Majalah Ilmiah Fisioterapi Indonesia
Indonesian Scientific Journal of Physiotherapy

Systematic Reviews / Literature Reviews
ISSN (Print): 2303-1921
ISSN (Online): 2722-0443
Volume 14, Number 2, Pages xx-xx (2026)
DOI: https://doi.org/10.24843/mifi.000001831

Effects of Aerobic Exercise on VO_2max in Overweight and Obese Adolescents: A Systematic Review

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Received 17 April 2026; Revised 21 April 2026; Accepted 23 April 2026; Published 15 May 2026

Abstract

Background: Overweight and obesity in adolescents are associated with reduced cardiorespiratory fitness (CRF) and increased cardiometabolic risk. Although aerobic exercise is widely recommended, its effectiveness in improving maximal oxygen consumption (VO_2max) in this population remains inconsistent.

Objective: To systematically evaluate the effects of aerobic exercise on VO_2max in overweight and obese adolescents.

Methods: This systematic review followed PRISMA guidelines and the PICOS framework. Literature searches were conducted in Scopus, PubMed, Semantic Scholar, and Google Scholar up to March 2026. Studies were screened independently by two reviewers. Eligible studies included experimental and quasi-experimental designs involving adolescents (10–19 years) with overweight or obesity, receiving aerobic exercise interventions, and reporting VO_2max or VO_2peak outcomes. Risk of bias was assessed using standard tools. Due to heterogeneity, a narrative synthesis was performed.

Results: Six studies were included. Aerobic exercise improved VO_2max across all studies, with increases ranging from +2.12 to +6.10 mL/kg/min in intervention groups compared to +0.34 to +1.70 mL/kg/min in controls. High-Intensity Interval Training (HIIT) consistently produced greater improvements than moderate-intensity continuous training ($p < 0.05$). Reductions in body fat and body mass index were also reported. Methodological limitations and moderate risk of bias were observed.

Conclusion: Aerobic exercise, particularly HIIT, improves VO_2max in overweight and obese adolescents. The overall strength of evidence is moderate, supporting the use of structured, time-efficient aerobic exercise programs in this population.

Keywords
Exercise; Maximal Oxygen Consumption; Adolescent; Obesity; Overweight; High-Intensity Interval Training

Introduction

Overweight and obesity among adolescents have emerged as one of the most critical global public health challenges. Recent estimates indicate that more than 390 million children and adolescents aged 5–19 years were overweight in 2022, including approximately 160 million living with obesity.[1,2] The prevalence has increased substantially over recent decades, with obesity rates rising nearly fourfold since 1990.[2] Furthermore, projections suggest that without effective interventions, the global burden of adolescent overweight and obesity will continue to escalate, thereby increasing the risk of long-term non-communicable diseases.[2]

Adolescence represents a critical developmental period characterized by rapid physiological, metabolic, and behavioral changes. Excess adiposity during this stage is strongly associated with an increased risk of cardiovascular disease, metabolic syndrome, and type 2 diabetes later in life.[2] In addition to physical health consequences, obesity during adolescence also affects psychosocial well-being and long-term quality of life, reinforcing the urgency of early and effective intervention strategies.[3]

Cardiorespiratory fitness (CRF), commonly assessed through maximal oxygen consumption (VO_2max), is a fundamental indicator of cardiovascular and respiratory efficiency and a strong predictor of overall health in children and adolescents.[4] Lower CRF levels are consistently observed in individuals with overweight and obesity and are associated with increased cardiometabolic risk and inflammation.[5] Consequently, improving CRF has become a central target in interventions aimed at mitigating the health consequences of adolescent obesity.[6]

Aerobic exercise is widely recognized as an effective intervention to improve CRF and overall health outcomes.[7] It enhances oxygen transport and utilization through central and peripheral adaptations, including increased stroke volume, capillary density, and mitochondrial efficiency.[8] High-Intensity Interval Training (HIIT), in particular, has gained increasing attention due to its time efficiency and its ability to induce greater physiological adaptations compared with moderate-intensity continuous training (MICT).[9,10]

Despite the growing body of literature, existing systematic reviews often include heterogeneous populations and do not specifically focus on overweight and obese adolescents. In many cases, cardiorespiratory fitness is not evaluated as the primary outcome, limiting the applicability of findings for this high-risk group.[11] Moreover, variations in exercise protocols, intervention duration, and outcome measurements contribute to inconsistent conclusions regarding the effectiveness of aerobic exercise on VO_2max.[12]

However, no systematic review has specifically evaluated the effects of aerobic exercise on VO_2max exclusively in overweight and obese adolescents using a focused and outcome-specific approach.

