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High-Intensity Interval Training Increases VO2Max in Karate Athletes

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Abstract Martial arts, such as karate, are competitive sports that require excellent physical conditioning during training and competition, generally measured by Maximum Oxygen Volumes (VO2Max). This study aims to increase the fitness of training in athletes of Dojo Garing Kherti Jembrana Regency. This research is an interventional research using the One Group Pretest-Posttest Design model and High-Intensity Interval Training as an intervention. The subjects in this study were all karate athletes of Dojo Garing Kherti. Results of this study found that the VO2Max improve among athletes before and after HIIT, significantly. The average VO2Max value increased from 39 in the pretest to 43.4 in the posttest, with a statistically significant difference ($p = 0.001$).

Keywords Maximum Oxygen Volume (VO2Max), High-Intensity Interval Training (HIIT), Athletes

1. Introduction

Physical fitness is the ability to perform daily activities without experiencing excessive fatigue. Regular physical activity of sufficient duration is one way to achieve optimal health [1]. To maintain physical fitness, it is recommended to engage in physical activity at least 3 to 5 times a week for 20-30 minutes [2]. Regular physical activity has a positive impact on an individual's physical fitness [3]. An individual's physical fitness is influenced by several factors, including genetics, age, body composition, activity, and training. Various physical activities can be performed, including martial arts. Martial arts are disciplines developed as a means of self-defense, emphasizing physical endurance and strength.

Practising martial arts is not only aimed at self-defense but is also highly beneficial for the body. The most popular martial art today is karate. Karate is a martial art originating from Japan. According to the Ministry of Youth and Sports of the Republic of Indonesia, Indonesia successfully won 13 medals at the 2023 SEA Games in Cambodia. Sporting achievements are attained through systematic and measured training processes. To achieve high performance in competitive sports, athletes require optimal physical condition tailored to the needs and demands of their sport. In modern times, karate is divided into traditional and sports disciplines. Traditional disciplines emphasize self-defense and combat techniques, while sports disciplines focus on competition techniques [4]. Karate competitions are divided into two categories: kumite and kata.

Martial arts place great importance on maximum oxygen volume, and some martial arts disciplines consider Maximum Oxygen Volume (VO2Max) as a performance parameter [5]. Maximum oxygen volume is the level of the body's capacity expressed in liters per minute or milliliters per minute per kilogram of body weight [6]. This not only serves as a parameter for physical ability to obtain more oxygen but also to deliver it to active muscles and facilitate metabolic waste removal. One effective training method to improve physical condition is High-Intensity Interval Training (HIIT). To increase Maximum Oxygen Volume (VO2Max), various training methods, including HIIT, can be used.

High-Intensity Interval Training (HIIT) is a training method that combines high-intensity exercises with low-intensity exercises [7]. HIIT is performed using moderate to high-intensity methods, such as sprints and jogging, conducted in intervals ranging from seconds to minutes [8]. HIIT induces physiological effects on the cardiovascular system through cardiac adaptation during interval training. High-intensity exercise accelerates and intensifies heart performance, leading to increased oxygen consumption [9].

The reason for this study is to increase the proportion of training. Over the past few years, athletes from the Dojo Garing Kherti in Jembrana Regency have often experienced fatigue that requires the use of a nebulizer during competitions. Therefore, this study aims to ensure that the maximum oxygen volume of karate athletes from the Dojo Garing Kherti in Jembrana Regency increases, allowing them to compete without fatigue, perform well, and achieve the desired results.

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2. Materials and Methods

2.1. Data Sources

This study used an experimental design. The purpose of the study was to determine the effect of High high-intensity interval Training on increasing maximum oxygen volume in karate athletes. In this study, the researchers applied High Intensity Interval Training (HIIT) to increase the athletes' VO2max capacity. The research model used was a One one-group pretest-posttest Design.

The sample in this study consisted of all karate athletes from Dojo Garing Kherti in Jembrana District, with a total population of 22 athletes who met the inclusion and exclusion criteria. The inclusion criteria were karate athletes from Dojo Garing Kherti, aged between puberty and adulthood, and in good health, including physical fitness and good heart health. The exclusion criteria were athletes under the age of 10 or those who experienced injuries during the study period or had a history of injuries that could interfere with the study. Sampling was conducted using purposive sampling, which involves selecting samples based on specific considerations deemed appropriate for the defined characteristics. The sample in this study consisted of 22 athletes from Dojo Garing Kherti, comprising 14 male athletes and 8 female athletes.

