

Effectiveness of interval training in increasing VO₂max in pencak silat athletes

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ABSTRACT

This study provides the most recent pertinent insights into the physiological factors influencing aerobic performance training in pencak silat athletes. An athlete's physical capacity is important for success in sports performance. Aerobic capacity is recognized as primary component. The prevailing consensus among authors identifies maximal oxygen uptake VO₂max as the best indicator of an organism's aerobic capacity, and a key metric for assessing the physical capacity in pencak silat athletes. Employing a quasi-experimental approach, this research was conducted between July and August 2023. Focusing on 45 pencak silat athletes from Senior High School 1 Basa Ampek Balai Tapan, using purposive sampling, 30 male athletes were selected as participants, with the bleep test used as the primary assessment tool. Statistical analysis via t-test revealed a positive impact of interval training on the VO₂max in pencak silat athletes, facilitating enhanced aerobic metabolism and energy production during maximum exertion.

KEYWORDS

Aerobic Performance; Physiological Determinants; Martial Arts; Sports

1. INTRODUCTION

Pencak silat, originating from the Malay ethnic group in Southeast Asia, particularly Indonesia (Hadiana, Subarjah, Ma, Yuliardi, & Nur, 2022; Razak et al., 2022). It has historical roots as a method of self-defense and a cultural art form during colonial. Since the post-colonial era, it has

devolved into a structured competitive sport, featuring in sanctioned tournaments such as the Southeast Asian Games (ASEA Games), European Championships, and World Championships. Its recent growth has been considerable, with participation from 37 countries reported in the 2016 World Championships. Similar to other Asian martial arts such as karate and taekwondo, pencak silat has gained popularity in Western nations, evidenced by the involvement of countries like the Netherlands, Belgium, United Kingdom, United States, and Australia in the 2016 World Championships. Moreover, prominent martial arts nations in the Eastern Hemisphere, such as Japan, China, and Korea, have embraced pencak silat, evidenced by their participation in the 2016 World Championships, and its inclusion in major events like the 2018 Asian Games and beyond.

In addition to being a means of self-defense, pencak silat offers avenues for competitive engagement and recognition (Irianto & Lumintuarso, 2020). Its training methodologies are characterized by innovative approaches tailored to diverse age groups, thereby enhancing their martial arts skills and fostering interest (Nugroho, Gontara, Angga, & Jariono, 2024).

Moreover, the students excelled in numerous competitions, winning bronze medals and other awards. This achievement is closely linked to the support provided by instructors and the resources offered by the institution, encompassing training aids and materials. Additionally, participants were thoroughly prepared for victory through their outstanding physical conditioning and unwavering determination during training. It is crucial to underscore that in pencak silat, physical fitness, which includes achieving an optimal maximal oxygen uptake (VO_{2max}) and maintaining peak physical condition throughout training and competition, significantly impacts success, mastery of techniques, and proficiency in movement practice.

Anaerobic capacity is the dominant activity during submaximal and maximal intensities influenced by factors such as the functionality of the cardiovascular and respiratory systems, morphological status, metabolism, and muscle structure (Szymczak & Sawicka, 2021). Furthermore, it represents the maximum amount of adenosine triphosphate that can be replenished through anaerobic metabolism (alactic and lactic systems) during maximal exertion. Exercise prescriptions involve a multifaceted approach, encompassing various manipulable variables like training intensity, duration, and frequency, as extensively reviewed in literature focusing on interval training (IT) for performance enhancement (Coates, Joyner, Little, Jones, & Gibala, 2023). IT, characterized by alternating high-intensity workouts with rest intervals, has been shown to confer significant physiological advantages, including enhanced aerobic energy provision and increased whole-body

VO₂max (Mueller et al., 2015). Studies have demonstrated its capacity to improve cardiovascular health, reduce blood pressure, enhance physical fitness, and optimize muscle oxygen delivery (Arboleda-Serna, Feito, Patiño-Villada, Vargas-Romero, & Arango-Vélez, 2019). Moreover, high-intensity interval training (HIIT) is associated with elevated prefrontal cortical oxygenation suggesting potential cognitive and metabolic benefits for athletes (Shao, He, Liu, & Fu, 2023). Given its efficacy, IT is a fast and effective method to enhance mental and physical well-being.