Therefore, this study aimed to systematically evaluate the effects of aerobic exercise on VO_2max in overweight and obese adolescents. The research question was formulated based on the PICOS framework: *In overweight and obese adolescents, does aerobic exercise, compared with usual activity or alternative interventions, improve VO_2max in experimental studies?*

Methods

This study employed a systematic review design conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review aimed to evaluate the effects of aerobic exercise on cardiorespiratory fitness, specifically maximal oxygen consumption (VO_2max), in overweight and obese adolescents. The study protocol was not registered in an international database such as PROSPERO. This represents a methodological limitation; however, all review procedures were predefined prior to data collection to minimize bias.

The eligibility criteria were established using the PICOS framework. The population included adolescents aged 10–19 years classified as overweight or obese according to standard criteria reported in each study. The intervention comprised structured aerobic exercise programs, including but not limited to High-Intensity Interval Training (HIIT) and moderate-intensity continuous training (MICT). Comparators included control groups, usual physical activity, or alternative exercise interventions. The primary outcome was cardiorespiratory fitness measured using VO_2max or VO_2peak. Only experimental and quasi-experimental study designs were included to ensure a higher level of evidence.

Studies were included if they were published between 2015 and 2025. This time restriction was applied to capture the most recent developments in exercise protocols and ensure the relevance of findings to current clinical and public health contexts. Studies were excluded if they involved non-adolescent populations, did not specifically include overweight or obese participants, did not report VO_2max outcomes, or were review articles, conference abstracts, or non-peer-reviewed publications.

A comprehensive literature search was conducted in four electronic databases, namely Scopus, PubMed, Semantic Scholar, and Google Scholar, with the final search performed in March 2026. The search strategy was developed by combining keywords related to aerobic exercise, cardiorespiratory fitness, maximal oxygen consumption (VO_2max), adolescents, overweight, and obesity using Boolean operators (AND, OR). To ensure reproducibility and transparency, the search strings were adapted to the specific syntax of each database. In PubMed, the search strategy was applied using field restrictions, as follows: (“aerobic exercise”[Title/Abstract] OR “aerobic training”) AND (“VO2max” OR “cardiorespiratory fitness”) AND (adolescent OR teenager) AND (overweight OR obese). In Scopus, the search was conducted using the TITLE-ABS-KEY function with an equivalent combination of keywords. For Semantic Scholar and Google Scholar, similar keyword combinations were used without field restrictions, following the platform-specific search capabilities. This structured approach was employed to maximize sensitivity and specificity in identifying relevant studies while maintaining consistency across databases.

All retrieved records were imported into Zotero reference management software for duplicate removal. The screening process was conducted using the Rayyan platform. Two independent reviewers screened titles and abstracts, followed by full-text assessment based on predefined eligibility criteria. Disagreements between reviewers were resolved through discussion and consensus to ensure objectivity and reduce selection bias.

Data extraction was performed using a standardized data extraction form developed prior to analysis. Extracted variables included study characteristics (author, year, country), participant details (sample size, age, sex, obesity status), study design, intervention characteristics (type, intensity, duration, frequency), comparator details, outcome measures (VO_2max or VO_2peak), and main findings. To enhance reliability, data extraction was conducted independently by two reviewers, and discrepancies were resolved through consensus. The measurement of VO_2max varied across studies, including both direct laboratory-based assessments and indirect field tests. Although these methods are widely used, variability in measurement approaches may influence comparability across studies.

