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VO_2max research: Endurance capacity levels of pencak silat martial artists

Ittaqwa[1]*, Triatmo Joko Purnomo[2], Widya Nur Afifa[3], Patrick Keilbart[4]

[1]Universitas Negeri Malang, Indonesia
[2]Universitas Negeri Malang, Indonesia
[3]Universitas Negeri Malang, Indonesia
[4]Goethe University Frankfurt, Germany

ABSTRACT

Background: Low aerobic capacity remains a significant concern in combat sports, including *pencak silat*, as endurance is crucial in sustaining performance throughout a match. Martial artists lacking adequate aerobic fitness are more likely to experience performance decline in the later stages of competition. ***Aims*:** To determine their aerobic fitness profiles, this study will evaluate the maximal oxygen uptake (VO_2max) levels of *pencak silat* martial artists. **Methods:** A quantitative approach with a test-and-measurement design was employed, involving 12 *pencak silat* martial artists as research subjects. The primary instrument used was the Bleep test, a standardized tool for accurately assessing aerobic capacity. **Result:** The results showed that the martial artists' average VO_2max was 30.74 ml/kg/min, which falls into the low category. The categorization revealed that 50% of the martial artists were in the "very poor" category, 8.3% in "poor," 25% in "fair," and 16.7% in the "moderate" category. These findings indicate that the martial artists' aerobic fitness levels are still far from optimal, which may hinder their ability to perform at their best during competitions. Therefore, this study recommends implementing more structured and targeted training programs to improve aerobic capacity. **Conclusion:** Appropriate training interventions will enhance physical endurance and help maintain technical quality and consistent performance throughout matches. The results of this study offer valuable insights for coaches in designing more effective physical conditioning strategies.

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INTRODUCTION

Pencak silat is a traditional Indonesian martial art that has evolved into a recognized competitive sport and a form of cultural heritage. In official matches, *pencak silat* is conducted in three rounds, each lasting two minutes, with one-minute breaks (Nur et al., 2025). During the match, martial artists must perform various offensive and defensive techniques for attacking, blocking, and evading with high intensity and precision (Krabben., 2019). This repetitive high-intensity activity, combined with short rest periods, classifies *pencak silat* as a sport that imposes a complex metabolic demand, relying heavily on both the aerobic and anaerobic energy systems, especially during recovery between rounds (Bridge t al., 2014)

Under such demands, VO_2max (maximum oxygen uptake) becomes a critical physiological indicator that directly supports athletic performance. VO_2max reflects the capacity of the

Correspondent Author: Ittaqwa, Universitas Negeri Malang, Indonesia, ittaqwa.2106148@students.um.ac.id

cardiovascular and respiratory systems to supply oxygen to working muscles during intense physical activity. A higher VO_2max allows martial artists to recover faster between rounds, sustain attack frequency, and delay fatigue, thereby maintaining technical execution and decision-making throughout the match (Sandford et al., 2021). Conversely, martial artists with low VO_2max tend to experience performance drops in later rounds due to poor recovery and early onset of fatigue (Gryko, 2021; Martínez-Aranda et al., 2023; Pueyo et al., 2024)

Previous studies on combat sports have highlighted the importance of aerobic endurance, particularly VO_2max, in sustaining performance across multiple rounds of high-intensity bouts. In sports such as boxing and taekwondo, martial artists with higher VO_2max levels demonstrate superior round-to-round consistency and faster recovery between efforts (McDougle et al., 2023). Although *pencak silat* has unique movement patterns involving sudden attacks, dodges, and counterattacks, its match format, three two-minute rounds with one minute rests, imposes a similar metabolic structure that requires substantial aerobic support (Hadiana et al., 2022)

Training models for *pencak silat* emphasize speed, reaction time, and power output, but often lack structured aerobic conditioning components (Ahmad, 2018; Tofikin, 2020). Studies emphasized the need for age-adaptive *pencak silat* training models but did not elaborate on energy system targeting (Nur et al., 2025). In reality, VO_2max is the base that determines an athlete's ability to recover between explosive efforts, allowing sustained technical and tactical sharpness throughout all three rounds (Uppal, 2021). In a related martial art (Adda, 2022; Polevoy, 2024), VO_2max values are associated with lower blood lactate accumulation and greater cardiovascular efficiency in high-intensity interval formats. These findings are particularly relevant to *pencak silat*, where the intermittent nature of combat requires the athlete to repeatedly perform submaximal to near-maximal efforts within short periods (Pugliese & Takala, 2015; Zanevskyy & Zanevska, 2024). Insufficient aerobic base can lead to performance drop-off by the second or third round, potentially affecting reaction time, balance, and defensive readiness.

