



The Effectiveness of High-Intensity Interval Training on Specific Endurance and Technical Performance of Pencak Silat Athletes

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Abstract. This study aims to examine the effectiveness of the HIIT protocol on the specific endurance capacity of pencak silat athletes and its contribution to technical performance during match simulations. The experimental procedure with the one-group pretest-posttest design was applied in this study. A total of 13 pencak silat athletes at Universitas Muhammadiyah Surakarta with weight and age criteria were willing to participate in this study. All subjects completed the punch and kick endurance test procedure for 30 s with a 1-min rest break for three sets. Technical performance data was collected by recording each technique performed in a simulated pencak silat match (2 min × 3 rounds). The t-test and Pearson correlation test were used to analyze the data with the help of SPSS software. The results show that the mean ± SD of specific resistance value (10.9 ± 13.9) increased by 10.96 with a significance value of $p = 0.01$ from pre-test to posttest. Technical performance (3.53 ± 3.45) increased by 3.54 between the two match simulations with a significance value of $p = 0.003$. In addition, the correlation test results show that the specific endurance capacity contributed 0.26 to the technical performance in the match simulation. Thus, the HIIT program has proven effective as a training method to improve specific endurance and technical performance of pencak silat athletes in the fight category. HIIT with a special design can be recommended as a new training model for pencak silat athletes.

Keywords: high-intensity interval training · specific endurance · technical performance

1 Introduction

Pencak silat is a branch of martial arts and one of Indonesia's internationally recognized cultural heritages. This sport has many benefits, such as physical, mental, and social benefits. According to [1], pencak silat is an original Indonesian culture that maintains existence and integrity to achieve harmony in life, which helps increase faith and piety in its creator. Pencak silat has developed into an achievement competition. In pencak silat, the competition categories are fight, singles, doubles, and team [2]. Pencak silat fight is the most famous category in the competition. This category contains two fighters

from different camps and involves full body contact with attack and defense elements [3]. The match is divided into three halves with 2 min each and a 1-min break. Physical, technical, tactical, and mental must be considered in supporting peak performance. Having a physical fitness component is an essential aspect of achieving pencak silat [4]. As in combat sports in general, the success of a match depends on a scoring system for the success of attacks, such as hitting, kicking, and slamming, even ending in absolute victory within a specific time [5]. Several studies have shown that success in competition is related to biomechanical, physiological, and psychological aspects, such as judo [6]. Hand and foot attack techniques are important to winning, gaining points, and defeating opponents [3]. This statement is supported by [7], that kick is the most dominant technique used in pencak silat with a percentage of 47%. Kick is one of the movement techniques in pencak silat with high value and is one of the dominant techniques used in matches. Using kicking techniques in a game tends to be more efficient in collecting points and achieving attack targets.

Pencak silat is performed with high speed and good endurance as a sport with complex and powerful movements [8]. If it is related to the energy system of pencak silat matches, this energy system uses the dominant energy system of anaerobic endurance. It aligns with the research by [9]. High-Intensity Interval Training (HIIT) is repetitive training with high-intensity intervals interspersed with periods between 80% and 100% recovery. Regarding how HIIT works, it is an alternative to moderate, sustained training, referring to activities with short intervals, interspersed with rest, and producing a solid cardiac response. HIIT training also increases the consumption of good stamina associated with pencak silat competitions by stimulating the heart to increase oxygen. It is supported by [10], whose findings suggest that HIIT training can positively impact physical, functional, and movement changes, such as providing significant benefits to physical health.

HIIT is widely used to increase work endurance in various sports, especially pencak silat. According to [11], cognitive abilities and performance affect the physical condition. Components of the physical condition include strength, speed, endurance, explosive muscle power, agility, balance, flexibility, and coordination [12]. After the physical condition is formed, the coach will find it easier to plan technical, strategic, tactical, and mental training. Professional trainers can develop physical conditions according to their experience when preparing a systematic training program. There are stages in compiling a training program: the general preparation stage, the specific preparation stage, the pre-match stage and the competition stage. Aspects of supporting good performance must be optimized during the general preparation phase because the basic foundation of athletes is the formation of physical conditions. The excellent physical condition must also be balanced with good stamina to support maximum performance. According to [12], endurance is a condition in which the body can training for a long time without feeling tired. Therefore, endurance is related to pencak silat in the condition of an athlete's body to fight fatigue during prolonged training. Fighters with excellent endurance can develop the basic techniques of pencak silat well.