IT typically comprises repeated bouts of intense exercise interspersed with short recovery periods, these methods are commonly classified into HIIT characterized by near-maximal effort (Khammassi et al., 2018). IT involves alternating short bursts of high-intensity exercise with recovery periods featuring passive or light-intensity movement (Hidayati et al., 2022; Nye, Grubic, Kim, O'Connor, & Deuster, 2023). In this study, we investigated the hypothesis that significant enhancements in VO₂max and aerobic capacity could be achieved by implementing a training program incorporating periods of high-intensity exercise at 90% effort. It is essential to include programs designed to maximize physiological adaptation when examining the biology of anaerobic trainability and VO₂max. Research indicates that rigorous IT and combining IT with continuous training CT can substantially increase VO₂max, with greater improvements observed with longer intervals (Maroon, 2022; Philp et al., 2022). Furthermore, more intensive training can challenge the notion that certain individuals may only exhibit marginal responses to standard training regimens in terms of VO₂max (Maroon, 2022; Philp et al., 2022). Enhancements in VO₂max primarily stem from increased stroke and red blood cell volumes, both adapting independently (Ghosh et al., 2023; Tanner & Gore, 2013). Genetic studies have identified numerous genes associated with VO₂max trainability, suggesting a hereditary component to individuals' responses to exercise interventions (Li et al., 2023; Mergiyaw, Rani, & Deyou, 2018). Consequently, assessing the biology of anaerobic trainability and VO₂max requires rigorous training programs to optimize physiological adaptations and account for genetic influences on response variability.

The extracurricular pencak silat trainer at Senior High School 1 Basa Ampek Balai Tapan was interviewed on April 11, 2023, and observations were performed. It was noted that the athletes' VO₂max capacity remains below the desired level. This deficiency becomes apparent during afternoon practices on the school pitch, where many athletes experience rapid fatigue and physical weakness after only a short training. Moreover, issues with breathing control arise particularly among athletes who exhibit signs of exhaustion after exercise or a few movements. These observations

suggest that there is still ample opportunity for enhancement in the VO₂max capacity of the extracurricular pencak silat athletes at Senior High School 1 Basa Ampek Balai Tapan.

The objective of this study was to assess the efficacy of IT in enhancing VO₂max among pencak silat athletes. By examining the influence of IT on these key physical fitness metrics, this research aims to offer fresh perspectives and make substantial contributions to improving the performance levels of pencak silat athletes. Through this investigation, we anticipate the emergence of more targeted and efficient training guidelines tailored to enhance the physical fitness of pencak silat practitioners, serving as the basis for developing superior training programs.

2. METHODS

2.1. Design

This study utilized a quasi-experimental design to evaluate the effect of an interval training (IT) program on enhancing VO₂max among pencak silat athletes at Senior High School 1 Basa Ampek Balai Tapan. The design involved measuring VO₂max levels both before and after the implementation of the IT regimen to assess any significant improvements in cardiovascular fitness. The pre- and post-intervention data provided a comparative analysis of the athletes' fitness levels and allowed for evaluation of the IT program's effectiveness.

2.2. Participants

The participants in this study consisted of 30 male athletes from the pencak silat extracurricular program at Senior High School 1 Basa Ampek Balai Tapan. Out of the total population of 45 athletes involved in the extracurricular activities, 30 athletes were selected based on their active participation and availability throughout the study period. Prior to inclusion, all participants underwent a screening process to ensure they met the eligibility criteria, which included health assessments and baseline physical measurements. Informed consent was obtained from all participants, ensuring that they understood the purpose and procedures of the study and agreed to participate voluntarily.