Moreover, despite the practicality of field testing, few *pencak silat* training institutions incorporate bleep tests or shuttle runs into their periodic evaluations. Yet, the bleep test remains a validated and accessible method for estimating VO_2max in the field (Adila et al., 2023; Su et al., 2024). Its applicability in martial arts has been documented, particularly in settings with limited access to lab-based gas analysis tools (Teunissen et al., 2025). Numerous previous studies have demonstrated that VO_2max is one of the key indicators supporting athletic performance in intermittent and high-intensity sports, such as boxing, taekwondo, judo, and football (Nur et al., 2025). Martial artists with higher VO_2max tend to exhibit better recovery capacity, greater resistance to fatigue, and more stable technique and concentration throughout competition. As such, VO_2max measurement is often used as a foundation for designing physiologically based training programs tailored to the sport's demands.

However, to date, scientific investigations examining the relationship between VO_2max and athlete performance have rarely focused on *pencak silat*, particularly at the regional or community level, where athlete development typically occurs outside professional sports systems (Anwar & Sukirman, 2024; Ma'mun et al., 2022). Although *pencak silat* shares similarities with other martial arts, three high-intensity rounds with limited rest time, research specifically analyzing the physiological demands of *pencak silat* concerning VO_2max remains scarce. Furthermore, most VO_2max assessments in previous studies have relied on laboratory-based methods (such as treadmill testing and ergospirometry)(Chwała et al., 2024; Heiber et al., 2024; Karlsson et al., 2022; Stevens et al., 2020), which are not always practically accessible to coaches and trainers in regional training environments. In this context, the bleep test presents a valid, efficient, and practical alternative, especially in settings with limited facilities (Perdana et al., 2025; Siddall et al., 2021). Nevertheless, the application of the bleep test as an evaluative tool in *pencak silat* has been poorly documented in scientific literature, despite its proven accuracy in estimating aerobic capacity across various sports disciplines (Kabir et al., 2025; Lubis et al., 2021; Putro et al., 2020).

Aerobic endurance plays a crucial role in the performance of *pencak silat* martial artists, particularly in sustaining attack intensity, facilitating recovery between rounds, and minimizing the early onset of fatigue during three-round matches. Despite this, there is a lack of empirical data concerning the VO_2max profiles of *pencak silat* martial artists at the training school level, particularly those engaged in community-based settings. This study addresses this gap by focusing on student-

aged martial artists (11–15 years old) from a local *pencak silat* school who routinely participate in regional competitions but have not previously undergone structured assessments of aerobic fitness. Numerous studies have affirmed the importance of VO_2max in high-intensity intermittent sports such as football, boxing, and taekwondo; however, there remains a notable deficiency of specific scientific data about *pencak silat* martial artists, particularly those in foundational or regional training environments. This indicates a critical gap in sports science literature concerning the physiological development of community-level *pencak silat* martial artists. In response to this gap, the purpose of this study is twofold: first, to measure and evaluate the VO_2max levels of *pencak silat* martial artists using the bleep test method; and second, to provide a scientific foundation for the development of more effective and targeted training programs tailored to the metabolic demands of *pencak silat* competition.

METHOD

Research Design

This study employed a quantitative approach with a test-and-measurement design to assess the aerobic fitness levels of *pencak silat* martial artists from a training center. This method was chosen to obtain objective data regarding the martial artists' maximum oxygen uptake (VO_2Max), which indicates aerobic capacity.