VO2max data collection was assisted using a Polar smartwatch. According to Gilgen (2019), the Polar Vantage multisensory smartwatch has moderate to high statistical accuracy, depending on the activity [10]. Activities such as sitting and reading provide good results, while unstable activities involving wrist and arm movements provide moderate results. However, compared to other monitors worn on the wrist, the Polar Vantage is recommended due to its superior performance.

2.2. Setting

This study was conducted at Dojo Garing Kherti in Jembrana Regency, and HIIT training was carried out at Pecangakan Stadium in Jembrana Regency in November 2024.

2.3. Variables

The independent variable in this study was high-intensity interval Training (HIIT), while the dependent variable was maximum oxygen volume (VO2max). The moderating variables were age and gender.

2.4. Data Analysis

Data analysis in this study used univariate analysis and the Wilcoxon Signed-Rank test. Univariate analysis is a type of statistical analysis that involves a single variable. The purpose of univariate analysis is to understand the basic characteristics of a variable. In this study, it was used to determine the average value and increase in maximum oxygen volume of karate athletes at Dojo Garing Kherti, as well as to understand the characteristics of athletes based on age and gender.

3. Results

A study on the effect of high-intensity interval training on improving VO2Max in karate athletes at the Garing Kherti Dojo in Jembrana Regency was conducted in November 2024. This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine and Health Sciences, Warmadewa University, with ethical approval number 514/Unwar/FKIK/EC-KEPK/X/2024. Research data were obtained from 18 athletes at the Garing Kherti Dojo who met the inclusion criteria.

Table 1. Characteristics of Karate Dojo Garing Kherti Athletes Based on Age and Gender

Variable	Age	Category	Total (n)	Percentage (%)
Age	10-17	Puberty	7	38,9
	18-21	Adult	11	61,1
Gender	10-21	Male	10	55,6
	10-21	Female	8	44,4

Based on Table 1, it is known that of the 18 karate athletes from Dojo Garing Kherti, the majority of athletes aged 18-21 years old numbered 11 athletes (61.1%), with 10 male athletes (55.6%) and 8 female athletes (44.4%).

Table 2. VO2Max Profile of Karate Dojo Garing Kherti Athletes Based on Age and Gender

Age/Gender	Frequency	Mean		Improvemen (%)
		Pretest	***Posttest***	
10-17	7	37,57	41,57	10,64
18-21	11	40	43	7,5
Male	10	42	48,5	15.48
Female	8	34,38	38,38	11.64

Based on Table 2, the results of VO2Max measurements for karate athletes at Dojo Garing Kherti aged 10–17 years showed a pretest average of 37.57, a posttest average of 41.57, and an increase of 10.64%. Athletes aged 18–21 years had an average pretest score of 38.73 and an average posttest score of 43, representing an increase of 7.5%. The average pretest score for males was 42.5, while the posttest score was 48.5, representing an increase of 15.48%. Females had an average pretest score of 34.38, while the posttest score was 38.38, representing an increase of 11.64%.

Table 3. Wilcoxon Signed-Rank

		N	Mean Ranks	Sum of Ranks
Posttest-Pretest	Negative Ranks	0[a]	0,00	0,00
	Positive Ranks	18[b]	9,50	171,00
	Ties	0[c]		

Based on Table 3, the results of the Wilcoxon Signed Ranks test show changes in values before and after treatment. A positive rank with a value of N equal to 18 means that the entire sample experienced an increase in scores from the pretest to the posttest. The mean rank or average increase was 9.50, and the sum of ranks or total positive ranking was 171.00, with ties equal to 0, meaning that there were no

similarities between the pretest and posttest values.

Table 4. Statistical Test

	Posttest-Pretest
Z	3.772[b]
Asymp. Sig. (2-tailed)	0,001

Based on Table 4, the Wilcoxon Signed-Ranks statistical test obtained an asymptotic Sig. The (2-Tailed) value for the two-tailed test was 0.001 because Sig was less than 0.05.

4. Discussion

4.1. Characteristics of Karate Dojo Garing Kherti Athletes Based on Age and Gender

Based on the results of the study, there were 11 athletes aged 18-21 years or 61.1% of the total athletes. Karate championships have different age classifications depending on skill level, competition category, and the policies of the organizing body. The age considered eligible to compete in Asian or world-level karate championships is typically 15–17 years old and 18 years old and above, depending on the age categories set by each organization. Athletes aged 15 years and above generally possess sufficient skills and experience to compete at the Asian and world levels, such as the Asian Games and World Karate Federation championships [11]. These findings are consistent with Raniva Aristina's (2022) research, which states that the ideal age to start and compete in the kumite category is between 8 and 35 years old, covering the beginner to senior categories in karate tournaments [12].

