ORIGINAL RESEARCH ARTICLE

Diponegoro International Medical Journal 2025 July, Vol 6, No.1: 7-15
e-ISSN: 2745-5815

A Systematic Review of High-Intensity Interval Training Protocols and Their Effects in BMI And Metabolic Biomarkers in Obese Adolescents: A Focus on Randomized Controlled Trials

Tanti Ajoe Kesoema[1*], Carissa Putri Crisdayani[2], Elita Syaravina[2], Denta Wulansari[3], Banundari Rachmawati[4], Hardhono Susanto[5], Angela Bibiana Maria Tulaar[6]

[1]*Doctoral Study Program of Medical and Health Science, Diponegoro University, Semarang, Indonesia*
[2]*Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Diponegoro University, Semarang, Indonesia*
[3]*General Practitioner, Panembahan Senopati Regional General Hospital, Bantul, Special Region of Yogyakarta, Indonesia*
[4]*Departement of Clinical Pathology, Faculty of Medicine, Diponegoro University, Semarang, Indonesia*
[5]*Department of Anatomy and Histology, Faculty of Medicine, Diponegoro University, Semarang, Indonesia*
[6]*Department of Physical Medicine and Rehabilitation, Faculty of Medicine, University of Indonesia, Jakarta, Indonesia*

Keywords:

Adolescent Obesity
Body Mass Index
High-Intensity Interval Training
Insulin Resistance
Metabolic Health

*) Correspondence to:
tantiajoekesoema@students.undip.ac.id.

Article history:

Received 04-05-2025
Accepted 06-05-2025
Availableonline 30-07 2025

ABSTRACT

Background: Adolescent obesity is a growing public health concern, associated with chronic diseases such as cardiovascular disease, type 2 diabetes, and non-alcoholic fatty liver disease. High-Intensity Interval Training (HIIT) has been identified as a potential intervention to improve weight management and metabolic health in this population.
Objective: To evaluate the impact of HIIT, alone or in combination with dietary advice, on weight management and metabolic health indicators, including Body Mass Index (BMI), fasting serum glucose levels, and metabolic biomarkers in adolescents with overweight or obesity.
Methods: : This systematic review included randomized controlled trials (RCTs) focusing on adolescents aged 16 to 19 with a BMI of 23 kg/m² or above. Studies were selected based on predefined criteria, excluding cross-over trials and quasi-randomized studies. Primary outcomes were changes in BMI, fasting serum glucose, and metabolic biomarkers. Secondary outcomes included measures of insulin resistance. The GRADE methodology was used to appraise the certainty of evidence.
Results: Five RCTs were included, demonstrating that HIIT, especially when combined with dietary advice, significantly improves insulin sensitivity, reduces waist circumference, and enhances cardiometabolic health. The interventions varied in duration and intensity but consistently showed positive outcomes in physical fitness, metabolic biomarkers, and body composition.
Conclusion: HIIT, particularly when integrated with dietary advice, offers a promising strategy for managing obesity and improving metabolic health among adolescents. This review supports the adoption of multidisciplinary approaches in clinical practice, aiming to enhance the overall health outcomes of adolescents with overweight or obesity.

DIMJ, 2025, 6(1), 7-15 DOI: https://doi.org/10.14710/dimj.v6i1.26720

1. Introduction

Overweight is defined based on the Body Mass Index (BMI), a simple index of weight-for-height commonly used to classify overweight and obesity in adults. It is defined as a person's weight in kilograms divided by the square of his height in meters (kg/m^2). For adults, WHO defines overweight as a BMI greater than or equal to 25, and obesity as a BMI greater than or equal to 30.[1] The prevalence of obesity has been rising alarmingly worldwide, with estimates suggesting that 1.5 billion adults were overweight or obese as of 2016, and this number is expected to rise to 3 billion by 2030.[1,2] : Globally, there has been a significant increase in the rates of obesity among children and adolescents, a trend that extends beyond adults.[3]

High-Intensity Interval Training (HIIT) has been studied extensively for its effects on various health parameters, including body composition and metabolic biomarkers in obese adolescents. The research indicates that HIIT can lead to improvements in cardiometabolic risk factors, body composition, and cardiorespiratory fitness. HIIT has been shown to improve body composition in terms of reducing body weight, body mass index (BMI), and body fat percentage in obese adolescents.[4–9] A study noted that a five-week HIIT program Each session started with a 5-minute standardized warm-up and concluded with a 5-minute cool-down with static stretching. Participants engaged in 20 minutes of high-intensity interval training (HIIT), which consisted of two segments, each containing 10 intervals of 30 seconds of cycling at 100% peak power output (PPO) at the ventilatory threshold, followed by 30 seconds of recovery cycling at 50% PPO; this intensity approximates the level that maximizes fat-burning rate. A 5-minute passive recovery interval separated the two blocks. A gradual increase in the total duration of training sessions was implemented, extending from 35 to 45 and then to 55 minutes, thereby enhancing glucose metabolism in obese young women.[8] Another study showed that people lost a lot of weight, body mass index (BMI), and fat after doing an 8-week high-intensity interval training (HIIT) program. This program included 2 sets of 15 rounds of 20 seconds of intense exercise at 85–95% of their maximum aerobic speed (MAS), followed by 15 rounds of 20 seconds of recovery at 50% MAS, done three times a week, compared to moderate-intensity continuous exercise (MICE).[9] HIIT has been linked to better lipid profiles, which means it can lower total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG), while sometimes raising high-density lipoprotein cholesterol (HDL-C).[6–8] Improvements in insulin sensitivity and reductions in fasting insulin levels have also been observed following HIIT interventions.[8] However, some studies have reported no significant changes in LDL and HDL cholesterol levels after HIIT interventions.[6]