Participants

The research subjects consisted of 12 active *pencak silat* martial artists who were selected through purposive sampling. The inclusion criteria included: aged between 11 and 15 years, in good health, and participating in regular training at least three times per week.

Instrument

The primary instrument used was the Multistage Fitness Test (commonly known as the bleep test), a validated indirect measure of VO_2Max. Before the test, martial artists were briefed about the test procedure and its objectives. A standardized warm-up session lasting 10 to 15 minutes was conducted to prepare the martial artists physically. The test was carried out on a flat 20-meter track, where martial artists performed continuous shuttle runs synchronized with recorded beep sounds that increased in frequency over time. The test concluded when the martial artists could no longer maintain the required pace. The data collection techniques in this research were tests and measurements, carried out using the bleep test by running back and forth on a 20-meter track while following the music beep. The expected objectives of this research are to find out the maximum oxygen volume level (VO_2Max) of *pencak silat* martial artists.

Analysis Plan

Each martial artist's performance was recorded based on the last completed level and the shuttle. These results were then converted into estimated VO_2max values using standard conversion tables. Data were analyzed descriptively to determine the average VO_2max and classify the martial artists' aerobic capacity based on established norms from the Cooper Institute.

RESULTS AND DISCUSSION

Results

The researchers processed the data to obtain the level of VO_2max physical condition in *pencak silat* Martial artists. This research discusses an overview of the physical condition, especially the VO_2Max, that martial artists have as their physical basis, so that with the bleep test, the endurance of the martial artist becomes measurable. Whatever is obtained from this test aims to determine whether the physical condition is strong, because VO_2max itself can be called endurance. The physical component of endurance is the main thing that must be paid attention to. Therefore, the results of this research are obtained from facts and data in the field.

Table 1. Description of Accumulated Test Martial Artist Data Based on the Bleep Test

Descriptive Statistics								
	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Male	6	17.6	24.4	42.0	213.6	35.600	8.1051	65.692
Female	6	9.7	23.2	32.9	155.3	25.883	3.7950	14.402
Valid N (listwise)	6							

Table 1 presents the scores obtained by male and female martial artists. For males, the sum was 213.6, the maximum score 42, the minimum score 24.4, the mean 35.6, the range 17.6, the standard deviation 8.1, and the variance 65.6. For females, the corresponding values were a sum of 155.3, a maximum score of 32.9, a minimum score of 23.2, a mean of 25.8, a range of 9.7, a standard deviation of 3.7, and a variance of 14.4.

Table 2. Male Martial Artists' VO_2max Data Description

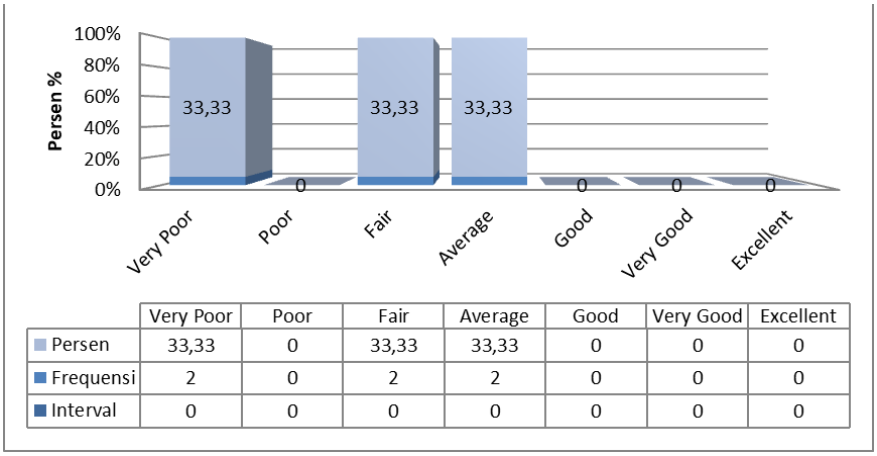
Descriptive Statistics								
	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Son	6	17.6	24.4	42.0	213.6	35.600	8.1051	65.692
Valid N (listwise)	6							

Based on Table 2 above, the data obtained from six male martial artists shows a total score of 213.6, with a maximum score of 42, a minimum of 24.4, a mean of 35.6, a range of 17.6, a standard deviation of 8.1, and a variance of 65.6.

