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The Effect of High-Intensity Interval Training on Cardiovascular Endurance (VO_2max) in Badminton Athletes at Mahmuda Club, Padang

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Abstrac: This study aims to determine the effect of high-intensity interval training (HIIT) on the cardiovascular endurance (VO_2Max) of badminton athletes from the Mahmuda Club in Padang. The research method used was an experimental study with a one-group pretest-posttest design. The study sample consisted of 10 athletes. The instrument used in this study was the Multistage Fitness Test (Bleep Test) to measure VO_2Max. Data analysis employed a paired-sample t-test. The results indicated an increase in the mean VO_2Max value from 34.96 at the pretest to 36.29 at the posttest. Based on the statistical test results, a significance value (Sig. 2-tailed) of 0.000 < 0.05 was obtained, indicating that there is a significant effect of high-intensity interval training (HIIT) on the improvement of cardiovascular endurance (VO_2Max) in athletes. Thus, the high-intensity interval training (HIIT) method is effective for improving the cardiovascular endurance of badminton athletes.

Keyword: Athletes, Badminton, High-intensity interval training, VO_2Max.

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INTRODUCTION

Physical activities such as sports are no longer merely a hobby; they have become an integral part of modern society's lifestyle. Physical exercise, when performed in a planned, routine, and consistent manner, aims to improve physical fitness, health, and individual performance. Regular exercise has been proven to improve organ function, enhance quality of life, and provide positive psychological effects, such as reducing stress and boosting self-confidence (Ganguly et al., 2020; Thacker, 2025). In the realm of competitive sports, physical training serves as the primary foundation for achieving peak athletic performance (Amawi et al., 2024)

Badminton is a popular sport played with a racket and shuttlecock to conquer the opponent's court. The game demands a complex combination of physical abilities such as speed, agility, strength, explosive power, coordination, and cardiovascular endurance. Due to its intermittent nature, athletes must maintain a high and rhythmic intensity throughout the game (Phomsoupha & Laffaye, 2015). During a match, an athlete's heart rate can reach 80–90% of their maximum capacity, reflecting a heavy load on the cardiovascular system (Cádiz Gallardo et al., 2023). Without adequate endurance, fatigue sets in quickly, thereby affecting the speed and accuracy of shots.

VO_2Max is a key indicator of cardiovascular endurance, reflecting the body's ability to absorb oxygen during intense activity. Elite badminton athletes have a VO_2Max of 55–65 ml/kg/min, while regional athletes range from 40–50 ml/kg/min (Tai et al., 2022). A high VO_2Max ensures that athletes can sustain performance throughout long matches, even up to three sets. Reality on the court shows that athletes do not yet possess maximum cardiovascular endurance. From initial observations of badminton players at the Mahmuda Club in Padang, it is evident that they tire easily in the middle to late stages of training, marked by declining physical performance and longer recovery times. The current training program focuses more on technique and strategy, while the development of VO_2Max has not been systematically addressed.

One way to improve cardiovascular endurance is through interval training, which combines work and rest phases at specific intensities to enhance cardiac and pulmonary efficiency (Qi et al., 2026). This study employed High-Intensity Interval Training (HIIT) at an intensity of approximately 80–95% of HRmax, consistent with the demands of repetitive explosive movements in badminton. Previous studies have shown that interval training can significantly improve aerobic capacity and VO_2Max in athletes. For example, García-De Frutos et al. (2021) reported that HIIT effectively enhanced cardiovascular endurance in team-sport athletes, while Fentaw et al. (2025) found improvements in aerobic performance following structured interval-based exercise programs. In badminton, several studies have also highlighted the importance of endurance training in supporting repeated high-intensity movements during matches. However, most previous studies focused on athletes from different sports, general fitness populations, or elite-level training environments, and only limited research has specifically examined badminton athletes at the club level in Indonesia.