Based on the research results, it was found that there were 10 male karate athletes, accounting for 55.6% of the total. This finding aligns with research conducted by Farkhan Nuky, which shows that karate classes are differentiated by gender for several reasons, primarily related to physical and biological differences between the two [12,13]. Men tend to have greater muscle mass and higher physical strength than women, which can affect performance in physical combat such as kumite. Men and women have physiological differences, such as lung capacity and body mass distribution, which can affect athletic performance in intensive sports such as karate.

4.2. Overview of VO2Max in Karate Athletes at Dojo Garing Kherti Based on Age and Gender

The results of the study indicate that karate athletes aged 10–17 years had an average pretest VO2Max of 37.57 and a posttest VO2Max of 41.57. Meanwhile, athletes aged 18–21 years had an average pretest VO2Max of 40 and a posttest VO2Max of 43. The increase in VO2Max based on age showed an increase of 10.64% in the 10–17 age group and 7.5% in the 18–21 age group. Gender showed an increase in VO2Max of 15.48% in males. Females showed an increase in VO2Max of 11.64%. These differences arise due to physiological factors and developmental changes during the growth and physical training stages. Hutajulu (2020) noted that during puberty, significant physical changes occur, thereby increasing oxygen efficiency. Maturity and training experience also influence VO2Max development [14,15].

During puberty, there is a significant increase in muscle mass, particularly in males, which helps improve the body's aerobic capacity. Larger muscles have a higher capacity to consume oxygen, thereby contributing to increased VO2Max. This study is similar to research conducted by Syahputra (2024), who stated that the body during adolescence has developed more significantly, with a higher cardiovascular system and aerobic capacity, the heart and lungs begin to function more efficiently, and muscles also develop stronger, enabling more efficient oxygen utilization [14-16]. Additionally, adolescents, especially those who are physically active or have good physical fitness, can have higher VO2max. For active adolescents or athletes, VO2max can reach approximately 40–55 ml/kg/minute, while the average VO2max for adolescents who do not engage in specific sports is between 35–45 ml/kg/minute [17,18]. In another study conducted by Manggala (2023), it was stated that the results of the Harvard step test showed that most participants had very good cardiorespiratory fitness levels at 77.5%, with a sample size of 55 participants. The adolescent age group tended to have very good cardiorespiratory fitness levels at 77.5% [19]. Hormonal changes during puberty significantly impact the increase in VO2Max compared to adulthood, as the peak increase in hormones occurs at ages 13–14.

Men's VO2Max results are higher than women's VO2Max results. These VO2Max results are influenced by several physiological factors. These findings align with research conducted by Kelsey J Santisteban (2022), which explains that women's cardiorespiratory fitness levels are lower than men's due to smaller airway diameters and lung volumes, resulting in lower peak expiratory flow rates and reduced capacity to increase ventilation compared to men. Additionally, the researchers found that nine out of ten women experienced significant expiratory flow limitations during the exercise protocol administered by the researchers [20,21]. Other researchers also noted that men tend to have a higher proportion of type II muscle fibers (particularly type IIa), which provide an advantage in short-term strength endurance, enabling them to achieve higher VO_2Max values (21). Meanwhile, women have type I muscle fibers, which are efficient in long-term aerobic activities. Although women have lower VO_2Max compared to men, they can increase their VO_2Max through aerobic exercise (such as running, cycling, and swimming) because their type I muscle fibers are more responsive to endurance training [18].

Other studies also indicate that anatomical differences between men and women may suggest that women experience a greater decline in lung function compared to men due to smaller lung surface area for oxygen exchange and lower oxygen flow rates [22]. A similar study was conducted by Novita (2019), who reported that the average VO2Max value for men with a sample size of 30 was 30.47, while for women with a sample size of 30, the average

VO2Max value was 26.9 [23]. The average values for men and women are influenced by higher hemoglobin levels and lower body fat in men compared to women, which results in differences in blood transport capacity, allowing men to obtain more oxygen during exercise, thereby improving aerobic capacity [24].