Table. 3 Data Classification Bleep Test for Male Martial Artists

Male					
		Interval	Frequency	Valid Percent	Cumulative Percent
Norm	*Very Poor*	<5/1	2	33,33	33,3
	Poor	5/1-6/8	0	0	33.3
	Fair	6/9-8/2	2	33,33	66,66
	Average	8/3-9/9	2	33,33	99.99
	Good	9/10-11/3	0	0	99,99
	Very Good	11/4-13/7	0	0	99,99
	Excellent	>13/7	0	0	99,99
Total			6	99.99	

The frequency of martial artists with bleep test level scores in the range of <5/1 is 2 martial artists, or 33.33% of the total sample. In the 5/1–6/8 level range, there are 0 martial artists, accounting for 0% of the total sample. The frequency of martial artists in the 6/9–8/2 level range is 2 martial artists, or 33.33% of the total sample. In the 8/3–9/9 level range, there are also 2 martial artists, making up 33.33% of the total sample. The frequency of the 9/10–11/3 level range is 0 martial artists or 0% of the total sample. Likewise, in the 11/4–13/7 level range, there are 0 martial artists or 0%. Finally, the frequency of martial artists in the >13/7 level range is 0, representing 0% of the total sample.



	Very Poor	Poor	Fair	Average	Good	Very Good	Excellent
Persen	33,33	0	33,33	33,33	0	0	0
Frequensi	2	0	2	2	0	0	0
Interval	0	0	0	0	0	0	0

Figure 1. Bar diagram of VO_2max Level of Male *Pencak Silat* Martial artists

Table 4. Description of VO_2max Data for Female *Pencak Silat* Martial Artists

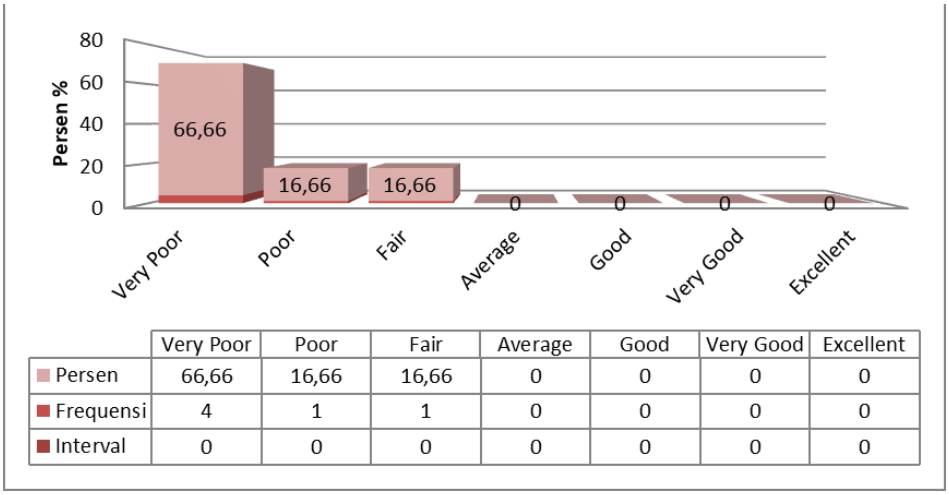
Descriptive Statistics								
	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Female	6	9.7	23.2	32.9	155.3	25.883	3.7950	14.402
Valid N (listwise)	6							

Based on Table 4 above, the data describe six female martial artists who scored 155.3. The maximum score was 32.9, the minimum was 23.2, the average (mean) was 25.8, the range was 9.7, the standard deviation was 3.7, and the variance was 14.4.