The methodological quality and risk of bias of included studies were assessed using established tools appropriate to study design. Randomized controlled trials were evaluated using the Cochrane Risk of Bias tool, while quasi-experimental studies were assessed using the ROBINS-I tool. These instruments are widely used and validated for assessing internal validity in intervention studies. The methodological quality and risk of bias of included studies were assessed using established tools appropriate to study design. Randomized controlled trials were evaluated using the Cochrane Risk of Bias tool (RoB 2), while quasi-experimental studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool. These instruments are widely recommended for assessing internal validity and potential bias in intervention studies.[13,14]

Due to substantial heterogeneity in study design, intervention protocols, duration, and outcome measurement methods, a quantitative meta-analysis was not performed. Instead, a narrative synthesis approach was applied. The synthesis focused on identifying patterns in VO_2max improvements, comparing intervention and control groups, and examining differences between HIIT and MICT protocols. Heterogeneity was addressed qualitatively by considering variations in intensity, duration, and intervention settings.

Effect measures were reported as changes in VO_2max (mL/kg/min) between pre- and post-intervention values, as well as differences between intervention and control groups where available. Statistical significance was reported based on p-values as presented in the original studies ($\alpha = 0.05$). Assessment of reporting bias, such as publication bias, was not formally conducted due to the limited number of included studies. Similarly, no formal grading of evidence certainty (e.g., GRADE approach) was performed, which should be considered a limitation of this review. Assessment of the certainty of evidence was conducted using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework. This approach evaluates the overall quality of evidence based on several domains, including risk of bias, inconsistency, indirectness, imprecision, and publication bias.[15]

The study selection process can be summarized as follows: A total of 417 records were identified through database searching. After removal of 112 duplicates, 356 records remained for title and abstract screening. Following this stage, irrelevant studies were excluded, and full-text articles were assessed for eligibility. Six studies met all inclusion criteria and were included in the final analysis.

Results

A total of 417 records were identified through database searching. After removing 112 duplicates, 356 records remained for title and abstract screening. Following this stage, 41 articles were assessed for full-text eligibility. Of these, 35 studies were excluded due to reasons including inappropriate population, absence of VO_2max outcomes, non-experimental design, or insufficient data reporting. Ultimately, six studies met all inclusion criteria and were included in the final synthesis. To ensure transparency in the study identification and selection process, the flow of included and excluded studies is presented in a structured format based on PRISMA guidelines. This presentation aims to clearly illustrate the number of records at each stage and the reasons for exclusion, thereby enhancing reproducibility and methodological rigor. The study selection process is summarized in Figure 1, presented according to the PRISMA 2020 guidelines.

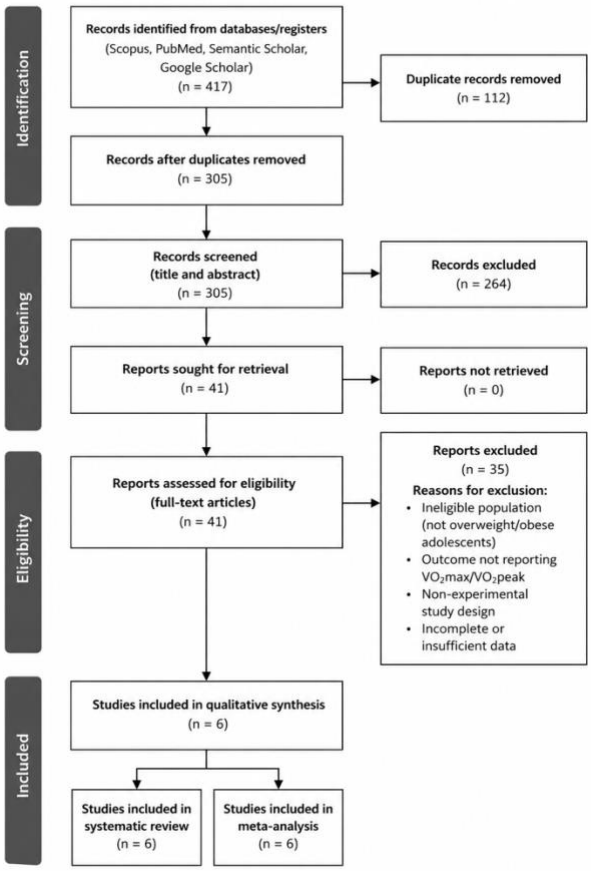

Figure 1. PRISMA 2020 Flow Diagram of Study Selection Process for the Systematic Review and Meta-analysis