4.3. Average and Increase in Maximum Oxygen Volume of Karate Athletes at Dojo Garing Kherti

Based on the research results, the Wilcoxon signed-rank test was conducted with a summary of statistical results. According to Table 4 of the Wilcoxon Signed Ranks test results, there was a change in values before and after the treatment. A positive rank with a value of N 18 indicates that all samples experienced an increase in scores from the pretest to the posttest. The mean rank or average increase was 9.50, the sum of ranks or total positive ranks was 171.00, and ties were 0, meaning there was no similarity between pretest and posttest values. The Wilcoxon Signed-Ranks test yielded an asymptotic Sig. (2-Tailed) value for the two-tailed test of 0.001, as Sig is less than 0.05, thus rejecting the null hypothesis. The researcher can conclude that there is no effect between physical activity and VO2Max levels in karate athletes at Dojo Garing Kherti in Jembrana District.

Based on the research results on karate athletes at Dojo Garing Kherti, it was found that athletes who achieved a good VO2Max level were those who engaged in high-intensity interval training (HIIT) regularly compared to those who had not received HIIT training previously. Differences in physical intensity and training significantly influence endurance or fitness when engaging in intense physical activity. This aligns with Parmar's (2021) statement that, in general, longer training frequency leads to better physical fitness conditions [25]. This study aligns with research conducted by Todi and Widhiyanti using a sample of male basketball athletes from Universitas PGRI Mahadewa Indonesia. The researchers administered pretest-posttest assessments to the treatment group and control group, finding that the treatment group achieved a higher percentage (22.73%) compared to the control group (15.91%), with the treatment group receiving HIIT training [26].

4.4. The Effect of High-Intensity Interval Training on Maximum Oxygen Volume (VO2Max)

Based on the research results, karate athletes from Dojo Garing Kherti experienced an average increase in VO2Max of 11.28% with a sample size of 18 athletes. HIIT training using the 30:90 training method had a significant effect on increasing VO2Max. Intensive sprints for 30 seconds stimulate aerobic and anaerobic adaptation, while jogging for 90 seconds aids active recovery and maintains a high heart rate [27]. Other researchers have noted that High-Intensity Interval Training is an effective exercise method for increasing VO2Max. In this study, it was found that interval training consisting of high-intensity sprints and active recovery periods showed a greater increase in VO2Max compared to prolonged moderate-intensity exercise [28,29]. This study aligns with research conducted by Calista (2019), who also stated that HIIT can increase oxygen utilization during exercise. This is because the body relies more on oxygen, even during short, intense workouts. This adaptation enhances the body's ability to utilize oxygen more efficiently during exercise or daily activities [30].

High-Intensity Interval Training is a high-intensity exercise method that combines two types of physical exercise: aerobic and anaerobic. Aerobic exercise is high-intensity exercise that relies on oxygen to produce energy. Anaerobic exercise is high-intensity exercise performed in short bursts, where the body uses stored energy in the muscles to produce energy [31]. Aerobic and anaerobic exercises in HIIT have six different types of exercises. These six types of HIIT exercises can influence the body's physiological systems, such as the cardiovascular system, muscle system, and metabolism. High-Intensity Interval Training is effective in improving cardiorespiratory capacity and oxygen efficiency, thereby increasing VO2Max. This study aligns with research conducted by Xianghua (2023), which states that HIIT plays a role in increasing maximum oxygen volume, one of which is an improvement in cardiovascular capacity. In improving cardiovascular capacity, HIIT increases the efficiency of the heart in pumping blood and oxygen to the muscles of the body because the heart and blood vessels are stimulated to adapt by increasing the volume of blood pumped [31].

5. Conclusions

Based on the research results, it can be concluded that karate athletes at Dojo Garing Kherti in Jembrana Regency are predominantly male and aged 18 to 21 years. The average pretest VO2Max score for athletes was 39, and the average posttest VO2Max score was 43.4, indicating an increase in VO2Max of 11.28%. Additionally, VO2Max scores also vary by age group. Athletes aged 10–17 years had an average post-test VO2Max score of 41.57, while athletes aged 18–21 years had a post-test score of 43. Male athletes showed higher VO2Max scores than female athletes, with an average posttest VO2Max of 48.5 for males and 38.38 for females. Finally, the study showed a statistically significant increase in VO2Max values between the pretest and posttest. The average VO2Max increased from 39 during the pretest to 43.4 during the posttest, with a statistically significant difference (p-value = 0.001). This increase was due to high-intensity interval training (HIIT), which had a major impact on aerobic fitness and endurance.

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