HIIT is a popular form of exercise involving short bursts of intense activity interspersed with rest or low-intensity periods. Despite its numerous benefits like enhancing cardiovascular fitness and boosting metabolic rate, HIIT also carries certain risks and adverse effects. These include increased risk of injuries, overexertion leading to fatigue and dehydration, stress on the heart especially for those with pre-existing conditions, mental health challenges like stress and anxiety, and frustration due to lack of progress. To mitigate these risks, it is important to warm up adequately, ease into HIIT gradually, stay hydrated and nourished, prioritize rest and recovery, and maintain proper form during workouts. Consulting with a healthcare professional is advisable.[10] The lack of studies exists due to the numerous variations of HIIT protocols; no single technique consistently influences BMI and metabolic parameters.

This study looks at how different types of high-intensity interval training (HIIT) affect weight management (BMI) and metabolic changes in adolescents with obesity.

2. Methods

Inclusion and Exclusion Criteria

Restriction criteria for this systematic review consist of inclusion criteria: randomized controlled studies (RCT) in the English language only, participants of the study were adolescents aged 16 to 19 diagnosed with obesity by healthcare professionals, with a BMI of 25 kg/m^2, a minimum follow-up duration of three weeks starting from the baseline, and full-text access study. Then, the exclusion criteria were cross-over trials and quasi- randomized studies because of their heterogeneity, subjects with comorbidities, including heart disease (METs <5), cancer, and cognitive impairment. We do not restrict study based on year publication or publication status. We compared structured HIIT protocols against varying durations and intensities of HIIT, which was the intervention of interest. Outcomes of interest included changes in BMI and metabolic biomarkers such as fasting serum glucose levels, cholesterol, and triglycerides.

This systematic review includes randomized controlled trials (RCTs) that meet specific criteria and leaves out cross-over trials and quasi-randomized studies to reduce differences among the studies. Eligibility for inclusion was not restricted by publication status or language, encompassing full texts, abstracts, and gray literature, provided the eligibility criteria were verifiable. Participants included were adolescents and adults with a BMI of 25 kg/m² or above, excluding individuals with specific comorbid conditions. We compared structured HIIT protocols against varying doses of HIIT, which was the intervention of interest. Outcomes of interest included changes in BMI, and metabolic biomarkers such as fasting serum glucose level, cholesterol and triglycerides. A minimum follow-up duration of three weeks from the baseline was required for study inclusion.

Outcome Measures

Primary outcome measures encompassed BMI, fasting serum glucose, and metabolic biomarkers including total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides. Secondary outcomes extended to measures of insulin resistance. These were measured using standard lab tests on blood samples taken before and after the intervention, along with follow-ups later on to see if the effects of HIIT lasted. The reliability of the evidence for each result was evaluated using the GRADE method, which led to a summary of findings that explained the size of the effects, the number of participants, and how confident we are in the effect estimates for each result. Any decisions to downgrade the certainty of evidence were to be explicitly justified, adhering to GRADE guidelines for formulating informative statements.

Search Strategy

We conduct the search on 23rd November 2024. Authors completed an initial computerized literature search in 3 electronic databases, including Scopus, ScienceDirect, and PubMed NCBI. The search was executed without language and year of publication limitations, incorporating additional strategies such as scanning reference lists and contacting study authors for potential inclusions. Boolean keyword used by authors were ("HIIT") AND ("MICT") AND ("Obesity") AND (“Adolescents").

Study Selection Process

The selection process involved comprehensive screening of records for relevance, with discrepancies resolved through consensus or third-party consultation. We employed a PRISMA flow diagram to visualize the selection process, listing excluded studies alongside their exclusion rationales.

Data Extraction

Data extraction was conducted independently by three reviewers, collating in-depth information on study methodology, participant demographics, intervention details, outcome measures, and study characteristics. In cases of insufficient information, study authors were contacted.

Assessment of Study Quality and Risk of Bias

The Cochrane RoB 2 tool was used to check for bias in the studies included, looking at both specific areas and the overall risk for the main results. Any disagreements were addressed through discussion or further consultation.

Data Synthesis

Data synthesis incorporated both quantitative and qualitative methodologies, adhering to statistical analysis guidelines outlined in the Cochrane Handbook. The analysis unit was determined by the level of randomization within RCTs. Efforts were made to obtain missing data from study authors, with attrition rates critically evaluated. The I^2 statistic was employed to quantify heterogeneity, with subgroup analyses conducted as warranted. The effects of the interventions were measured as risk ratios (RR) or odds ratios (OR) for yes/no outcomes, and as mean difference (MD) or standardized mean difference (SMD) for continuous outcomes, with each result including a 95% confidence interval (CI).

Publication Bias

Addressing potential publication bias involved seeking unpublished studies and scrutinizing bias within included studies during data synthesis and interpretation phases.