Table 5. Data Classification of Female Martial Artists' Bleep Test

Girl's					
		Interval	Frequency	Valid Percent	Cumulative Percent
Norm	*Very Poor*	<4/2	4	66,66	66,66
	Poor	4/2-5/6	1	16,66	83,32
	Fair	5/7-7/1	1	16,66	99.98
	Average	7/2-8/4	0	0	99.98
	Good	8/5-9/7	0	0	99,98
	Very Good	9/8-11/10	0	0	99,98
	Excellent	>11/10	0	0	99.98
Total			6	99.98	

The frequency of martial artists with bleep test scores in the <4/2 range is 4, or 66.66% of the total sample. In the 4/2–5/6 level range, there is 1 martial artist, accounting for 16.66% of the sample. Similarly, in the 5/7–7/1 level range, there is also 1 martial artist, or 16.66% of the total sample. No martial artists (0%) are in the 7/2–8/4, 8/5–9/7, 9/8–11/10, or >11/10 level ranges.



	Very Poor	Poor	Fair	Average	Good	Very Good	Excellent
Persen	66,66	16,66	16,66	0	0	0	0
Frequensi	4	1	1	0	0	0	0
Interval	0	0	0	0	0	0	0

Figure 2. Bar Diagram of VO_2max Level of Female Pencak silat Martial artists

Table 6. VO_2max Rate Data

No	Codes	Level	Come back	VO_2MAX	Age	Category
1	Code A	8	7	42	17	*Average*
2	Code B	7	10	39,9	16	*Fair*
3	Code C	4	4	24,4	16	*Very Poor*
4	Code D	8	4	41,1	16	*Average*
5	Code E	8	1	40,2	16	*Fair*
6	Code F	3	8	26	16	*Very Poor*
7	Code G	4	4	24,4	16	*Very Poor*
8	Code H	4	4	27,6	17	*Poor*
9	Code I	3	4	23,6	16	*Very Poor*
10	Code J	4	4	23,6	16	*Very Poor*
11	Code K	9	5	32,9	16	*Fair*
12	Code L	1	3	23,2	16	*Very Poor*
	Average			30,74		*Poor*

The frequency of martial artists in the "very poor" category is 6 martial artists, representing 50% of the total sample. The frequency in the "poor" category is 1 martial artist, or 8.3% of the total sample. In the "fair" category, there are 3 martial artists, accounting for 25% of the total sample. The "average" category includes 2 martial artists, or 16.67% of the total sample. The overall average falls into the "poor" category, with a value of 30.74.

Discussion

Maximum Oxygen Volume (VO_2max) is an indicator of cardiovascular health—the higher the VO_2max, the better the cardiovascular condition, and vice versa (Ma et al., 2023). More intensive training can challenge the idea that some individuals show only marginal improvements in VO_2max from standard training regimens (Gras & Gras, 2022). The increase in VO_2max mainly results from increased stroke and red blood cell volumes, both of which adapt independently (Nur et al., 2025). Genetic studies have identified numerous genes associated with VO_2max training ability, indicating a hereditary component in how individuals respond to exercise interventions (Buchheit, 2013; Zanevskyy & Zanevska, 2024). Therefore, assessing the biology of anaerobic training ability and VO_2max requires a rigorous training program to optimize physiological adaptations and account for genetic influences on response variability.

Individuals can extend their workout duration by performing high-intensity exercises at a higher percentage of their VO_2max (Karlsen et al., 2017; Scott et al., 2019). Traditionally, high-intensity workloads during training sessions have been used to prepare martial artists for VO_2max requirements (O'Donovan et al., 2017).

Regarding the bleep test results, the frequency of male silat martial artists with recorded times in the <5/1 level range was 2 athletes, or 33.33% of the total sample. Those in the 6/9–8/2 range were also 2 athletes (33.33%); similarly, 2 athletes (33.33%) fell within the 8/3–9/9 level range. Among female silat martial artists, 4 athletes (66.66%) recorded times in the <4/2 level range, while 1 athlete (16.66%) was in the 4/2–5/6 range, and 1 athlete (16.66%) in the 5/7–7/1 range.

The research results showed that the VO_2max endurance level of the Domas Cimande Perawang Pencak Silat martial artists fell into the poor category, averaging 30.74. Pencak Silat martial artists should possess good endurance, essential for competing optimally. During matches, martial artists must perform well and display their technical and tactical skills. Those with good endurance can do this effectively, while those lacking endurance will struggle to perform at their best.