The included studies comprised randomized controlled trials and quasi-experimental designs conducted between 2017 and 2025. Sample sizes ranged from 27 to 40 participants, with participants aged between 10 and 17 years. All studies involved adolescents classified as overweight or obese based on standard criteria. To provide a clear overview of study characteristics, interventions, and outcomes, a summary of the included studies is presented in Table 1.

Table 1. Summary of Included Studies on Aerobic Exercise and VO_2max

Study	Design	Sample (n)	Intervention	Duration	Outcome (VO_2max/VO_2peak)
Habibi & Ghanbarzadeh (2017)[16]	Quasi-experimental	27	Aerobic exercise (70–85% HRmax)	8 weeks, 3x/week	↑ VO_2max (+2.12), ↓ BMI, BF
Das (2023)[17]	Experimental	40	Aerobic + health program	12 weeks, 3x/week	↑ VO_2max (+7.22 vs +0.34 control), p<0.05
Gao et al. (2025)[18]	RCT	30	Concurrent training (HIIT/SIT)	8 weeks, 2x/week	↑ VO_2max (+6.1), ↓ BMI, fat
Meng et al. (2022)[19]	RCT	36	HIIT vs MICT	12 weeks, 3x/week	HIIT > MICT (Δ6.1 vs 3.8), p<0.01
Cao et al. (2022)[20]	RCT	40	HIIT	12 weeks, 3x/week	↑ VO_2max (+4.5 vs +1.7), p<0.05
Malau et al.[21]	Quasi-experimental	30	Bodyweight HIIT	8 weeks, 3x/week	↑ VO_2max (+5.78 vs +0.71), p<0.001

Across all included studies, aerobic exercise interventions consistently improved cardiorespiratory fitness, as measured by VO_2max or VO_2peak. The magnitude of improvement in intervention groups ranged from +2.12 to +6.10 mL/kg/min, whereas control groups showed smaller increases ranging from +0.34 to +1.70 mL/kg/min. These findings indicate a consistent beneficial effect of aerobic exercise compared with usual activity or non-intervention controls. Effect size measures such as standardized mean difference and confidence intervals were not consistently reported across included studies, precluding quantitative synthesis. Therefore, only mean changes in VO_2max were descriptively summarized.

Intervention characteristics showed a clear pattern across studies. Most interventions employed High-Intensity Interval Training (HIIT), either as a standalone protocol or in combination with other training modalities. Exercise frequency typically ranged from two to three sessions per week, with intervention durations between 8 and 12 weeks. Session durations varied from 11 to 90 minutes depending on protocol design. Intensity levels were generally reported within moderate to high ranges (approximately 70–100% of maximal capacity or maximal aerobic speed).

Comparative analyses within studies demonstrated that HIIT consistently produced greater improvements in VO_2max compared to moderate-intensity continuous training (MICT). For example, one randomized controlled trial reported an increase of approximately +6.1 mL/kg/min in the HIIT group compared to +3.8 mL/kg/min in the MICT group ($p < 0.01$). Similarly, other studies reported significantly greater improvements in intervention groups compared with controls ($p < 0.05$), supporting the superior effectiveness of higher-intensity aerobic exercise protocols.

In addition to improvements in cardiorespiratory fitness, several studies reported secondary outcomes, including reductions in body mass index, body fat percentage, and visceral fat. Although these outcomes were not the primary focus of this review, they consistently aligned with improvements in VO_2max.

Risk of bias assessment indicated that most studies had a moderate risk of bias. Common methodological limitations included small sample sizes, lack of participant and personnel blinding, and, in quasi-experimental studies, absence of randomization. These factors should be considered when interpreting the overall findings.