Sensitivity Analyses

Planned sensitivity analyses aimed to test the robustness of the review's findings, including considerations such as the exclusion of studies with high risk of bias or the implications of varying inclusion criteria.

Reporting

This review adheres to the PRISMA guidelines to ensure the transparency of reporting procedures.

Protocol Registration

The protocol registration process emphasizes the value of transparency in systematic reviews, facilitating peer review of the methodology before conducting the review and mitigating the risk of selective result reporting. This involves a detailed documentation of the review's rationale, hypothesis, objectives, methodologies, and analytical strategies on a platform such as PROSPERO (International Prospective Register of Systematic Reviews) (CDR42024596239).

Acknowledgment of Limitations

The review transparently acknowledges potential limitations, including biases and uncertainties within the findings, underscoring the commitment to rigorous and transparent methodological practices. This aligns closely with the research objective, offering a comprehensive evaluation of HIIT's effectiveness in managing obesity among adolescents.

3. Result

The PRISMA flow diagram presented illustrates a comprehensive systematic review process for identifying and selecting relevant research articles. The search strategy began with database searches across three major scientific databases: Scopus (31 articles), ScienceDirect (33 articles), and PubMed (30 articles), yielding an initial total of 94 records. Combining these search results led to the removal of 29 duplicate articles, leaving 65 unique articles for initial screening.

Predetermined exclusion criteria guided the evaluation of articles during the primary screening phase, resulting in the removal of 56 articles for a variety of reasons. The largest number of exclusions were due to wrong study design (30 articles), followed by wrong population (17 articles). Furthermore, we excluded seven articles because they used incorrect outcome measures, one because they used the wrong intervention type, and one because of language barriers.

The secondary screening phase involved accessing and reviewing full-text articles. At this stage, two articles were excluded because their full texts were inaccessible. The remaining seven full-text articles underwent detailed review against the inclusion criteria, resulting in the further exclusion of two articles based on full-text review criteria. This thorough selection process ultimately yielded five articles that met all inclusion criteria and quality standards for the final systematic review.

The systematic nature of this selection process ensures transparency and reproducibility while minimizing selection bias. The step-by-step narrowing down from a wide initial search to a specific final choice shows a careful method for finding the best and most relevant research to answer the specific research question. The clear documentation of reasons for exclusion at each stage provides important context for understanding the scope and limitations of the final article selection. This methodical approach to article selection strengthens the validity of the subsequent analysis and conclusions drawn from the selected studies.

The final five articles represent a carefully curated collection of research that specifically addresses the research objectives while meeting rigorous quality standards. These articles form the foundation for a comprehensive analysis of high-intensity interval training versus moderate-intensity continuous training in adolescents with obesity, offering helpful details about their comparative effectiveness for improving various health outcomes.