Interval Training is better than Endurance Training (Karlsen et al., 2017; Wajib et al., 2022). The more intense and frequent the training, the greater the increase in VO_2Max. Previous studies have proven that interval training effectively increases VO_2max. Additionally, research shows interval training can increase hemoglobin levels (MacInnis & Gibala, 2017). Higher hemoglobin levels improve oxygen absorption, enhancing oxygen delivery to cells and energy production, positively impacting muscle contraction stability.

High-Intensity Interval Training (HIIT) has been found to improve exercise capacity and cardiorespiratory fitness, providing benefits comparable to continuous exercise and improving ventilatory control (Gjinovci et al., 2017; Vasquez-bonilla et al., 2022). HIIT, in particular, creates an environment where increased CO2 and oxygen production influence ventilation dynamics, indirectly enhancing aerobic capacity. This study provides strong evidence supporting VO_2max improvements in Pencak Silat martial artists.

Future research could explore the long-term effects of such training protocols and identify optimal training schedules to improve aerobic capacity across various martial arts disciplines. Additionally, incorporating other performance indicators alongside VO_2max would offer a more comprehensive understanding of the overall impact.

Research Contributions

This study significantly contributes to the development of sports science, particularly in the context of pencak silat training. The findings present empirical data on the VO_2max condition of adolescent pencak silat martial artists at the Domas Cimande Perawang training center, which is generally categorized as low. These results provide a critical foundation for designing more targeted physical training programs that align with the physiological needs of martial artists. Furthermore, the study reinforces the relevance of fitness assessments, such as the Bleep Test, in pencak silat training as a tool to regularly monitor physical progress. This research also highlights the potential of High-Intensity Interval Training (HIIT) as an effective method to improve aerobic capacity in martial artists, aligning with modern athletic training approaches that emphasize efficiency and optimal physiological adaptation.

Research Limitations

This study has several limitations that need to be acknowledged. First, the small sample size of only 12 martial artists limits the generalizability of the findings to a broader and more diverse pencak silat population. Second, using the Bleep test as an indirect measure of VO_2max is estimative and lacks the accuracy of laboratory-based methods, which calls for careful interpretation of the results. Third, the study did not control for external factors such as nutritional intake, sleep quality, or psychological conditions, which may influence athlete performance during testing. Lastly, the cross-sectional design of this study does not allow for assessment of VO_2max development over time, making it impossible to capture the long-term effects of training interventions.

Suggestions

Based on the findings and limitations, several suggestions are offered. For coaches and pencak silat training centers, it is recommended to design and implement structured HIIT programs to improve martial artists' aerobic capacity, particularly for those currently in the low VO_2max category. For future researchers, longitudinal studies with larger sample sizes are encouraged,

incorporating additional variables such as training intensity, body composition, and dietary habits. Regarding measurement tools, using laboratory-based methods such as treadmill tests or cycle ergometers with gas analyzers is advised for greater validity and reliability in assessing VO_2max. Furthermore, a holistic training approach should be adopted, integrating physical training with nutritional education, recovery strategies, and mental health management to support optimal athletic performance. Schools or institutions offering pencak silat extracurricular activities are also advised to design a structured physical fitness curriculum with VO_2max as a key indicator of foundational fitness levels.

CONCLUSION

This study successfully achieved the initial objective stated in the introduction, namely to measure and assess the VO_2max levels of adolescent pencak silat athletes using the bleep test method. The findings revealed that most athletes had low to moderate aerobic capacity, supporting concerns that training at the community level has not fully developed the aerobic endurance needed to maintain performance throughout three competitive rounds. These results underscore the importance of incorporating more structured High-Intensity Interval Training (HIIT) programs into the development of young athletes. Moreover, the study opens up opportunities for further in-depth research, including longitudinal studies with larger sample sizes, evaluation of additional performance indicators, and the design of training curricula aligned with the physiological demands of pencak silat at the foundational level.

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