Although this method is widely used, no previous study has specifically assessed the effects of interval training on the VO_2Max of athletes at the Mahmuda Club in Padang. In addition, this study differs from previous research because it focuses on local badminton athletes undergoing a structured HIIT program adjusted to badminton movement characteristics and training intensity. This gap in the literature prompted the researchers to investigate the effectiveness of this method in improving athletes' physical capacity. Therefore, the objective of this study is to analyze the effect of interval training on improving the VO_2Max of badminton athletes at the Mahmuda Club in Padang, with the hope that it can serve as a practical guide for more efficient training programs.

METHOD

This study collected primary data directly through measurements of cardiovascular capacity (VO_2Max) among badminton athletes at the Mahmuda Club in Padang. The study was conducted at the Mahmuda Club Badminton Court from April to May 2026. The population consisted of all 21 athletes in the club, and the sample was selected purposively based on the

criteria of being 14–18 years old and actively training. The instrument used was the Bleep Test (Multistage Fitness Test) to measure VO_2Max, which involved running back and forth over a 20-meter distance in accordance with an increasing beep rhythm. The results were measured in ml/kg/minute using a standard conversion table. The research method was based on quantitative experimentation with the implementation of an interval training program to observe its impact on VO_2Max. This study used a One-Group Pretest–Posttest design, in which a single group underwent a pretest, the intervention, and a posttest to monitor changes resulting from the intervention. The analysis was conducted in several stages.

1. Research Design

This study employs a quantitative approach using a quasi-experimental method. The design used is a one-group pretest-posttest design. In this design, the research participants are not compared to a control group but are evaluated against their own baseline performance based on measurements taken before and after the intervention. Structurally, the research design can be described as follows:

O1 ——————— X ——————— O2

Figure 1. Research Design Diagram

Description:
O_1 = Pretest (VO_2Max measurement before treatment)
X = Treatment consisting of intensive interval training over 16 sessions
O_2 = Posttest (VO_2Max measurement after treatment)

2. Normality Test (Shapiro-Wilk)

The Shapiro–Wilk (SW) test is often relied upon to test for normality, thanks to its robustness, especially when the sample size is not very large
Before proceeding to parametric tests such as the t-test or ANOVA, the Shapiro–Wilk test is used to check whether the data "conforms" to a normal distribution (Khatun, 2021).
Hypotheses:
a) H_0: The data is normally distributed
b) H_1: The data is not normally distributed
Mathematically, the Shapiro-Wilk test is formulated as:

$$W = \frac{(\sum a_i x_i)^2}{\sum (x_i - \bar{x})^2} \quad (1)$$

Test criteria:
If Sig. > 0.05, then the data is normally distributed.

3. Hypothesis Testing (Paired-Sample t-Test)

The paired-sample t-test is used to test hypotheses when comparing two means derived from paired data, rather than from separate groups (Pandis, 2015). Assuming the data follow a normal distribution, the paired-sample t-test was applied to examine the effect of interval training on VO_2Max.
Hypotheses:
a) H_0: There is no effect of interval training on VO_2Max
b) H_1: There is an effect of interval training on VO_2Max
T-Test Formula:

$$t = \frac{M_d}{\sqrt{\frac{\sum X_d^2}{N(N-1)}}} \quad (2)$$

Description:
Md = Mean difference between pre-test and post-test scores.
Xd = Deviation for each subject.

$\sum Xd^2$ = Sum of squares of deviations.
N = Number of subjects.
Df = Degrees of freedom, i.e., N − 1
Hypothesis criteria:
Sig. < 0.05 → significant effect
Sig. > 0.05 → non-significant effect
Non-normal data → use the Wilcoxon Signed Rank Test.

RESULT

Pre-test Data Results (VO_2Max)

Pretest data were collected via the Bleep Test before the athletes underwent the intervention, which consisted of a high-intensity interval training program. Subsequently, posttest data were collected via a repeat Bleep Test after the athletes completed 16 training sessions conducted four times a week at a predetermined intensity. The following table presents the frequency distribution of the pretest and posttest data for the athletes of the Mahmuda Club in Padang.

