, 1903-1913. https://doi.org/10.1016/s0140-6736(02)11911-8

Racil, G., Ben Ounis, O., Hammouda, O., Kallel, A., Zouhal, H., Chamari, K. and Amri, M. (2013) Effects of high vs. moderate exercise intensity during interval training on lipids and adiponectin levels in obese young females. *European Journal of Applied Physiology* **113**, 2531-2540. https://doi.org/10.1007/s00421-013-2689-5

Racil, G., Coquart, J.B., Elmontassar, W., Haddad, M., Goebel, R., Chaouachi, A., Amri, M. and Chamari, K. (2016a) Greater effects of high-compared with moderate-intensity interval training on cardio-metabolic variables, blood leptin concentration and ratings of perceived exertion in obese adolescent females. *Biology of Sport* **33(2)**, 145-152. https://doi.org/10.5604/20831862.1198633

Racil, G., Zouhal, H., Elmontassar, W., Abderrahmane, A.B., De Sousa, M.V., Chamari, K., Amri, M. and Coquart, J.B. (2016b) Plyometric exercise combined with high-intensity interval training improves metabolic abnormalities in young obese females more so than interval training alone. *Applied Physiology, Nutrition, and Metabolism* **41(1)**, 103-109. https://doi.org/10.1139/apnm-2015-0384

Rahmati-Ahmadabad, S., Shirvani, H., Ghanbari-Niaki, A. and Rostamkhani, F. (2018) The effects of high-intensity interval training on reverse cholesterol transport elements: A way of cardiovascular protection against atherosclerosis. *Life Sciences* **209**, 377-382. https://doi.org/10.1016/j.lfs.2018.08.036

Reljic, D., Frenk, F., Herrmann, H.J., Neurath, M.F. and Zopf, Y. (2020) Low-volume high-intensity interval training improves cardiometabolic health, work ability and well-being in severely obese individuals: A randomized-controlled trial sub-study. *Journal of Translational Medicine* **18(1)**, 1-15. https://doi.org/10.1186/s12967-020-02592-6

Reeves, B.C., Deeks, J.J., Higgins, J.P. and Wells, G.A. (2008) Including non-randomized studies. *Cochrane handbook for systematic reviews of interventions: Cochrane book series*. 389-432. https://doi.org/10.1002/9780470712184.ch13

Rosenkranz, S.K., Rosenkranz, R.R., Hastmann, T.J. and Harms, C.A. (2012) High-intensity training improves airway responsiveness in inactive nonasthmatic children: evidence from a randomized controlled trial. *Journal of Applied Physiology* **112(7)**, 1174-1183. https://doi.org/10.1152/japplphysiol.00663.2011

Rossow, L., Yan, H., Fahs, C.A., Ranadive, S.M., Agliovlasitis, S., Wilund, K.R., Baynard, T. and Fernhall, B. (2010) Postexercise Hypotenstion In An Endurance-trained Population Of Men And Women Following High-intensity Interval And Steady-state Cycling. *American Journal of Hypertension* **23(4)**, 358-367. https://doi.org/10.1038/ajh.2009.269

Ryan, B.J., Schleh, M.W., Ahn, C., Ludzki, A.C., Gillen, J.B., Varshney, P., Van Pelt, D.W., Pitchford, L.M., Chenevert, T.L., Gioscia-Ryan, R.A. and Howton, S.M. (2020) Moderate-intensity exercise and high-intensity interval training affect insulin sensitivity similarly in obese adults. *The Journal of Clinical Endocrinology & Metabolism* **105(8)**, 2941-2959. https://doi.org/10.1210/clinem/dgaa345

Salus, M., Tillmann, V., Remmel, L., Unt, E., Mäestu, E., Parm, Ü., Mägi, A., Tali, M. and Jürimäe, J. (2022a) Effect of sprint interval training on cardiometabolic biomarkers and adipokine levels in adolescent boys with obesity. *International Journal of Environmental Research and Public Health* **19(19)**, 12672. https://doi.org/10.1055/a-1068-9331

Salus, M., Tillmann, V., Remmel, L., Unt, E., Mäestu, E., Parm, Ü., Mägi, A., Tali, M. and Jürimäe, J. (2022b) Effect of supervised sprint interval training on cardiorespiratory fitness and body composition in adolescent boys with obesity. *Journal of Sports Sciences* **40(18),** 2010-2017. https://doi.org/10.1080/02640414.2022.2125199