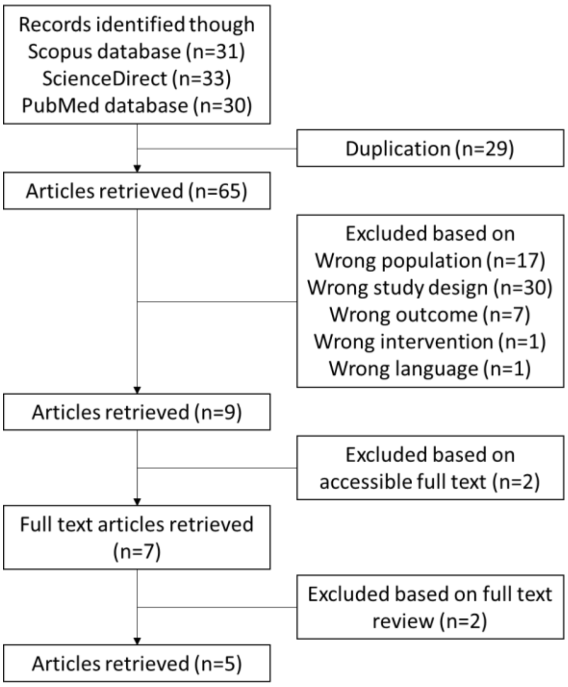

Figure 1. Flow Diagram of Study Selection

Table 1. Research Characteristics and Effect to BMI

Author	Country	Methods	Research Subject	Intervention	Results
Liao et al. (2024)	China	Randomized Controlled Trial	28 obese boys aged 10-18 years old, BMI 24–35 kg/m^2	12-weeks exercise program : 60-minute sessions: 10-min warm-up, 1-min exercise (80-90% max HR), 1-min recovery, 10-min stretching; aquatic vs. land environment	HIIT-Land: ↓ BMI (-1.8 kg/m); HIIT-Aquatic: ↓ BMI (-1.2 kg/m²)
Leite et al. (2022)	Brazil	Randomized Controlled Trial	62 obese boys aged 10-16 years old, BMI >25.0 kg/m^2	12-weeks exercise program: MICT, HIIT, or control (physical education classes only) HIIT : indoor cycling, 45 – 54 minutes sessions : 2 sets x 8 bout (100% Maximum Aerobic Speed) ; 30 seconds workout + 45 sec rest , 4-min recovery, 90 minutes warm up and cool down / weeks MICT : 90 minutes sessions ; 45 min indoor cycng, 45 min outdoor walking / running (35 – 75 % Functional Capacity reserve)	HIIT: ↓ BMI (-1.565 kg/m²) MICT: ↓ BMI (-0.035 kg/m²)
Meng et al. (2022)	China	Randomized Controlled Trial	42 obese boys aged 11.2 ± 0.7 years BMI 24.2 ± 1.0 kg/m^2	12- weeks exercise program : HIIT: 2 sets of 8 bouts, 15-sec high-intensity running (90-100% max aerobic speed) with low-intensity recovery; MICT: 30-min moderate-intensity running (60-70% max aerobic speed); Control: normal behaviors	HIIT: ↓ BMI (-1.8 kg/m²) MICT: ↓ BMI (-1.2 kg/m²)
Dias et al. (2018)	Australia and Norway	Randomized Controlled Trial	99 obese boys aged 7-16 years old, BMI >25.0 kg/m^2	12- weeks exercise program : HIIT: 4x4 min at 85-95% HRmax, 3x/week, 12 weeks; MICT: 44 min at 60-70% HRmax, 3x/week, 12 weeks	There was no significant intervention effect on BMI EMDs for the intervention group on BMI HIIT vs MICT , HIIT vs nutrition, MICT vs nutrition (0.0)
van Biljon et al. (2018)	South Africa	Randomized controlled trial	109 children aged 10-13 years (mean age 11.1 ± 0.8 years)	5 weeks exercise program of MICT (65-70% max HR), HIIT (>80% max HR), combined HIIT+MICT, or no training (control); 3 sessions/week	MICT, HIIT, and HIIT+MICT slightly increase in BMI MICT : ↑ BMI (0,1± 0.2 kg/m²) HIIT : ↑ BMI (0,7± 1.3 kg/m²) HIIT+MICT : ↑ BMI (0,6 ± 1.0 kg/m²) HIIT+MICT reduced waist circumference (-5.4%) and waist-to-hip ratio (-2.5%) more than MICT or HIIT alone.

*BMI : *body mass index ;* HR *: Heart Rate; HRmax : Maximal Heart Rate; HIIT : High Intensity Interval Training ; MICT :Moderate Intensity Continuous Training ; EMDs : Estimated mean differences*

Table 2. Research Effects to Metabolic Biomarkers

Author	Metabolic Biomarkers	VO2
Liao et al. (2024)	HIIT-Land: ↓ body fat% (-3.1%) HIIT-Aquatic: ↓ body fat% (-2.7%),	HIIT-Land:↑ VO_2max (+6.1 mL/kg/min); HIIT-Aquatic: ↑ VO_2max (+3.8 mL/kg/min)
Leite et al. (2022)	HIIT: ↓ body fat% (-3.9%); MICT: ↓ body fat% (-2.6%)	HIIT:↑ VO_2peak (+3.6 mL/kg/min); MICT: ↑ VO_2peak (+2.8 mL/kg/min)
Meng et al. (2022)	HIIT: ↓ fat mass (-1.6 kg), ↓ VAT (-53g), ↓ LDL-C (-17.2%); MICT: ↓ fat mass (-3.7 kg)	HIIT: ↑ VO_2max (+6.1 mL/kg/min), MICT: ↑ VO_2max (+3.8 mL/kg/min)
Dias et al. (2018)	HIIT: ↓ total body fat (-0.9%); MICT: ↓ total body fat (-0.8%)	HIIT: ↑ VO_2peak (+3.6 mL/kg/min), MICT: ↑ VO_2peak (+2.8 mL/kg/min),
van Biljon et al. (2018)	MICT, HIIT, and HIIT+MICT improved fasting glucose (-0.6, -0.9, -0.1) and CRP (-0.2, -1.0, -0.5).	MICT, HIIT, and HIIT+MICT improved VO2peak (0.5, 0.9, 0.5),

*BMI : *body mass index ; HR : Heart Rate; HRmax : Maximal Heart Rate; HIIT : High Intensity Interval Training ; MICT :Moderate Intensity Continuous Training ; EMDs : Estimated mean differences; VO_2max : Volume Oxygen Maximal ; VAT: Visceral Adipose Tissue ; LDL -C : Low Density Lipoprotein cholesterol; CRP : C- reactive Protein*.

Table 3. Risk of bias assessment for the RCT, taking into account the five ROB 2 criteria and the overall risk of bias. Include: bias

from how participants were randomly assigned (R), bias from changes in the planned treatments (D), bias from missing data on results (Mi), bias in how outcomes were measured (Me), bias in choosing which results to report (S), and the overall risk of bias (O).

Study	R	D	Mi	Me	S	O
Liao et al. (2024)	?	+	+	?	?	?
Leite et al. (2022)	?	+	+	?	+	?
Meng et al. (2022)	?	+	+	?	+	?
Dias et al. (2018)	+	+	?	+	+	?
Van Biljon et al. (2018)	?	+	+	?	+	?

4. Discussion

Mass Index (BMI) and body composition

Recent research has shown significant interest in the impact of high-intensity interval training (HIIT) on body mass index (BMI) and body composition in obese adolescents. The studies included in this systematic review consistently demonstrate the positive effects of HIIT on these parameters.