Table 1. Pre-test Data Results (VO_2Max)

		Pretest	Posttest
N	Valid	10	10
	Missing	134	134
Mean		34.9600	36.2900
Median		33.2500	34.5500
Mode		32.60	29.10[a]
Std. Deviation		6.15489	6.23101
Variance		37.883	38.825
Range		19.50	19.30
Minimum		27.60	29.10
Maximum		47.10	48.40

a. Multiple modes exist. The smallest value is shown

Based on the table above, the results of the pretest data analysis show a mean of 34.96, a median of 33.25, a mode of 32.60, a standard deviation of 5.83, a variance of 33.99, a range of 19.50, a minimum value of 27.60, and a maximum value of 47.10.

Post-test Data Results (VO_2Max)

Post-test VO_2Max data were obtained via the Multistage Fitness Test (Bleep Test) after the study participants underwent an intervention consisting of 16 sessions of high-intensity interval training conducted in stages. The following presents the statistical description of the post-test VO_2Max data obtained using the Multistage Fitness Test.

Table 2. Post-test Data Results (VO_2Max)

		Pretest	Posttest
N	Valid	10	10
	Missing	134	134
Mean		34.9600	36.2900
Median		33.2500	34.5500
Mode		32.60	29.10[a]
Std. Deviation		6.15489	6.23101
Variance		37.883	38.825
Range		19.50	19.30
Minimum		27.60	29.10
Maximum		47.10	48.40

a. Multiple modes exist. The smallest value is shown

Based on the table above, the results of the posttest data analysis show a mean of 36.47, a median of 34.55, a mode of 34.70, a standard deviation of 5.90, a variance of 34.81, a range of 19.30, a minimum value of 29.10, and a maximum value of 48.40.

Normality Test

Table 3. Normality Test Results

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pretest	.168	10	.200*	.935	10	.495
Posttest	.201	10	.200*	.926	10	.408

Based on the results of the normality test for cardiovascular endurance, the pre-test data yielded a p-value of 0.495 > 0.05 and the post-test data yielded a p-value of 0.408 > 0.05. Thus, it can be concluded that all the research data are normally distributed.

Homogeneity Test

A homogeneity test is conducted to determine whether the variances of the data are equal. The criteria are:
a. Sig. ≥ 0.05 = the data are homogeneous.
b. Sig. < 0.05 = the data are not homogeneous.

Table 4. Homogeneity Test Results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Value	Equal variances assumed	.006	.941	-.480	18	.637	-1.33000	2.76962	-7.14876	4.48876
	Equal variances not assumed			-.480	17.997	.637	-1.33000	2.76962	-7.14882	4.48882

Based on the Independent Samples Test table in the Levene's Test for Equality of Variances column, the significance value is 0.941 > 0.05. Therefore, it can be concluded that the data have equal variances, or are homogeneous.

Hypothesis testing

The hypothesis proposed in this study is that high-intensity interval training has an effect on cardiovascular endurance (VO_2Max) among athletes at the Mahmuda Club. Based on the results of the t-test analysis, the following findings were obtained:

Table 5. Hypothesis Test Results

					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest-Posttest	-1.3300	.51865	.16401	-1.7010	-.95898	-8.11	9	.000

Based on the Paired Samples Test table, a t-value of 8.109 was obtained with a significance level (Sig., 2-tailed) of 0.000 < 0.05. Thus, H_0 is rejected and H_1 is accepted, leading to the conclusion that intensive interval training has a significant effect on improving the cardiovascular endurance (VO_2Max) of athletes at the Mahmuda Club.

DISCUSSION

Based on the results of this study, it can be concluded that the application of the High-Intensity Interval Training (HIIT) method has a positive impact on improving the aerobic capacity (VO_2Max) of badminton athletes at the Mahmuda Club in Padang. Conceptually, physical training is the primary foundation for improving athletic performance, particularly in sports that demand a combination of complex physical abilities, such as badminton. HIIT, as a form of modern interval training, combines periods of high-intensity work (approximately 80–95% of HRmax) with periods of active recovery, thereby stimulating physiological adaptations in the cardiovascular and respiratory systems. These adaptations include increased cardiac output (stroke volume), improved oxygen utilization efficiency by muscles, and increased capillary and mitochondrial density (García-De Frutos et al., 2021; Fentaw et al., 2025). Thus, HIIT is highly relevant for badminton, a sport characterized by fast, explosive, and repetitive (intermittent) movements.