No quantitative synthesis or meta-analysis was performed due to heterogeneity in study design, intervention protocols, and outcome measurement methods. Similarly, no subgroup analysis was conducted, and publication bias was not formally assessed due to the limited number of included studies.

The risk of bias assessment indicated that most included studies had a moderate overall risk of bias. Randomized controlled trials generally demonstrated adequate randomization procedures but lacked blinding, which is common in exercise-based interventions. Quasi-experimental studies showed higher susceptibility to bias due to the absence of randomization and allocation procedures. Incomplete outcome data were generally well addressed across studies, while selective reporting was unclear in several studies due to limited methodological reporting.

Effect size measures such as standardized mean differences and confidence intervals were not consistently reported across the included studies, precluding quantitative synthesis. Therefore, the findings are presented as descriptive changes in VO_2max. The certainty of evidence was assessed using the GRADE framework. Overall, the certainty of evidence for VO_2max improvement was rated as moderate, considering the consistency of results across studies, despite methodological limitations and imprecision.

To provide a structured evaluation of the strength and certainty of the evidence, the GRADE approach was applied. This assessment considers methodological quality, consistency of findings, directness of evidence, precision, and potential publication bias across the included studies. The results of the GRADE evaluation are presented in Table 2.

Table 2. Certainty of Evidence (GRADE)

Outcome	No. of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Certainty
VO_2max improvement	6	RCT + quasi-experimental	Serious	Not serious	Not serious	Serious	Possible	Moderate

The certainty of evidence for VO_2max improvement was rated as moderate. This rating reflects consistent findings across studies demonstrating improvements in cardiorespiratory fitness following aerobic exercise interventions. However, the certainty was downgraded due to methodological limitations, including moderate risk of bias and small sample sizes, as well as imprecision resulting from limited statistical reporting. Inconsistency and indirectness were not considered serious, as the included studies showed a consistent direction of effect and directly addressed the research question. Publication bias could not be formally assessed and remains a potential concern.

Discussion

This systematic review demonstrates that aerobic exercise, particularly High-Intensity Interval Training (HIIT), is effective in improving cardiorespiratory fitness, as measured by VO_2max, in overweight and obese adolescents. Across all included studies, consistent improvements were observed in intervention groups compared with controls, supporting the role of structured aerobic exercise as a key strategy in addressing impaired CRF in this high-risk population. These findings are aligned with previous systematic reviews and meta-analyses reporting significant improvements in CRF following HIIT interventions in youth populations.[22]

The magnitude of VO_2max improvement varied across studies, ranging from moderate to substantial increases. This variability appears to be primarily influenced by differences in exercise intensity, duration, and intervention design. High-intensity protocols (≥85% of maximal capacity) consistently yielded greater improvements compared with moderate-intensity continuous training (MICT), reinforcing the importance of exercise intensity as a key determinant of physiological adaptation.[2025] This observation is supported by exercise physiology literature indicating that higher-intensity stimuli induce greater cardiovascular and metabolic adaptations, including increased stroke volume, enhanced mitochondrial biogenesis, and improved oxidative enzyme activity.[23–25]

In addition to intensity, intervention duration also plays an important role. While longer interventions (≥12 weeks) generally produced more stable improvements, several studies demonstrated that shorter-duration HIIT programs (8 weeks) could still generate substantial gains in VO_2max when exercise intensity was sufficiently high. This finding suggests that time-efficient interventions may be particularly advantageous for adolescents, who often face barriers related to time constraints and adherence.[26]

The implementation context further influences the effectiveness of aerobic exercise interventions. Most studies included in this review employed school-based programs, which provide structured environments that may enhance adherence and scalability. School-based interventions are particularly relevant for public health implementation, as they allow integration of exercise into daily routines and may improve long-term sustainability. However, differences in supervision, program fidelity, and participant engagement across settings may contribute to variability in outcomes.