Sayevand, Z., Nazem, F., Nazari, A., Sheykhlouvand, M. and Forbes, S.C. (2022) Cardioprotective effects of exercise and curcumin supplementation against myocardial ischemia-reperfusion injury. *Sport Sciences for Health* **18(3)**, 1011-1019. https://doi.org/10.1007/s11332-021-00886-w

Schenk, S. and Horowitz, J.F. (2007) Acute exercise increases triglyceride synthesis in skeletal muscle and prevents fatty acid-induced insulin resistance. *The Journal of Clinical Investigation* **117(6)**, 1690-1698. https://doi.org/10.1172/JCI30566

Sessa, W.C., Harrison, J.K., Barber, C.M., Zeng, D., Durieux, M.E., D'angelo, D.D., Lynch, K.R. and Peach, M.J. (1992) Molecular cloning and expression of a cDNA encoding endothelial cell nitric oxide synthase. *Journal of Biological Chemistry* **267(22)**, 15274-15276. https://doi.org/10.1016/S0021-9258(19)49528-8

Shaw, I., Shaw, B.S. and Krasilshchikov, O. (2009) Comparison of aerobic and combined aerobic and resistance training on low-density lipoprotein cholesterol concentrations in men: cardiovascular topic. *Cardiovascular Journal of Africa* **20(5)**, 290-295.

Sheykhlouvand, M., and Gharaat, M. (2024) Optimal homeostatic stress to maximize the homogeneity of adaptations to interval interventions in soccer players. *Frontiers in Physiology*. **15**:1377552 (2024). https://doi.org/10.3389/fphys.2024.1377552

Sheykhlouvand, M., Arazi, H., Astorino, T.A. and Suzuki, K. (2022) Effects of a new form of resistance-type high-intensity interval training on cardiac structure, hemodynamics, and physiological and performance adaptations in well-trained kayak sprint athletes. *Frontiers in Physiology* **13**, 850768. https://doi.org/10.3389/fphys.2022.850768

Sheykhlouvand, M., Khalili, E., Gharaat, M., Arazi, H., Khalafi, M. and Tarverdizadeh, B. (2018) Practical model of low-volume paddling-based sprint interval training improves aerobic and anaerobic performances in professional female canoe polo athletes. *The Journal of Strength & Conditioning Research* **32(8)**, 2375-2382. https://doi.org/10.1519/JSC.0000000000002152

Song, Y., and Sheykhlouvand, M. (2024) A Comparative Analysis of High-Intensity Technique-Specific Intervals and Short Sprint Interval Training in Taekwondo Athletes: Effects on Cardiorespiratory Fitness and Anaerobic Power. *Journal of Sports Science and Medicine*, **23(3)**, 672-683. https://doi.org/10.52082/jssm.2024.672

Sterne, J.A. and Egger, M. (2001) Funnel plots for detecting bias in meta-analysis: guidelines on choice of axis. *Journal of Clinical Epidemiology* **54(10)**, 1046-1055. https://doi.org/10.1016/s0895-4356(01)00377-8

Sugawara, J., Komine, H., Hayashi, K., Yoshizawa, M., Otsuki, T., Shimojo, N., Miyauchi, T., Yokoi, T., Maeda, S. and Tanaka, H. (2009) Reduction in α-adrenergic receptor-mediated vascular tone contributes to improved arterial compliance with endurance training. *International Journal of Cardiology* **135(3)**, 346-352. https://doi.org/10.1016/j.ijcard.2008.04.007

Tadiotto, M.C., Corazza, P.R.P., Menezes-Junior, F.J.D., Moraes-Junior, F.B.D., Tozo, T.A.A., Purim, K.S.M., Mota, J. and Leite, N. (2023) Effects and individual response of continuous and interval training on adiponectin concentration, cardiometabolic risk factors, and physical fitness in overweight adolescents. *European Journal of Pediatrics* **182(6)**, 2881-2889. https://doi.org/10.1007/s00431-023-04974-6

Tao, T., Zhang, N., Yu, D., and Sheykhlouvand, M. (2024) Physiological and Performance Adaptations to Varying Rest Distributions During Short Sprint Interval Training Trials in Female Volleyball Players: A Comparative Analysis of Interindividual Variability. *International Journal of Sports Physiology and Performance*, *1*(aop), 1-10. https://doi.org/10.1123/ijspp.2024-0104

Taylor, C., Sanders, R., Hoon, M., Starling, J. and Cobley, S. (2019) Can Sprint Interval Training (SIT) improve the psychological and physiological health of adolescents with SMI? *Evidence-Based Practice in Child and Adolescent Mental Health* **4(3)**, 219-234. https://doi.org/10.1080/23794925.2019.1586497