Liao et al. (2024) explore the possible implementation of converting the Land HIIT to the aquatic environment with the high-intensity interval training of Aquatic calisthenics. The results showed there were no significant differences in body composition, physical function, blood pressure, and

lipid metabolism index between two groups after intervention, which might be due to the high similarity of intervention regimens between the two groups. It was found that both the Aquatic HIIT group and the Land HIIT group could only reduce LDL-C concentrations without significant effects on other lipid metabolism indexes. The body may undergo adaptive changes due to HIIT, which could potentially promote fat catabolism, increase excessive oxygen consumption after intense exercise, and suppress appetite.[11]

Leite et al. reported a significant reduction in BMI of 1.6 kg/m² ($p<0.001$) in the HIIT group.[12] Similarly, Meng et al. noted a BMI reduction of 1.8 kg/m² in adolescents undergoing HIIT.[13] These consistent results across multiple studies strengthen the evidence supporting HIIT's effectiveness in reducing BMI among obese adolescents.

The impact of HIIT on body composition extends beyond BMI. Miguet et al. found that HIIT was particularly effective in reducing fat mass percentages, with a greater reduction observed in the HIIT group compared to Moderate-Intensity Continuous Training (MICT) (-4.7% vs. -2.8%, $p = 0.046$).[14] The evidence suggests that HIIT may be more efficient than MICT in targeting fat mass while potentially preserving lean body mass.

Song et al.'s study provided further insight into the effects of HIIT on body composition, reporting that body fat percentage decreased significantly more in the HIIT group compared to MICT.[15] Male participants experienced a 23.71% reduction, while females saw a 26.76% reduction ($p<0.05$). These findings indicate that HIIT may be particularly effective in reducing bodyfat percentages across genders.

The effectiveness of HIIT in improving body composition is supported by research not included in this review. For instance, a meta-analysis by Cao et al. corroborated the positive effects of HIIT on body composition in overweight and obese children and adolescents. Their analysis found that HIIT significantly reduced body fat percentage (MD = -1.60%, 95% CI: -2.32 to -0.88, $p < 0.001$) and body fat mass (MD = -1.37 kg, 95% CI: -1.99 to -0.75, $p < 0.001$) compared to control groups.[16]

However, it's important to note that not all studies have found HIIT to be superior to MICT in all aspects of body composition improvement. For example, Dias et al. reported no significant differences between HIIT and MICT groups in changes to visceral or subcutaneous fat.[17] This evidence suggests that while HIIT is effective, its superiority over MICT may depend on specific outcome measures and individual factors.

The mechanisms behind HIIT's effectiveness in improving body composition are multifaceted. HIIT has been shown to increase post-exercise oxygen consumption and fat oxidation, which may contribute to its fat-reducing effects. Additionally, HIIT has been associated with improvements in insulin sensitivity, which can positively influence body composition by enhancing glucose uptake and utilization in muscle tissue.

It's worth noting that the studies in this review implemented various HIIT protocols, ranging from 4x4 minute intervals at 85-95% HRmax to 4x3 minute intervals at 80-90% VO2peak. Despite these variations, the positive effects on BMI and body composition were consistent across studies, suggesting that different HIIT protocols can be effective for improving body composition in obese adolescents.

The long-term sustainability of these improvements is an important consideration. While the studies in this review demonstrated significant short-term benefits, research by Wewege et al. has suggested that the long-term effects of HIIT on body composition may be comparable to those of MICT when total energy expenditure is matched. This study highlights the need for further research into the long-term impacts of HIIT on body composition in obese adolescents.[18]

It's also crucial to consider the potential risks associated with HIIT in this population. While the studies included in this review did not report significant adverse events, other research has cautioned about the potential for overuse injuries or cardiovascular complications in untrained individuals engaging in high-intensity exercise. Therefore, proper supervision and gradual progression in HIIT programs for obese adolescents are essential.

The effectiveness of HIIT in improving body composition may also be influenced by dietary factors. While this review focused primarily on exercise interventions, it's important to note that combining HIIT with dietary interventions may lead to more pronounced improvements in body composition. A study by Paoli et al., although focused on adults, demonstrated that combining HIIT with a ketogenic diet led to greater reductions in body fat and improvements in body composition compared to HIIT alone.[19]

In contrast to the positive findings, some studies have reported less dramatic effects of HIIT on body composition. For instance, a study by Keating et al. found no significant differences in fat mass or fat-free mass changes between HIIT and MICT groups in overweight adults. While this study was not specific to adolescents, it points out that there is caution in generalizing the effects of HIIT across all populations and the importance of considering individual responses to different exercise modalities.[20]

The study by van Biljon et al. offers helpful information regarding the effects of short-term exercise interventions on BMI and body composition in children. Despite a slight increase in body weight observed across all groups, the combined HIIT+MICT intervention showed superior reductions in waist circumference (WC) compared to HIIT alone, with no improvement seen in the MICT group. The HIIT+MICT group significantly reduced the waist-to-hip ratio (WHR) compared to the HIIT group, while the MICT group showed no improvement. These findings align with previous research, such as the study by Racil et al., which demonstrated that 12 weeks of HIIT at 100%-110% of maximal aerobic speed led to greater improvements in WC compared to moderate-intensity interval training. The results suggest that combining HIIT and MICT may be more effective in reducing central obesity indicators than either method alone, which is particularly important as WC and WHR are recognized as independent predictors of cardiometabolic risk in children.[21]