Beyond improvements in cardiorespiratory fitness, several studies also reported reductions in body mass index, body fat percentage, and visceral adiposity. These findings highlight the broader cardiometabolic benefits of aerobic exercise in overweight and obese adolescents. Importantly, improvements in VO_2max may occur independently of substantial weight loss, suggesting that CRF should be considered a primary therapeutic target rather than solely focusing on body composition.[27–29]

Despite these positive findings, the overall quality of evidence should be interpreted with caution. The risk of bias assessment indicated that most studies had moderate methodological limitations. Common issues included small sample sizes, lack of blinding, and, in quasi-experimental designs, absence of randomization. These factors may introduce selection and performance bias, potentially overestimating intervention effects. Additionally, variations in VO_2max measurement methods, such as indirect field tests versus direct laboratory assessments, may affect the accuracy and comparability of results across studies.

Another important limitation is the absence of formal assessment of reporting bias, including publication bias. Studies reporting positive outcomes are more likely to be published, which may lead to an overrepresentation of favorable findings in the literature. Furthermore, the heterogeneity in study design and intervention protocols precluded quantitative synthesis and subgroup analysis, limiting the ability to determine optimal exercise prescriptions. Publication bias could not be formally assessed due to the limited number of included studies. This may result in overrepresentation of studies reporting positive findings.

The interpretation of these findings should consider several methodological limitations. The overall moderate risk of bias across included studies, particularly due to lack of blinding and small sample sizes, may have influenced the observed effects. Additionally, the absence of standardized reporting, including confidence intervals and effect size measures, limits the precision and comparability of findings. Although the direction of effect was consistent across studies, these limitations contributed to the downgrading of evidence certainty in the GRADE assessment.

The strength of evidence from this review can be considered moderate. While consistent positive effects were observed across studies, the limited number of high-quality randomized controlled trials and methodological variability reduce the certainty of conclusions. Future research should prioritize larger, well-designed randomized controlled trials with standardized intervention protocols and outcome measures.

From a clinical and practical perspective, the findings of this review support the implementation of structured aerobic exercise programs, particularly HIIT, as an effective strategy to improve cardiorespiratory fitness in overweight and obese adolescents. Based on the included studies, effective programs typically involve exercise sessions performed two to three times per week, with durations of 8–12 weeks and intensities reaching ≥80% of maximal capacity. These parameters may serve as a preliminary guideline for exercise prescription, although individualization based on participant characteristics remains essential. Based on consistency of findings, study design, and risk of bias, the overall certainty of evidence can be considered moderate, although it is limited by small sample sizes and methodological heterogeneity.

Conclusion

This systematic review demonstrates that aerobic exercise effectively improves cardiorespiratory fitness, as measured by VO_2max, in overweight and obese adolescents. High-Intensity Interval Training (HIIT) consistently produces greater improvements compared with moderate-intensity continuous training, particularly when implemented at moderate-to-high intensity over 8–12 weeks. The overall strength of evidence is moderate due to methodological variability, small sample sizes, and heterogeneity across studies. Despite these limitations, the findings support the use of structured aerobic exercise, especially HIIT, as a practical and time-efficient strategy to enhance cardiorespiratory fitness in this population.

From a practical perspective, exercise programs conducted two to three times per week with sufficient intensity (≥80% maximal capacity) appear effective and feasible, particularly in school-based settings. Future research should focus on large-scale randomized controlled trials with standardized protocols, long-term follow-up, and comprehensive assessment of confounding factors to strengthen the evidence base and improve generalizability.

Author Contribution

Lintang Zerlina Arsa Wibowo: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft, Supervision, Correspondence.
Dela Fariha Fuadi: Investigation, Data Collection, Literature Review, Validation, Writing – Review & Editing.

Acknowledgments

The authors acknowledge all researchers whose studies were included in this review for their valuable scientific contributions.

Conflict of Interest Statement

The authors declare no conflict of interest.

Funding Sources

This study received no external funding.

Ethics Statement

Ethical approval was not required as this study was based exclusively on previously published data. The data supporting this study are derived from previously published articles and are available from the corresponding author upon reasonable request. This systematic review was not registered in PROSPERO.

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