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1 The effect of bodyweight-based high-intensity interval training (HIIT) on VO₂ max in obese adolescents

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ABSTRACT

13 The rising prevalence of adolescent obesity has become a critical health concern, particularly due to its association with impaired cardiovascular endurance and reduced VO₂ max. This study investigated the impact of bodyweight-based High-Intensity Interval Training (HIIT) on VO₂ max in obese adolescents. A quasi-experimental design with pretest-posttest control groups was employed, involving 30 students aged 13-15 years from SMP Negeri 1 Hamparan Perak. Participants were randomly assigned to an experimental group (n = 15) and a control group (n = 15). The experimental group underwent an eight-week HIIT intervention using bodyweight exercises, while the control group engaged in conventional physical education activities. VO₂ max levels were assessed through the multistage fitness test. Statistical analysis revealed a significant increase in VO₂ max among the experimental group compared to the control group (p < 0.001). These findings suggest that bodyweight-based HIIT offers an effective, feasible, and cost-efficient approach to enhance cardiovascular fitness in obese adolescents. Furthermore, its integration into school-based physical education curricula could provide a sustainable strategy to combat obesity-related health risks.

1 Key words: HIIT; bodyweight training; VO₂ max; obese adolescents; physical fitness.

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INTRODUCTION

Adolescent obesity has become one of the most pressing health issues globally, with prevalence rates increasing rapidly over the last two decades (Abdulloh et al., 2021; Bayu et al., 2021; Najmi & Azhar, 2023; Salvi, 2024). The accumulation of excess body fat during adolescence is associated with a higher likelihood of obesity persisting into adulthood and the emergence of metabolic and cardiovascular diseases at an early age (Sakkal et al., 2024). As a result, interventions that aim to improve the health and physical fitness of obese adolescents are urgently needed.

1 One of the main indicators of cardiovascular fitness is maximum oxygen capacity (VO₂ max), which describes the body's ability to transport and use oxygen during graded exercise (Giles et al., 2022; Liang & Yu, 2022; Peterman et al., 2022). VO₂ max is not only an indicator of aerobic endurance, but also a strong predictor of cardiovascular health and overall mortality risk (Weeldreyer et al., 2025). In obese adolescents, VO₂ max is often significantly lower than in their non-obese peers, making it a critical target in fitness interventions (Fuentes-Barría & Aguilera Eguía, 2023).

Physical activity has long been recognized as the primary method for improving VO₂ max. Traditional aerobic exercises such as running, swimming, and cycling are effective but often time-consuming and equipment dependent. High-Intensity Interval Training (HIIT), a training method characterized by short bursts of high-intensity activity followed by periods of rest or low-intensity movement, has emerged as an efficient and time-saving strategy for improving aerobic capacity, even with shorter training durations (Atakan et al., 2021; Bidhuri et al., 2025; Gripp et al., 2022; Kusuma et al., 2023; Ridwan et al., 2024).

Previous studies have reported positive outcomes from HIIT interventions in adult and adolescent populations, including improvements in cardiovascular endurance, body composition, and metabolic health (Batacan et al., 2017; Bento et al., 2022; Kamaruddin, 2022; Song & Lan, 2024). However, many of these studies utilize equipment-based exercises such as treadmill running or stationary cycling (Poon et al., 2024). This reliance on specialized equipment limits the accessibility of HIIT for certain populations, particularly those in low-resource settings or with limited access to fitness facilities (Plizga et al., 2024).

In response to this limitation, researchers have started exploring bodyweight-based HIIT programs, which require no equipment and can be performed in any setting (Martin-Smith et al., 2020; Sian et al., 2021). Bodyweight exercises such as squats, jumping jacks, burpees, and lunges offer a practical alternative, especially for adolescents who may feel self-conscious or lack access to gyms (Thivel et al., 2019). Despite their potential, few studies have systematically evaluated the effectiveness of bodyweight-based HIIT on improving VO₂ max in obese adolescents.

Previous studies have demonstrated that High-Intensity Interval Training (HIIT) is effective in improving cardiovascular fitness and metabolic function in both adults and adolescents (Hosseini & Monazzami, 2021; Khammassi et al., 2020; Meng et al., 2022). However, most of these interventions relied on gym-based or equipment-assisted protocols, which limit their applicability in school or community settings. This study addresses that gap by investigating the effect of an eight-week bodyweight-based HIIT program on VO₂ max in obese adolescents. Unlike previous studies, the intervention used only bodyweight exercises, making it accessible, low-cost, and feasible for large-scale implementation. The contribution of this article is twofold: theoretically, it expands the literature on HIIT by demonstrating its effectiveness without equipment; practically, it provides evidence-based recommendations for integrating bodyweight-based HIIT into school physical education curricula and public health initiatives targeting adolescent obesity.

