JOSSAE (Journal of Sport Science and Education)

OPEN ACCESS
E-ISSN Online: 2548-4699
http://journal.unesa.ac.id/index.php/jossae/index
http://dx.doi.org/10.26740/jossae.v7n2.p127-135

The Effect of the High-Intensity Interval Training Program in Increasing VO_2max Capacity and Heart Rate Recovery

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Received: 30 Oct 2023 **Accepted**: 22 Nov 2023 **Published**: 24 Nov 2023

Abstract
This research aims to test the effects of the program High-Intensity Interval Training (HIIT) on VO_2max capacity and heart rate recovery. A total of 13 student-level Pencak Silat athletes met the conditions set out in this study, namely: (fighting category athlete, male, age 19.5±1.4 years, and actively practicing = 4.9±0.9 years). Experimental procedures by design one group pretest-posttest applied for 4 weeks, where data was taken for each subject before and after training using the procedure Yo-yo Intermittent Recovery Test Level 1 (YYIR1) and monitoring heart rate recovery with the heart rate monitor Polar-H10 on the HIIT protocol work: rest ratio (1:1). Data from all subjects was processed using the SPSS tool, where the hypothesis testing process was carried out using prerequisite tests. The results showed a significant increase ($p<0.05$) in VO_2max capacity (2.9 ± 1.4 ml.kg-1.min-1) and heart rate recovery (9.8±9.1). With increasing VO_2max given heart rate recovery it can be concluded that the HIIT program has proven to be effective in increasing aerobic ability and a faster recovery process, so that it will support more optimal athlete performance.

Keywords: heart rate recovery; high-intensity interval training; pencak silat; VO_2max capacity

1. Introduction

Pencak Silat is a martial art that has been recognized by UNESCO as one of Indonesia's cultural heritages which must be protected and preserved. Although historical records cannot explain exactly when Pencak Silat was born, it is believed that Pencak Silat was born in the Indonesian archipelago, it is estimated that since the existence of civilization human life. In pre-historic times, the law that applied was that whoever was strong would be able to survive, so the closest thing that was of concern and focus was how to survive and maintain life in the form of self-defense instincts. Over time, Pencak Silat began to develop in various countries and competed at the international level (Subekti et al., 2019).

As a competitive sport, the quality of physical fitness is the main factor in supporting technical-tactical performance and determining the success of a pencak silat athlete in the competition (Yuliana & Wahyudi, 2022). Optimal physical performance and non-technical technical factors determine success and failure in a match. In line with the opinion, (Bafirman & Wahyuri, 2019) stated that fundamental achievement is optimal physical performance to support other components in a match such as technical, tactical, and mental skills. According to (Bompa & Buzzichelli, 2019), achievement success will be achieved optimally if the training program is designed appropriately. There is a need to modify training methods to suit the characteristics and needs of Pencak Silat competitions. Based on the results of the survey entitled Worldwide Survey of Fitness Trends for 2019 which was conducted by

the American College of Sports Medicine, High-Intensity Interval Training (HIIT) is among the most popular exercises (Thompson, 2021). HIIT is an exercise that uses a combination of high-intensity exercise interspersed with moderate or low intensity, which can stimulate the heart to work harder so that it can increase the body's oxygen and metabolism (Micah, 2014). According to (Subekti et al., 2021), the results of the analysis of the category Pencak silat matches fight characterized by an alternating pattern, the presence of combat and non-combat activities. Based on these competition activities, Pencak Silat reflects the HIIT protocol.

The lack of variations in HIIT training programs in Pencak Silat martial arts in improving athlete performance, and limited information regarding HIIT training models that are relevant to Pencak Silat sports, are some of the factors that cause most coaches not to understand the correct procedures (Subekti & Warthadi, 2022). Apart from that, the HIIT protocol is important in considering the physical demands required in sports, this aims to enable athletes to adapt to motor actions so that physical performance can increase (Monteiro et al., 2020). Athletes who have excellent physical endurance have a greater opportunity to participate in the complete and maximum training program that has been prepared by the coach (Putera et al., 2019, 2023). Endurance is divided into two, namely aerobic and anaerobic endurance. Aerobic endurance has the characteristics of activity over a relatively long period. and in its implementation, it involves oxygen, aerobic endurance is related to maximum oxygen consumption in the body and is often called VO_2max. That way, an athlete has physical demands in the form of endurance VO_2max to be able to carry out training tasks and maximize techniques and strategies in competing.