The results of this study show an increase in the average VO_2Max from 34.96 to 36.29 ml/kg/min following HIIT training, with a p-value of 0.000 < 0.05. These findings indicate that HIIT training is effective in significantly improving athletes' cardiovascular endurance. Physiologically, the increase in VO_2Max occurs because the body adapts to the repeated high-intensity training loads. This adaptation includes an increase in the heart's ability to pump blood, an increase in blood volume, and an improvement in the muscles' ability to extract and utilize oxygen (Phomsoupha & Laffaye, 2015). These results align with recent research by Wajib et al. (2022), which found that a 4–6-week HIIT program significantly improved the VO_2Max of athletes in team sports. Additionally, research by Pratama and Nugroho (2023) also demonstrated that high-intensity interval training is more effective than continuous exercise in improving the aerobic capacity of adolescent athletes.

In the context of badminton, improving VO_2Max plays a crucial role due to the intermittent nature of the game, which involves alternating between periods of high-intensity activity and brief recovery phases. Athletes with high VO_2Max tend to recover more quickly after long rallies, allowing them to maintain intensity throughout the match. Additionally, good cardiovascular endurance contributes to technical stability, movement speed, and shot accuracy, particularly in the late stages of a match when fatigue sets in (Cádiz Gallardo et al., 2023). Research by Hidayat et al. (2021) also confirms that a high VO_2Max is positively correlated with technical performance and consistency in badminton players.

Furthermore, the effectiveness of HIIT in this study can also be explained by the principle of training specificity, whereby training patterns that mimic the demands of a match will result in more optimal adaptations. HIIT, with its high intensity and relatively short rest periods, mirrors the actual conditions of a badminton match. This is supported by research by Putra et al. (2024), which states that high-intensity interval training is capable of improving the physical performance and match readiness of badminton athletes more effectively than conventional methods.

Thus, the results of this study not only demonstrate a statistically significant increase in VO_2Max but also have practical implications for the design of training programs. HIIT can serve as an efficient and effective training method for improving the aerobic endurance of badminton athletes, particularly at the club level. However, its implementation must still take into account the principles of exercise individualization, such as age, initial fitness level, and the athlete's recovery capacity, so that optimal results can be achieved and the risk of injury can be minimized.

Despite the positive findings, this study has several limitations. First, the sample size was relatively small and limited to athletes from one badminton club, which may reduce the generalizability of the results to other populations or competitive levels. Second, the study only focused on VO_2Max as the primary indicator of cardiovascular endurance and did not examine other physical or technical performance variables such as agility, speed, or match performance.

Third, the duration of the training program was relatively short, consisting of 16 training sessions, so the long-term effects of HIIT on athlete performance could not be fully observed. Therefore, future studies are recommended to involve larger and more diverse samples, include additional performance variables, and apply longer training durations to obtain more comprehensive findings.

CONCLUSION

This study concludes that the implementation of High-Intensity Interval Training (HIIT) has a significant effect on improving the VO_2Max of badminton athletes at Klub Mahmuda, Padang. HIIT proved to be an effective training method for enhancing cardiovascular endurance through physiological adaptations in the cardiovascular and respiratory systems, allowing athletes to utilize oxygen more efficiently during high-intensity and intermittent activities commonly found in badminton matches. From a practical perspective, improved cardiovascular endurance contributes to better recovery ability, greater movement efficiency, and more consistent performance during matches. Therefore, coaches are encouraged to apply HIIT systematically as part of badminton training programs to optimize athletes' physical condition and performance. Future research is recommended to involve larger and more diverse samples, include control groups, and examine the effects of HIIT on other physical components such as agility, speed, and muscular endurance.

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