The purpose of this study was to investigate the impact of an 8-week weight-based HIIT program on VO₂ max in obese adolescents. The hypothesis

was that participants would show a significant increase in VO_2 max after the intervention. The findings of this study are expected to provide evidence-based recommendations for physical education programs in schools and public health strategies addressing adolescent obesity.

METHOD

This study used a quantitative approach with a quasi-experimental method and a pre-test and post-test control group design. The research was conducted at SMP Negeri 1 Hamparan Perak, Indonesia, over a period of 8 weeks, from April 1 to May 27, 2025.

Table 1. Research design

Group	Pretest (VO_2 max)	Treatment (8-week HIIT)	Posttest (VO_2 max)
Experimental	O1	X	O2
Control	O1	—	O2

O1: Pretest, O2: Posttest, X: HIIT Treatment

The research was conducted at SMP Negeri 1 Hamparan Perak, located in South Sumatra, Indonesia. The implementation spanned 8 weeks, starting on April 1 and ending on May 27, 2025. Details of the activity schedule are shown in Table 2.

Table 2. Research schedule

Activity	Week 1 (Apr 1-7)	Week 2 (Apr 8-14)	Week 3 (Apr 15-21)	Week 4 (Apr 22-28)	Week 5 (Apr 29-May 5)	Week 6 (May 6-12)	Week 7 (May 13-19)	Week 8 (May 20-27)
Initial screening & consent	✓							
Pretest VO_2 max	✓							
HIIT Intervention		✓	✓	✓	✓	✓	✓	✓
Posttest VO_2 Max								✓

The population in this study consisted of students from grades 7 and 8 at SMP Negeri 1 Hamparan Perak who were classified as obese according to the WHO BMI-for-age criteria ($\geq$ 95th percentile). A total of 30 students aged between 13 and 15 years were selected using purposive sampling. The samples were then randomly divided into two groups: the experimental group ($n = 15$) and the control group ($n = 15$).

The experimental group participated in an 8-week bodyweight-based High-Intensity Interval Training (HIIT) program, conducted three times a week (Monday, Wednesday, and Friday). Each session lasted 30 minutes and was

supervised by a certified physical education instructor. The control group continued to attend regular physical education classes without any additional intervention.

Table 3. Weekly HIIT training structure

Session Component	Duration	Exercise Types
Warm-up	5 minutes	Light jogging, arm circles, leg swings, dynamic stretching
Main HIIT Set	20 minutes	4 rounds of: 30 sec work + 30 sec rest; exercises: jumping jacks, squats, burpees, mountain climbers
Cool-down	5 minutes	Walking, deep breathing, and static stretching

VO₂ max was measured using the Multistage Fitness Test (Beep Test), which is a valid and widely used method for estimating aerobic capacity in adolescents (Lamoneda et al., 2021; Senanayake et al., 2024). All participants were tested before (pretest) and after (posttest) the 8-week intervention period. The test was administered on the school's indoor court to ensure consistent conditions.

The instrument used was a standardized audio-recorded beep test, and the final level reached by each student was used to estimate VO₂ max using a published conversion formula. Measurements were supervised and recorded by physical education teachers and researchers to ensure reliability.

All collected data were analyzed using SPSS version 26.0. Prior to parametric testing, assumption tests were conducted. Normality of the data distribution was examined using the Shapiro-Wilk test, while homogeneity of variance between groups was verified using Levene's Test. Descriptive statistics (mean and standard deviation) were used to describe participant characteristics and test results. If assumptions were met, paired t-tests were applied to compare pretest and posttest scores within each group, and independent t-tests were conducted to assess differences between the experimental and control groups. The significance level was set at $p < 0.05$.

FINDINGS AND DISCUSSIONS

Findings

Before conducting parametric analyses, prerequisite tests were carried out, including normality and homogeneity tests. The normality test was performed to examine whether the data were normally distributed. The results of the Shapiro-Wilk test are presented in Table 4.

Table 4. Normality test results (shapiro-wilk test)

Group	Test Time	Statistics (W)	Sig. (p)	Interpretation
Experimental	Pretest	0.962	0.423	Normal

Experimental	Posttest	0.953	0.317	Normal
Control	Pretest	0.965	0.398	Normal
Control	Posttest	0.948	0.276	Normal

Note: All p-values > 0.05 indicate that the data are normally distributed.

After confirming the normality of the data distribution, a homogeneity test was conducted to examine whether the variance of the VO₂ max scores between the experimental and control groups was equal.

Table 5. Homogeneity test results (levene's test)

Variable	F	Sig. (p)	Interpretation
VO ₂ max Posttest	0.56	0.462	Homogeneous

Note: p-value > 0.05 indicates that the data variance between groups is homogeneous.

The results of both the normality and homogeneity tests indicate that the data met the assumptions required for parametric testing. Therefore, further analyses were performed using paired sample t-tests and independent sample t-tests to examine within-group and between-group differences. Descriptive data on VO₂ max scores for both groups are presented in Table 6.