The HIIT method is more effective in increasing VO_2max, reducing recovery heart rate, and reducing resting heart rate (Fatikhawati et al., 2021). Heart rate recovery or recovery pulse is the pulse measured after completing an activity. Decline heart rate quickly reflects good heart function. According to (Kurniawan et al., 2022), an athlete's physical performance is influenced by their ability to recover (heart rate recovery). So, a Pencak Silat athlete needs to have a heart rate recovery or a quick pulse recovery period so that athletes can carry out their tasks during training or in competitions without experiencing significant fatigue. However, so far, and to the author's knowledge, many martial arts training programs are still implemented based on tradition, intuition, and previous trainer experience (Artioli et al., 2009), and only a few use modern methods in training (Nusufi, 2015).

Based on previous studies, researchers were interested in focusing on testing the effectiveness of the HIIT program applied to trained individuals, which was designed based on the demands of Pencak Silat competitions. The HIIT program will be tested for its effect on increasing aerobic capacity, assessed based on VO_2max capacity and the initial recovery speed or heart rate recovery of Pencak Silat athletes.

2. Method

Types of research and samples

This research was quantitative research with methods experiment using groups pretest-posttest design. The research was carried out at the integrated laboratory of Sports Education, Muhammadiyah University of Surakarta, from March 17 2022 to April 22 2022 including initial data collection (pretest), training programs (treatment) held 3 meetings a week for 4 weeks, and final data was collected (posttest). All 13 subjects were Pencak Silat athletes from the Muhammadiyah University of Surakarta, signed a consent form. The research sample met the specified criteria, namely: athletes in the competition category, gender male, age = 19.5±1.4 years, and actively practicing = 4.9±0.9 years) and obtain a minimum average score based on the criteria tableVO_2max yo-yo intermittent test recovery level 1.

High-Intensity Interval Training Protocol (HIIT)

Based on the analysis of the time movements of Pencak Silat matches in the fight category, time-combat (mounting posture, step pattern) is 3.6-8.4 seconds, and combat activity time is 0.6-2.6 seconds (Subekti et al., 2021). To control and make training easier, the specified time is 10 seconds, the HIIT protocol simulates a Pencak Silat match, consisting of 3 minutes by 3 rounds with 1-minute intervals between them, the athlete performs a series of movements (punches, kicks, and falls) on the punch/target according to the program has been determined, carried out in 4 weeks, the 1st week uses HIIT 1: 3 (10-second activity 30-second interval), the 2nd and 3rd week uses 1:2 (10-second activity 20-second interval), and the 4th week using HIIT 1:1 (10-second activity 10-second interval).

Table 1. HIIT workout protocol for 4 weeks

Micro	Monday	Wednesday	Friday
1	Prayer	Prayer	Prayer
	Warming up (static and dynamic)	Warming up (static and dynamic)	Warming up (static and dynamic)
	ABC Running	SAQ	Aerobics (10 minutes) Interval Speed (30' slow 10' fast) 8x rep
	HIIT 1:3 training program	HIIT 1:3 training program	Exercise program HIIT 1:3
	Perform a punch (10 x 2 set)	The Slam	The perform punch is followed by 1-3 reaction pitching (10 x 3 set)
	Defend a punch (10 x2 set)	Cooling down, PNF	Cooling down, PNF
	The combination with a punch is followed by a Slam (10 x 2 set)	Prayer	Prayer
	Cooling down + Prayer		
2	Prayer	Prayer	Prayer
	Warming up (static and dynamic)	Warming up (static and dynamic)	Warming up (static and dynamic)
	ABC Running	ABC Running	Fun Games
	Warming up with pitching	HIIT 1:2 training program	Test Speed, dodge sickle kick and sickle kick right - left (5' x 2 set)
	HIIT 1:2 training program	The Takedown	HIIT 1:2 training program
	Psalm right and left 10 x	Cooling down, PNF	The attack directly (10 x 2 set)
	The anticipation slam 10 x	Prayer	The attack indirectly (10 x 2 set)
	Cooling down		Cooling down
	Prayer		Prayer
3	Prayer	Prayer	Prayer
	Warming up (PNF)	Warming up (static and dynamic)	Warming up (PNF)
	SAQ 5 minutes x 2 sets	Skipping 30' slow and 15' fast (4 minutes)	Interval workout jumping jacks, push up,
	Warming up with pitching	HIIT 1:2 training program	squats, Russian twists (30' do
	HIIT 1:2 training program	The Takedown	30' rest x 3 sets)