Timmis, A., Townsend, N., Gale, C.P., Torbica, A., Lettino, M., Petersen, S.E., Mossialos, E.A., Maggioni, A.P., Kazakiewicz, D., May, H.T. and De Smedt, D. (2020) European Society of Cardiology: cardiovascular disease statistics 2019. *European Heart Journal* **41(1)**, 12-85. https://doi.org/10.1093/eurheartj/ehz859

Tjønna, A.E., Stølen, T.O., Bye, A., Volden, M., Slørdahl, S.A., Ødegård, R., Skogvoll, E. and Wisløff, U. (2009) Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clinical Science* **116(4)**, 317-326. https://doi.org/10.1042/CS20080249

Trapp, E.G., Chisholm, D.J. and Boutcher, S.H. (2007) Metabolic response of trained and untrained women during high-intensity intermittent cycle exercise. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* **293(6)**, 2370-2375. https://doi.org/10.1152/ajpregu.00780.2006

Van Aggel-Leijssen, D.P., Saris, W.H., Wagenmakers, A.J., Senden, J.M. and Van Baak, M.A. (2002) Effect of exercise training at different intensities on fat metabolism of obese men. *Journal of Applied Physiology* **92(3)**, 1300-1309. https://doi.org/10.1152/japplphysiol.00030.2001

van Biljon, A., McKune, A.J., DuBose, K.D., Kolanisi, U. and Semple, S.J. (2018) Do short-term exercise interventions improve cardiometabolic risk factors in children? *The Journal of Pediatrics* **203**, 325-329. https://doi.org/10.1016/j.jpeds.2018.07.067

Wan, X., Wang, W., Liu, J. and Tong, T. (2014) Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Medical Research Methodology* **14**, 1-13. https://doi.org/10.1186/1471-2288-14-135

Whyte, L.J., Gill, J.M. and Cathcart, A.J. (2010) Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men. *Metabolism* **59(10)**, 1421. https://doi.org/1428. 10.1016/j.metabol.2010.01.002

Williams, R.A., Dring, K.J., Morris, J.G., Sunderland, C., Nevill, M.E. and Cooper, S.B. (2022) Effect of two-weeks of school-based sprint training on physical fitness, risk factors for cardiometabolic diseases and cognitive function in adolescent girls: A randomized controlled pilot trial. *Frontiers in Sports and Active Living* **4**, 884051. https://doi.org/10.3389/fspor.2022.884051

Xie, X., Atkins, E., Lv, J., Bennett, A., Neal, B., Ninomiya, T., Woodward, M., MacMahon, S., Turnbull, F., Hillis, G.S. and Chalmers, J. (2016) Effects of intensive blood pressure lowering on cardiovascular and renal outcomes: updated systematic review and meta-analysis. *The Lancet* **387(10017)**, 435-443. https://doi.org/10.1016/S0140-6736(15)00805-3

Zhu, L., Liu, J., Yu, Y. and Tian, Z. (2021) Effect of high-intensity interval training on cardiometabolic risk factors in childhood obesity: a meta-analysis. *The Journal of Sports Medicine and Physical Fitness* **61(5)**, 743-752. https://doi.org/10.23736/S0022-4707.20.11329-X

Key points

- This study indicates broad efficacy of HIIT, with significant improvements in insulin and insulin resistance, triglyceride, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, systolic blood pressure, and diastolic blood pressure in the mentioned categories.
- Importantly, subgroup analysis revealed SIT as a highly effective modality of HIIT in modulating the mentioned variables.
- Integrating HIIT, especially SIT, into pediatric exercise regimens can significantly improve metabolic markers, offering a promising strategy to reduce the long-term risk of cardiovascular diseases in this vulnerable population.

AUTHOR BIOGRAPHY

Yuan SONG
Employment
Lecturer, Department of Physical Education, Chongqing University of Technology, China
Degree
MSc. PhD student
Research interests
Physical education, training, exercise, Taekwondo, Traditional Chinese Sports
E-mail: songyuan1986@outlook.com

Huihui LAN
Employment
Faculty of Social Sciences and Liberal Arts, UCSI University, Kuala Lumpur, Malaysia
Degree
MSc. PhD student
Research interests
Teacher education, educational management, ICT-based teaching
E-mail: lanhuihui1987@outlook.com

✉ **Huihui Lan**
Faculty of Social Sciences and Liberal Arts, UCSI University, Kuala Lumpur, Malaysia