HIIT has the potential to preserve or even increase lean body mass while reducing fat mass, which is particularly relevant for obese adolescents. Maintaining muscle mass during weight loss is crucial for long-term metabolic health and weight management. A study by Racil et al., although not included in this review, found that HIIT combined with strength training was more effective than MICT in improving body composition and preserving lean mass in obese adolescents.[22]

In conclusion, the evidence from this systematic review and supporting literature strongly suggests that HIIT is an effective intervention for improving BMI and body composition in obese adolescents. The consistent findings across multiple studies, despite variations in protocols, underscore the robustness of HIIT's effects. However, the mixed results in some areas and the potential risks associated with high-intensity exercise in this population call for individualized approaches and further research into long-term outcomes and optimal HIIT protocols for obese adolescents. Future studies should focus on identifying the most effective and safe HIIT protocols for this population, as well as investigating the combined effects of HIIT with dietary interventions to maximize improvements in body composition and overall health outcomes.

Metabolic Biomarker

Recent research has shown significant interest in the impact of high-intensity interval training (HIIT) on metabolic biomarkers in obese adolescents. The studies included in this systematic review provide compelling evidence for the positive effects of HIIT on various metabolic parameters.

Leite et al. reported significant improvements in lipid profiles following HIIT interventions. Their study indicated that HIIT led to an increase in HDL cholesterol (+5.6 mg/dL, $p=0.002$) and a reduction in triglycerides (-38.6 mg/dL, $p<0.001$).[12] These findings suggest that HIIT can positively influence lipid metabolism in obese adolescents, potentially reducing cardiovascular risk factors.

The study by Meng et al. offered additional information about the metabolic benefits of HIIT, demonstrating a significant decrease in LDL cholesterol (-17.2%, $p<0.05$) in the HIIT group.This reduction in LDL cholesterol is particularly important, as elevated LDL levels are associated with increased cardiovascular risk. The same study also reported improvements in insulin sensitivity, with HOMA-IR decreasing by 27.3% ($p<0.05$) in the HIIT group.[13]

Song et al.'s research corroborated these findings, showing significant reductions in total cholesterol (TC) and LDL cholesterol in male participants undergoing HIIT, with decreases of 10.64% and 11.73%, respectively.[15] Interestingly, their study also found significant differences in triglyceride levels between HIIT and MICT groups for both males and females ($p<0.01$), suggesting that HIIT may be particularly effective in improving lipid profiles across genders.

These results are supported by research not included in this review. For example, a study by Cao et al. showed that HIIT greatly lowered fasting insulin levels (MD = -2.39 μU/mL, 95% CI: -3.98 to -0.79, $p = 0.003$) and HOMA-IR (MD = -0.79, 95% CI: -1.06 to -0.52, $p < 0.001$) in overweight and obese kids and teens compared to those who didn't do HIIT. This meta-analysis also reported significant improvements in triglycerides and HDL cholesterol, further supporting the positive effects of HIIT on lipid profiles.[16]

However, it's important to note that not all studies have found consistent improvements across all metabolic biomarkers. In the study by Dias et al. (2018), reported no significant differences in visceral fat or subcutaneous fat were reported between a HIIT and MICT group. These findings suggest that although HIIT is powerful, its relative benefit over MICT may vary depending on both the measured outcome and the characteristics of the individuals involved. The underpinning mechanisms for HIIT 's body composition are complex. Separate observations have shown that HIIT enhances post-exercise oxygen consumption and fat oxidation, potentially contributing positively to its fat-reducing effects. In addition, HIIT is associated with improved insulin sensitivity, which can positively affect body composition by promoting glucose uptake and utilization in muscle tissue. The use of different HIIT protocols, including 4x4-minute intervals at 85-95% HRmax and 4x3-minute intervals at 80-90% VO2peak, is also noteworthy. However, all these studies reported beneficial effects on BMI and body composition, thus indicating that different protocols can work effectively to improve body composition for obese adolescents.[17]

The mechanisms behind HIIT's effectiveness in improving metabolic biomarkers are multifaceted. HIIT has been shown to enhance mitochondrial function and increase skeletal muscle oxidative capacity, which can lead to improved glucose uptake and insulin sensitivity. Additionally, HIIT may stimulate the release of myokines and other beneficial molecules that can positively influence metabolic health.

It's worth noting that the studies in this review implemented various HIIT protocols, ranging from 4x4 minute intervals at 85-95% HRmax to 4x3 minute intervals at 80-90% VO2peak. Despite these variations, the positive effects on metabolic biomarkers were generally consistent across studies, suggesting that different HIIT protocols can be effective for improving metabolic health in obese adolescents.

The long-term sustainability of these improvements is an important consideration. While the studies in this review demonstrated significant short-term benefits, research by Wewege et al. has suggested that the long-term effects of HIIT on metabolic health may be comparable to those of MICT when total energy expenditure is matched. This study highlights the need for further research into the long-term impacts of HIIT on metabolic biomarkers in obese adolescents.[18]

It's also crucial to consider the potential risks associated with HIIT in this population. While the studies included in this review did not report significant adverse events, other research has cautioned about the potential for overuse injuries or cardiovascular complications in untrained individuals engaging in high-intensity exercise. Therefore, proper supervision and gradual progression in HIIT programs for obese adolescents are essential.