Micro	Monday	Wednesday	Friday
	The series begins with a kick-straight,	Cooling down (PNF)	HIIT 1:2 training program
	then 1-3 reactions perform (10x 2 set)	Prayer	Perform one point (10 x 2 set)
	The series begins with a kick-straight,		Perform one point + Slam (10 x 2 set)
	then 1-3 reaction pitching + slam (10x 2 set)		Cooling down
	Cooling down		Prayer
	Prayer		
4	Prayer	Prayer	Prayer
	Warming up (static and dynamic)	Warming up (PNF)	Warming up (PNF)
	Skipping 10 minutes	Fun game ball	Interval workout jumping jacks, push up,
	Interval skipping (30' slow 30' fast 4-minutes)	1:1 HIIT program	squats, Russian twist (30' do
	1:1 HIIT training program	The slam	30' rest x 3 sets)
	The performance begins with a sickle kick, then performs another attack	Cooling down, PNF	1:1 HIIT training program
	(10 x 2 set)	Prayer	The combination with a punch is followed by a Slam (10 x 2 set)
	Cooling down		Cooling down (PNF)
	Prayer		Prayer

Procedure

At the first meeting, athletes were explained the aims of the research and then signed a written consent form. After that, the athlete prepares for initial data collection(pretest) and begins with a standard warm-up for 15 minutes consisting of a static and dynamic warm-up, The pretest VO_2max uses yo-yo intermittent test recovery level 1. In the second meeting, athletes carry out test heart rate recovery using HIIT 1:1 (10-seconds of activity 10-second intervals) with the help of equipment heart rate monitoring in the form of polar H10. After that, the athlete underwent a 4-week training program consisting of 4 weekly sessions. Before the training session, athletes perform a static and dynamic warm-up, after recovery for 2 minutes, the athletes are arranged in pairs, where one of them holds the punching and the other will carry out the HIIT protocol. The first athlete completes the HIIT protocol for 3 minutes in 3 rounds and a 1-minute rest period in each round, then the roles are swapped. After the 4-week training program is completed, the posttest is carried out again to determine changes before and after undergoing the HIIT training program.

Data collection

Data collection using a pretest and posttest was carried out before and after receiving the HIIT training program. Data collectionVO_2max uses yo-yo intermittent test recovery level 1 and data collection heart rate recovery using tools heart rate monitoring in the form of polar H10. To count heart rate recovery according to (Parmar & Modh, 2013) after completing the exercise, it was taken at minute 1, minute 2, and minute 3. This aims to compare how much the decreased heart rate back to normal.

Statistical analysis

Quantitative data analysis and descriptive statistics are used to describe the results of the data obtained, variables are presented in mean, variance, standard deviation, minimum, maximum, and sum. Data normality and homogeneity tests were proven using each test Shapiro Wilk and Levene. Significance level $p > 0.05$ This means that the data distribution is normally distributed. Hypothesis testing in this research uses an analysis statistic paired sample t-test, decision making if, sig < 0.05 then the hypothesis is accepted. Analyzes were carried out using the SPSS 22 statistical package.

3. Result

After the 4-week training program was completed, the results of the data analysis pretest and posttest on VO_2max and heart rate recovery were presented in table form as follows:

Table 2. Descriptive research data

Statistics	VO_2max		Heart Rate Recovery	
	Pretest	Posttest	Pretest	Posttest
Mean	43.48	46.38	36.15	46.00
Std. Deviation	2.13	3.28	9.48	9.64
Variance	4.54	10.75	89.97	93.00
Min	41.10	41.80	25.00	30.00
Max	48.50	53.90	55.00	60.00
Sum	565.20	603.00	470.00	598.00

Table 2 shows increasing changes in the results pretest with the posttest on VO^2max and heart rate recovery. This can be proven by obtaining an average value of 43.48 and 46.39 with a difference value of 2.91, while the variable heart rate recovery is 36.15 and 46.00 with a difference of 9.84. Before data analysis is carried out, it is necessary to carry out data normality test prerequisites which can be seen in the following table.