2.3. Procedures

The study took place over an eight-week period from July to August 2023 at the designated training field of Senior High School 1 Basa Ampek Balai Tapan. During this time, participants engaged in a customized interval training program aimed at improving cardiovascular fitness, particularly VO₂max. The training program was designed to be performed three to four times a week

and consisted of a structured warm-up phase, the main interval training phase, and a cool-down phase. Before the intervention, each participant's VO₂max was measured, alongside other physical parameters such as weight, height, and blood pressure, to establish baseline fitness levels. The intervention itself involved regular sessions of sprinting, skipping, and burpees, with specific rest periods in between. After the eight-week program, the same measurements were taken again to determine the changes in fitness levels following the intervention.

2.4. Instruments

Several instruments were used in the study to collect data on the participants' physical parameters and monitor their progress. These included blood pressure meters to assess participants' blood pressure before and after each training session, height meters to measure their height, and weight scales for body weight measurements. VO₂max was measured using standard methods such as treadmill or step tests, which allowed for an assessment of each participant's cardiovascular fitness before and after the intervention. Data collection sheets were used to record all measurements and observations during both the pre- and post-intervention phases. Additionally, various sports equipment, including skipping ropes and other relevant tools, were used during the IT sessions to facilitate the exercises and ensure proper implementation of the training regime. Here is the IT Regimen for more details:

Table 1. IT Regimen

Session	Activity	Duration	Rest
Warm-up	1. Light jogging	5 min	-
	2. Dynamic stretching	5 min	-
IT	1. Round 1 (Maximum sprinting: 5–8 laps)	20 s	40 s
	2. Round 2 (Skipping/rope jumping: 5–8 rounds)	30 s	30 s
	3. Round 3 (Burpees: 5–8 rounds)	30 s	30 s
Cooling	1. Take a leisurely walk or jog	5 min	-
	2. Static stretching	5 min	-

Note: This regimen should be adhered to three to four times a week for eight weeks. When determining the exercise duration, number of repetitions, and intensity, consider the athletes' conditions and abilities. It is crucial to monitor the athletes' fatigue levels and ensure adequate recovery time between training sessions.

2.5. Statistical analyses

The data collected from the pre- and post-intervention measurements were analyzed using appropriate statistical methods to evaluate the effectiveness of the IT program in improving VO₂max. The primary outcome was the change in VO₂max levels, measured before and after the

intervention. Paired t-tests or other relevant statistical tests were employed to compare the VO2max scores, with a significance level set at $p < 0.05$ to determine whether the differences observed were statistically significant. The statistical analysis aimed to confirm whether the IT program resulted in meaningful improvements in cardiovascular fitness among the athletes.

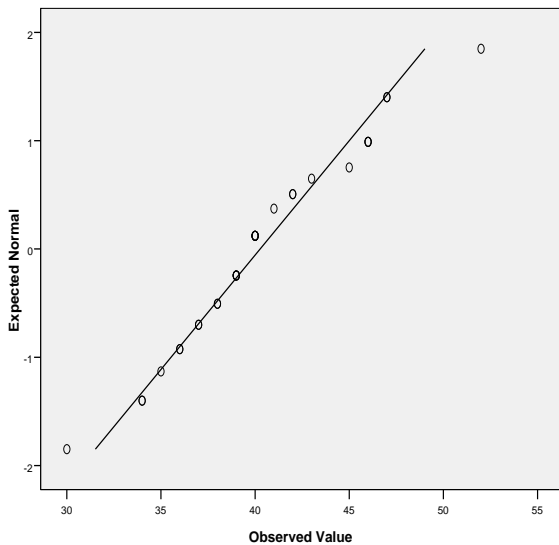
3. RESULTS

The primary focus of this research is assessing the variance in VO2max capacity before and after IT. Building upon insights gleaned from prior findings, it can be concluded that:

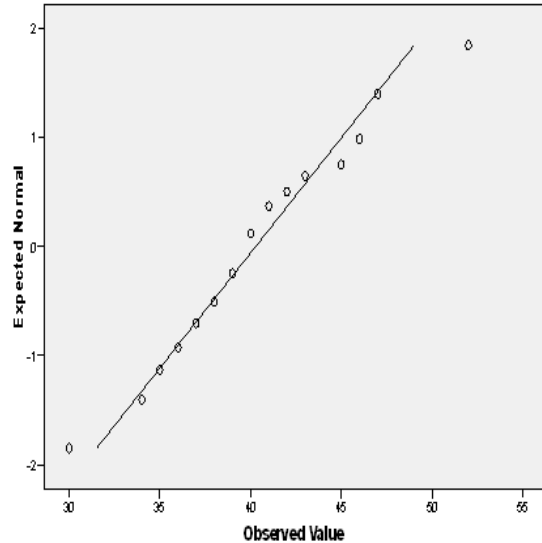
Table 2. Tests of Normality

	Kolmogorov–Smirnov(a)			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Before_VO2max	.156	30	.061	.973	30	.615
After_VO2max	.085	30	.200(*)	.983	30	.888

The obtained output indicates that before IT, the statistical value for Kolmogorov–Smirnov is 0.085 with 114, samples, yielding a significance value sig or p-value - of 0.200, which is greater than the threshold of 0.05 for VO2max capacity. Consequently, the null hypothesis (H0) is accepted indicating that the data pertaining to VO2max capacity exhibit a normal distribution. Refer to the normal quantile–quantile (Q-Q) plot for further insights.



(1)



(2)

Figures 1 and 2. Normal Q–Q plot before and after the IT

In addition to the standard Q–Q plot, normality testing of VO2max capacity data can also utilize the detrended normal Q-Q plot. The normal distribution is indicated when the data points, represented as dots, do not exhibit a discernible pattern and cluster around a horizontal line intersecting the zero point.

Table 3. Homogeneity of the Variance Test

		Levene statistic	df1	df2	Sig.
Data	Based on the mean	.810	3	116	.491
	Based on the median	.832	3	116	.479
	Based on the median and with adjusted df	.832	3	110.777	.479
	Based on the trimmed mean	.799	3	116	.497

Levene's statistical test results in all criteria have sig. values, above 0.05. Given that the sig value is > 0.05, it can be inferred that variables Y1 and Y2 originate from a homogeneous population.

Table 4. Paired Samples Statistics

		Mean	N	Std. deviation	Std. error mean
Pair 1	Vo2max	40.27	30	4.734	.864
	Vo2max	42.87	30	5.507	1.005

The paired sample statistics table shows that the mean VO2max capacity before IT was 40.27. After IT, it increased to 42.87. Descriptively, there is a difference in the mean VO2max before and after the implementation of interval training exercises.

Table 5. Paired samples test

		Paired differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence interval of the difference				
					Upper				Lower
Pair 1	Vo2max - Vo2max	-2.600	2.222	.406	-3.430	-1.770	-6.409	29	.000

4. DISCUSSION

These findings have significant implications for training regimens that enhance athletes' aerobic capacity, particularly for sports like pencak silat, characterized by brief yet intense bursts of activity. IT programs like the one investigated in this study, can substantially increase athletes' VO2max capacity. This enhancement could translate into improved competitive performance and

endurance for athletes. Interval training is a potent and efficient approach for inducing central (cardiovascular) and peripheral (skeletal muscle) adaptations associated with improved health. This method has enhanced athletes' VO₂max (Mueller et al., 2015; Shao et al., 2023). Individuals can prolong their exercise duration by engaging in high-intensity exercise while operating at a higher percentage of their VO₂max (Darajat et al., 2024). Traditionally, high-intensity workloads during training sessions have been utilized to prepare athletes requiring VO₂max (Bahtra, Asmawi, Widiastuti, & Dlis, 2020). It is important to recognize that different physiological responses to IT must be considered. Comparing IT formats with similar (and maximal) cardiorespiratory responses may yield varied anaerobic energy contributions. Training at high intensities of 90–95% of the minimum speed/power that elicits VO₂max at up to 100% of one's maximum running speed has been emphasized (Castagna, D'Ottavio, Vera, & Álvarez, 2009; Hargreaves & Spriet, 2020; Suchomel, Nimphius, Bellon, Hornsby, & Stone, 2021).