The effectiveness of HIIT in improving metabolic biomarkers may also be influenced by dietary factors. While this review focused primarily on exercise interventions, it's important to note that combining HIIT with dietary interventions may lead to more pronounced improvements in metabolic health. A study by Paoli et al., although focused on adults, demonstrated that combining HIIT with a ketogenic diet led to greater improvements in lipid profiles and insulin sensitivity compared to HIIT alone.[19]

In contrast to the positive findings, some studies have reported less dramatic effects of HIIT on metabolic biomarkers. For instance, a study by Keating et al. found no significant differences in fasting glucose or insulin levels between HIIT and MICT groups in overweight adults.[20] While this study was not specific to adolescents, it points out that there is caution in generalizing the effects of HIIT across all populations and the importance of considering individual responses to different exercise modalities.

Van Biljon et al.'s study revealed significant improvements in several metabolic biomarkers across all exercise intervention groups. Fasting glucose levels showed significant reductions in all groups, with a trend towards greater improvement in the HIIT group compared to MICT and HIIT+MICT. C-reactive protein (CRP) levels were also significantly lower after training in all three groups, with HIIT showing the largest effect size. These findings are consistent with other studies in the field. For instance, Racil et al. found that HIIT led to improvements in glucose metabolism in obese young women after a five-week program. The study also reported significant reductions in resting heart rate across all intervention groups, with HIIT and HIIT+MICT showing larger effect sizes compared to MICT. This aligns with research by Gutin et al., which demonstrated a strong correlation between cardiorespiratory fitness and cardiac autonomic control in children. However, the study found no significant changes in fasting insulin levels or arterial stiffness after the 5-week interventions, contrasting with some longer-duration studies that have shown improvements in these areas. These results suggest that while short-term HIIT and combined HIIT+MICT interventions can effectively improve several metabolic biomarkers in children, some parameters may require longer intervention periods to show significant changes.[21]

The potential for HIIT to improve insulin sensitivity is particularly relevant for obese adolescents, given the increased risk of type 2 diabetes in this population. A study by Racil et al., although not included in this review, found that HIIT was more effective than MICT in improving insulin sensitivity and reducing fasting glucose levels in obese adolescents.[22] This supports the findings of Meng et al. and emphasizes the promise of HIIT as a strategy for preventing or managing insulin resistance in obese youth.[4]

In conclusion, the evidence from this systematic review and supporting literature strongly suggests that HIIT is an effective intervention for improving metabolic biomarkers in obese adolescents. The consistent findings across multiple studies, despite variations in protocols, underscore the robustness of HIIT's effects on lipid profiles, insulin sensitivity, and overall metabolic health. However, the mixed results in some areas and the potential risks associated with high-intensity exercise in this population call for individualized approaches and further research into long-term outcomes and optimal HIIT protocols for obese adolescents. The literature predominantly highlights boys, potentially influencing the outcomes of BMI and metabolic indicators due to the distinct metabolic differences between genders. Future studies should focus on identifying the most effective and safe HIIT protocols for this population, as well as investigating the combined effects of HIIT with dietary interventions to maximize improvements in metabolic health and overall health outcomes. The intensity and duration of HIIT sessions are crucial factors in determining the extent of its effects, with higher-intensity regimens leading to more pronounced benefits in fat loss, metabolic markers, and cardiovascular health. Tailoring HIIT interventions based on individual health goals and characteristics may further enhance its effectiveness, especially in populations dealing with obesity and its associated comorbidities. The review transparently acknowledges potential limitations, including biases and uncertainties within the findings, underscoring the commitment to rigorous and transparent methodological practices. This aligns closely with the research objective, offering a comprehensive evaluation of HIIT's effectiveness in managing obesity among adolescents,

5. Conclusion

This study demonstrates that High-Intensity Interval Training (HIIT) combined with dietary advice is an effective strategy for managing adolescent obesity and improving metabolic health. Evidence from randomized controlled trials shows HIIT enhances BMI, metabolic biomarkers, and physical fitness, regardless of exercise type or duration. A frequency of three weekly sessions at 80–95% HR 45 – 60 min max yields significant benefits. The most significant exercise from this study is indoor cycling, consisting of 45 to 54-minute sessions: 2 sets of 8 bouts at 100% Maximum Aerobic Speed; 30 seconds of exercise followed by 45 seconds of rest, with a 4-minute recovery, and 90 minutes allocated for warm-up and cool-down every week. These findings support implementing tailored, multidisciplinary interventions—integrating HIIT and nutrition—to effectively address adolescent obesity in clinical settings

Ethical Approval

Human ethics and consent to participate declarations not applicable in this study.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions

Tanti Ajoe Kesoema, Carissa Putri Crisdayani, Elita Syaravina, Denta Wulansari, Banundari Rachmawati, Hardhono Susanto, Angela Bibiana Maria Tulaar contributed to the design and implementation of the review, to the analysis of the results and to the writing of the manuscript.

Acknowledgments

The authors would like to express their gratitude towards the management of Diponegoro University for their support in conducting the study.