Table 3. Normality test analysis results

Variable	Sig	Conclusion
Pretest VO_2max	0.149	Normal
Posttest VO_2max	0.356	Normal
Pretest HRR	0.660	Normal
Posttest HRR	0.574	Normal

Based on table 3, it can be concluded that the data is normally distributed. This conclusion implies that parametric statistical analysis can be used to test the hypothesis proposed for hypothesis testing that has been fulfilled. Next, a homogeneity test was carried out using the Levene test which is presented in Table 3 below.

Table 4. Homogeneity test analysis results

Variable	Sig	Conclusion
VO_2max	0.323	Homogeneous
HRR	0.515	Homogeneous

Homogeneity test using the Levene test, was carried out to determine the similarity of the variances of the variables. Decision making is if the Sig value is >0.05 then the sample criteria are homogeneous. The homogeneity test shows that the VO_2max variable is 0.323 and the variable heart rate recovery is 0.515. The homogeneity test results of the two variables above show a Sig value of >0.05. It can be concluded that the sample variance is homogeneous. So that the data meets the prerequisites for hypothesis testing, the differences pretest-posttest use paired sample t-test which is presented in Table 4 below.

Table 5. Pretest-posttest hypothesis test data

Variable	Mean	Std. Deviation	Significance Value
Pretest-Postest VO_2max	2.907	1.479	0.000
Pretest-Postest HRR	9.846	9.136	0.002

Hypothesis testing in this research uses analysis statistic paired sample t-test, known value mean ± SD data pretest-posttest VO_2max 2.9 ± 1.4 with a Sig value = 0.000 while the data results pretest-posttest heart rate recovery 9.8 ± 9.1 Sig = 0.002.This proves that there is an increase in the average value of pretest-posttest VO_2max and heart rate recovery after a HIIT training program.

4. Discussion

This study aimed to test the HIIT protocol for improvement VO_2max and heart rate recovery in the Pencak Silat athlete category fight. Consider that Pencak Silat is a sportful body contact with high aerobic and anaerobic demands (Mirfen, 2018), and the ability to recover from heart rate recovery, in terms of the characteristics of Pencak Silat matches, there are interval breaks, stop signals, stance, start and rest in each round of the match (Subekti et al., 2021). Decline heart rate quickly reflects good heart function, so athletes need to have heart rate recovery quickly so that they can return to their activities without experiencing significant fatigue. The main finding of the study was that training 3 sessions per week over the 4 weeks of the training program, resulted in significant increases in improvement VO_2max and heart rate recovery.

Results from HIIT training analysis VO_2max found that the mean was 2.907 ± 1.479 while the results of heart rate recovery have an average value 9.846 ± 9.136. These results prove that there is increasing change. Experiment HIIT protocol 3 minutes times 3 rounds with 1-minute intervals in each round, training program 3 times per week for 4 weeks proven to be effective in increasing VO_2max and heart rate recovery UMS Pencak Silat athlete category fight. This research is in line with the previous study which states that the HIIT training program carried out 8 weeks 3 times a week with a duration of 60 minutes can improve the physical condition of STKIP Muhammadiyah Kuningan silat athletes. The research results show an increasing effect percentage in the HIIT group it was 5.119% on average pretest amounted to 877.538 while the average value post-test amounted to 922.462 reinforced by the findings (Monteiro et al., 2020) of the HIIT training protocol for wushu sanda athletes, consisting of 2 minutes by 3 rounds with 1-minute intervals between them, each round is divided into 8 blocks of 15 seconds. Each block consists of 5 seconds of high-intensity activity, 5 seconds of low-intensity activity, and 5 seconds of rest. The program is run 2 sessions/week for 4 weeks. The conclusion is that the addition of the HIIT wushu sanda training protocol can improve neuromuscular, aerobic, and anaerobic performance.