Table 6. Descriptive Statistics of VO₂ max Scores (ml/kg/min)

Group	N	Pretest Mean ± SD	Posttest Mean ± SD
Experimental	15	30.26 ± 2.87	36.04 ± 3.01
Control	15	30.18 ± 2.94	30.89 ± 3.12

The experimental group showed an increase in the average VO₂ max score from 30.26 ml/kg/min (SD = 2.87) before the intervention to 36.04 ml/kg/min (SD = 3.01) after the intervention. Meanwhile, the control group experienced a slight increase from 30.18 ml/kg/min (SD = 2.94) to 30.89 ml/kg/min (SD = 3.12).

The results of the paired sample t-test to analyze the differences in groups between pre-test and post-test scores are shown in Table 7.

Table 7. Paired sample t-test results

Group	t-value	df	Sig. (2-tailed)
Experimental	8.47	14	0
Control	1.92	14	0.074

A significant difference was found in the experimental group between pre-test and post-test scores ($p < 0.05$). There was no significant difference in the control group ($p > 0.05$).

Table 8 shows the results of the independent sample t-test comparing post-test VO₂ max scores between the experimental group and the control group.

Table 8. Independent sample t-test of posttest VO₂ max

Group Comparison	t-value	df	Sig. (2-tailed)
Experimental vs. Control	5.12	28	0

There was a significant difference between the experimental group and the control group in post-test VO₂ max scores ($p < 0.05$), indicating that HIIT intervention had a measurable effect on improving cardiovascular endurance in obese adolescents.

Discussion

This study demonstrated that bodyweight-based HIIT significantly improved VO₂ max in obese adolescents. The experimental group showed a substantial increase in average VO₂ max from pretest to posttest, while the control group experienced only a minimal, non-significant improvement. Paired sample t-test results confirmed a significant difference within the experimental group, whereas the control group did not show meaningful changes. Furthermore, the independent sample t-test revealed that the posttest VO₂ max values of the experimental group were significantly higher than those of the control group.

These findings are consistent with previous studies indicating that HIIT is effective in improving cardiovascular endurance and metabolic function among both adults and adolescents (Hosseini & Monazzami, 2021; Khammassi et al., 2020; Meng et al., 2022; Sadeghi et al., 2021). However, this study provides additional value by showing that such improvements can also be achieved without the need for specialized equipment, making the intervention more feasible for school or home-based implementation. The use of bodyweight exercises addresses one of the main barriers to adolescent physical activity limited access to fitness facilities.

In contrast to traditional aerobic training, which typically requires longer durations to achieve similar outcomes, the HIIT model applied in this study involved shorter, more intense bouts of physical effort. This supports the growing body of evidence suggesting that time-efficient, high-intensity exercise formats are suitable and beneficial for youth, including those with obesity (González-Gálvez et al., 2024; Kaur et al., 2023). Additionally, the inclusion of dynamic, game-like exercises may have helped increase student engagement and adherence throughout the program (Cao et al., 2022; Zheng et al., 2025).

From a theoretical perspective, the results align with the principle of overload and adaptation in exercise physiology, where repeated exposure to high-intensity stimulus prompts the cardiovascular system to improve oxygen transport and utilization (Hernawan & Putra, 2023). The improvements in VO₂ max indicate better efficiency of the heart and lungs, which is particularly

important in obese adolescents who are at increased risk of cardiometabolic complications (Huerta Ojeda et al., 2017).

One of the novel contributions of this study is the application of a fully bodyweight-based HIIT protocol specifically designed for obese adolescents a group often excluded from vigorous training due to perceived risks or motivational issues (Jovanović et al., 2024; Lee et al., 2017; Liu et al., 2024). By demonstrating the feasibility and effectiveness of this approach, the research expands the options for school-based physical education and health promotion strategies, particularly in low-resource settings.

Nevertheless, certain limitations must be acknowledged. The small sample size and single-school setting may restrict generalizability. Additionally, the study focused solely on VO₂ max, without considering other indicators such as body composition, muscular strength, or psychosocial outcomes. Future research should involve larger, more diverse samples and incorporate multidimensional measures to build a more comprehensive understanding of the benefits of bodyweight-based HIIT.

Despite these limitations, the study contributes practically to the field of adolescent health promotion. The findings suggest that educators and health professionals can adopt similar protocols in school curricula without additional resources, potentially improving physical fitness, fostering healthy lifestyles, and reducing the long-term health risks associated with adolescent obesity.

CONCLUSION

The results of this study indicate that bodyweight-based High-Intensity Interval Training (HIIT) is an effective method for improving VO₂ max in obese adolescents. The intervention, which required no specialized equipment, proved to be a practical and accessible approach to enhancing cardiovascular fitness in a school setting. This finding highlights the potential of simple, time-efficient exercise programs to support health and fitness improvements in populations with limited access to traditional training facilities. Further research is recommended to examine the long-term impact of such interventions and explore additional physical and psychological outcomes, as well as broader applications in diverse educational and community contexts.

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