References

1. Ritchie H, Roser M. Obesity. Our World Data. 2017;
2. Zubery D, Kimiywe J, Martin HD. Prevalence of Overweight and Obesity, and Its Associated Factors Among Health-care Workers, Teachers, and Bankers in Arusha City, Tanzania. Diabetes Metab Syndr Obes. 2021;14:455–65.
3. WHO. Obesity and overweight [Internet]. Who.int. 2024 [cited 2024 Mar 17]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
4. Cao M, Tang Y, Li S, Zou Y. 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. Int J Environ Res Public Health. 2021 Nov;18(22).
5. Cao M, Tang Y, Zou Y. Integrating High-Intensity Interval Training into a School Setting Improve Body Composition, Cardiorespiratory Fitness and Physical Activity in Children with Obesity: A Randomized Controlled Trial. J Clin Med. 2022 Sep;11(18).
6. Khammassi M, Ouerghi N, Hadj-Taieb S, Feki M, Thivel D, Bouassida A. Impact of a 12-week high-intensity interval training without caloric restriction on body composition and lipid profile in sedentary healthy overweight/obese youth. J Exerc Rehabil. 2018 Feb;14(1):118–25.

7. Hu J, Liu M, Yang R, Wang L, Liang L, Yang Y, et al. Effects of high-intensity interval training on improving arterial stiffness in Chinese female university students with normal weight obese: a pilot randomized controlled trial. J Transl Med. 2022 Feb;20(1):60.
8. Racil G, Chelly MS, Coquart J, Padulo J, Teodor DF, Russo L. Long- and Short-Term High-Intensity Interval Training on Lipid Profile and Cardiovascular Disorders in Obese Male Adolescents. Child (Basel, Switzerland). 2023 Jul;10(7).
9. Zuo C, Ma X, Yang Y, Cui Y, Ye C. School-based high-intensity interval exercise program in children with overweight induce a greater improvements in body composition and physical fitness than moderate-intensity continuous exercise. BMC Public Health [Internet]. 2023;23(1):2210. Available from: https://doi.org/10.1186/s12889-023-17149-7
10. Joisten N, Gehlert S, Zimmer P. Is high-intensity interval training harmful to health? Trends Endocrinol Metab. 2022 Feb;33(2):85–6.
11. Liao T, Zheng C, Xue J, Wang YT. Effects of aquatic and land high-intensity interval trainings on selected bio- and physiological variables among obese adolescents. Front Endocrinol (Lausanne). 2024;15:1381925.
12. Leite N, Pizzi J, de Menezes Junior FJ, Tadiotto MC, de Jesus ÍC, Corazza PRP, et al. Effect of Mict and Hiit on Cardiometabolic Risk and Body Composition in Obese Boys. Rev Bras Med do Esporte. 2022;28(4):274–80.
13. Meng C, Yucheng T, Shu L, Yu Z. 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 Pediatr [Internet]. 2022;22(1):1–11. Available from: https://doi.org/10.1186/s12887-021-03079-z
14. Miguet M, Fearnbach NS, Metz L, Khammassi M, Julian V, Cardenoux C, et al. Effect of HIIT versus MICT on body composition and energy intake in dietary restrained and unrestrained adolescents with obesity. Appl Physiol Nutr Metab. 2020;45(4):437–45.
15. Song X, Cui X, Su W, Shang X, Tao M, Wang J, et al. Comparative effects of high-intensity interval training and moderate-intensity continuous training on weight and metabolic health in college students with obesity. Sci Rep [Internet]. 2024;14(1):1–13. Available from: https://doi.org/10.1038/s41598-024-67331-z
16. Cao M, Li S, Tang Y, Zou Y. A Meta-Analysis of High-Intensity Interval Training on Glycolipid Metabolism in Children With Metabolic Disorders. Front Pediatr. 2022;10(May).
17. Dias KA, Ingul CB, Tjønna AE, Keating SE, Gomersall SR, Follestad T, et al. Effect of High-Intensity Interval Training on Fitness, Fat Mass and Cardiometabolic Biomarkers in Children with Obesity: A Randomised Controlled Trial. Sport Med. 2018;48(3):733–46.
18. Wewege M, van den Berg R, Ward RE, Keech A. The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis. Obes Rev an Off J Int Assoc Study Obes. 2017 Jun;18(6):635–46.
19. Paoli A, Moro T, Marcolin G, Neri M, Bianco A, Palma A, et al. High-Intensity Interval Resistance Training (HIRT) influences resting energy expenditure and respiratory ratio in non-dieting individuals. J Transl Med. 2012 Nov;10:237.
20. Keating SE, Croci I, Wallen MP, Cox ER, Thuzar M, Pham U, et al. High-Intensity Interval Training is Safe, Feasible and Efficacious in Nonalcoholic Steatohepatitis: A Randomized Controlled Trial. Dig Dis Sci. 2023 May;68(5):2123–39.
21. van Biljon A, McKune AJ, DuBose KD, Kolanisi U, Semple SJ. Do Short-Term Exercise Interventions Improve Cardiometabolic Risk Factors in Children? J Pediatr [Internet]. 2018;203:325–9. Available from: https://doi.org/10.1016/j.jpeds.2018.07.067
22. Racil G, Russo L, Migliaccio GM, Signorelli P, Larion A, Padulo J, et al. High-Intensity Interval Training in Female Adolescents with Moderate or Severe Obesity. Child (Basel, Switzerland). 2023 Sep;10(9).