The findings show that the HIIT protocol was designed based on the movement structure during a Pencak Silat match (work 10 seconds and rest 30, 20, and 10 seconds) applied for 4 weeks with a frequency of 3-4 times per week, proven to improve physical performance; performance aerobic (VO_2max) anaerobic power and special speed of pencak silat (Subekti & Warthadi, 2022). Monitoring

The heart rate showed a faster decrease after HIIT with a ratio of 1:1. Strengthened by research from (Herrera-Valenzuela et al., 2021) a short duration HIIT program using techniques during a special boxing match simulation with a protocol of 3 blocks of 5 repetitions with all-out effort for 30 seconds, 1-minute interval between blocks, training frequency 3 times a week for 4 weeks. The results show that the HIIT program is effective in improving physical condition. In connection with HIIT training for combat sports, research by (Kamandulis et al., 2018) simulated training consisting of 3 rounds (14 sets of 3-second all-out punches with 10-second rest) against a bag. After 4 weeks at a frequency of 3 times a week, upper body aerobic strength and punching ability increased in amateur boxers. HIIT has an influence on changes in the aerobic and anaerobic performance of combat sports athletes, in line with (Franchini, Emerson,; Cormack, Stuart; Takito, Monica, 2019), the HIIT protocol can improve the physical performance of a fighting athlete with a low training volume. This has a good impact on coaches and athletes, the duration of training does not have to be long to improve physical performance . Therefore, training with the HIIT program is quite relevant for combat sports.

HIIT training can increase heart rate recovery as proven by the results of research (Yudha & Basuki, 2023) entitled "Effectiveness of High-Intensity Interval Training with Moderate Intensity Continuous Training on Sedentary Behavior on Changes in Heart Rate Recovery". Training once a week for 4 weeks, the results showed that HIIT was more effective in accelerating heart rate recovery with a value of $p = 0.04$, and MICT was not effective in accelerating heart rate recovery with a value of $p = 0.124$. There was no difference in effectiveness between HIIT and MICT in accelerating heart rate with a value of $p = 0.529$, and HIIT is more effective than MICT in reducing heart rate recovery with the mean difference test results obtained being -6.63 (HIIT group) and -3.95 (MICT group). Strengthened by research (Kurniawan et al., 2022), the results of the study concluded that HIIT training with a passive recovery model for 8 weeks increased the quality of VO^2max and recovery heart rate monitoring (HRM, and HRR 2min, 5min, 10min). The results of the research (Kusuma et al., 2020) stated that there was a significant difference in the average resting pulse, and heart rate recovery in the 1st, 2nd, and 3rd minutes between subjects who regularly exercised and those who did not.

The physical requirements in Pencak Silat are more complex than in all sports, athletes who have a high metabolic condition can maintain endurance and develop technique (Laursen & Buchheit, 2019). Pencak Silat is a combat sport, characterized by alternating patterns, combat, and non-combat activities. Based on these competition activities, Pencak Silat reflects the HIIT protocol. Pencak Silat is a martial sportful body contact that requires athletes to have endurance and good technical quality to support performance when competing (Alonso-Fernández et al., 2017). According to (Boyle, 2016), athletes who have good endurance components have little risk of injury. In addition to endurance capacity (VO_2max), original recovery ability (heart rate recovery) is also important for an athlete (Gustian et al., 2022), so that the athlete is again able to carry out tasks during training and in competitions without experiencing significant fatigue. This is an important part of the sport of Pencak silat, considering the appropriate training program needed by the athlete to support performance when competing. Several limitations must be considered in interpreting this study. First, the small sample size can affect the power of statistical data processing. Second, researchers have not been able to fully control; the athlete's rest period and nutritional intake required by the athlete.

5. Conclusion and Recommendation

This research concludes that the Pencak Silat specific HIIT training program (3 minutes by 3 rounds and 1-minute intervals between them) applied 3 times per week for 4 weeks is effective in increasing VO_2max and heart rate recovery category Pencak Silat athlete fight. The HIIT program, which was designed based on the demands of Pencak Silat competitions, has proven to be effective in increasing aerobic ability and a faster recovery process so that it will support athletes' performance more

optimally. Ratio demands work and Rest can be used as a reference for preparing training programs. This specific HIIT protocol can be recommended as a new model of exercise to improve VO_2max and heart rate recovery especially the sport of Pencak silat. Coaches, sports practitioners, and other professionals can modify the HIIT protocol by considering the characteristics of the sport, training stages, and training targets.

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