Across diverse training, modalities, IT formats are currently among the most effective methods for enhancing cardiorespiratory and metabolic function, consequently improving athletes' physical performance (Brinsley, Girard, Smout, & Davison, 2021; Reljic, Frenk, Herrmann, Neurath, & Zopf, 2021; Rifki, Ilham, Ndayisenga, & Zakaria, 2023). Moreover, HIIT has been shown to elicit adaptations comparable to those observed with resistance training (Garc, Javier, Marcos-pardo, Rubio-arias, & Mart, 2021; Kokarev, Kokareva, Atamanuk, Terehina, & Putrov, 2023). Maximum Oxygen Volume (VO₂Max) is the body's ability to use oxygen, being an indicator of the level of cardiovascular health, the higher the VO₂max, the higher the level of cardiovascular health, and vice versa (Syamsudin, Wungu, Qurnianingsih, & Herawati, 2021). Research conducted by Lavoué et al (2020) proves that Interval Training is better than Endurance Training. The higher and more training, the higher the results obtained for increasing VO₂max. So from previous studies it has been shown that interval training has proven to be effective in increasing VO₂max. Other studies have shown that interval training is able and proven to increase hemoglobin levels (Dhuha, Yogaswara, Hajar, & Firdaus, 2024). If hemoglobin levels increase, this will also increase oxygen uptake, so that the oxygen supply to cells will also increase and energy production will increase, which will have an impact on the stability of muscle contractions.

Owing to high-intensity exercise, HIIT may lead to increased CO₂ generation, influencing ventilation regulation. Research conducted on individuals with heart failure (HF) and coronary artery disease (CAD) has shown that HIIT significantly enhances anaerobic threshold (AT) and peak

oxygen consumption (VO₂) levels compared to moderate-intensity continuous training (MICT) (Reljic et al., 2021; Sansone et al., 2018). HIIT has been found to increase exercise capacity and cardiorespiratory fitness, demonstrating benefits comparable to continuous exercise and improving ventilation control (Magor-Elliott, Fullerton, Richmond, Ritchie, & Robbins, 2021; Rifki et al., 2023). Consequently, IT, particularly HIIT, can create environments where CO₂ generation increases, thereby affecting ventilation dynamics. This indirectly affects the athlete's aerobic capacity.

The study provides compelling evidence showcasing the efficacy of IT in enhancing VO₂max in pencak silat athletes. Future investigations could focus on the long-term implications of such training protocols and determine optimal training schedules for increasing athletes' aerobic capacity across different sports. Additionally, incorporating additional performance indicators alongside VO₂max capacity may yield a more comprehensive understanding of the training's overall impact on athletic performance.

5. CONCLUSIONS

This study provides compelling evidence regarding the effectiveness of IT in enhancing VO₂max in pencak silat athletes. Statistical analysis revealed a significant increase in the mean VO₂max following the intervention and notable variations in VO₂max capacity before and after IT. These findings suggest that IT is promising for improving athletes' aerobic endurance, critical factor in enhancing performance in sports such as pencak silat. These enhancements will enable athletes to withstand longer intense activities in challenging competitive environments and improve their recovery abilities between training sessions or games. This study provides a strong foundation for developing training strategies to enhance the aerobic fitness of pencak silat competitors. IT is a potent technique capable of substantially improving athlete performance. Future research endeavors could explore the long-term effects of these exercise regimens and identify optimal training schedules tailored to athletes participating in various sports, thereby maximizing their gains in aerobic capacity.

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CONFLICTS OF INTEREST

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