This study aims to examine the effectiveness of the HIIT protocol for specific endurance capacities. In addition, we investigate the contribution of technical performance to pencak silat athletes during match simulations. Thus, the HIIT program has

proven effective in improving specific endurance and technical performance in pencak silat athletes at Universitas Muhammadiyah Surakarta, especially in the fight category. HIIT with a specific design can be recommended as a new training model in sports, especially pencak silat.

2 Method

2.1 Experimental Approach to Problems

The approach used in this research was quantitative. The result of this study is a training program for specific endurance capacity and contribution to technical performance during match simulations that produce training designs under HIIT protocol guidelines. The training design is according to the needs of the ratio of work and rest and can be used as a guideline for determining the time protocol for the HIIT training phase. The specific HIIT protocol is based on a ratio of 1:3, 1:2, and 1:1, according to research by [13]. The HIIT protocol program design is presented in Table 1.

2.2 Subject

The sample consisted of 13 student-level male athletes from UMS pencak silat. Athletes were grouped by weight categories for pencak silat competitions: light class >45 to <60 kg, middle class >61 to <70 kg, and heavy class >71 to <95 kg.

2.3 Procedure

The experimental group participated in HIIT protocol exercise sessions three times a week for four weeks, every Monday, Tuesday, and Friday. Each training session lasted 90 min and consisted of warm-up exercises, core exercises (HIIT), and closing exercises. The session started with around 15 min of a static and dynamic warm-up, followed by punches and kicks on the bag/petching. The core exercise lasted 60 min and consists of high-intensity tactical drills to prepare athletes for combat. Flexibility exercises were conducted in the last 15 min to cool down and relax.

Data collection involved experienced and professional practitioners recording results from samples. The data collected was specific endurance and technical performance. The specific endurance data collection step began with the athlete standing before the bag/petching in a ready position to kick and punch. After the whistle, the athletes kicked and punched for 30 s with 1-min rest three times. These steps were simulated the duration of a match. It aligns with [14] that the analysis of pencak silat combat results in the fight category is characterized by irregular patterns. The average duration of combat time was 2.6 ± 0.6 s and interspersed with the preparation step of non-combat activities with an average of 8.4 ± 3.6 s. In addition, in a match situation, there is a "pause" or stoppage by the referee with an average time of 11.3 ± 1.8 s.

The step for collecting technical performance data began with matching athletes according to their class, duration according to a 2-min pencak silat match, and a 1-min rest break in 3 rounds. Next is the technique video observation. The number of punches,

Table 1. HIIT Program

Micro	Monday	Tuesday	Friday
1	Pray	Pray	Pray
	Dynamic Static Warm-up	Warm-up, PNF	Warm-up
	ABC Running	SAQ	Skipping (10') Interval skip
	1:3 HIIT Program	1:3 HIIT Exercise Program	(30'' slow 10'' fast) 8x rep
	Perform punches (10 × 2 set)	Slam	1:3 HIIT Exercise Program
	Defend punches (10 × 2 set)	Cooling down, PNF	Punches and
	Combination of punches	Pray	1–3 reactions using patching (10 × 3 set)
	Slam (10 × 2 set)		Cooling down
	Cooling down + Pray		Pray
2	Pray	Pray	Pray
	Dynamic Static Warm-up	Warm-up, PNF	Dynamic Static Warm-up
	Fun Games	ABC Running	ABC Running
	Patching Warm-up	1:2 HIIT Exercise Program	Speed test, dodge sickle kick
	1:2 HIITS Exercise Program	Takedown	and sickle kick right - left (5'' × 2 sets)
	Right and Left Slam 10x	Cooling down, PNF	1:2 HIIT Exercise Program
	Anticipation slam 10x	Pray	Direct attack (10 × 2 set)
	Cooling down		Indirect attack (10 × 2 set)
	Pray		Cooling down + Pray
3	Pray	Pray	Pray
	Dynamic Static Warm-up	Warm-up, PNF	Fun ball game
	SAQ 5' × 2 set	Skipping 30'' slow 15'' fast (4')	Interval workout jumping jacks, push up,
	Warm-up with Patching	1:2 HIIT Exercise Program	squat, Russian twist (30'' work

(continued)

Table 1. (continued)

Micro	Monday	Tuesday	Friday
	1:2 HIIT Exercise Program	Takedown	30'' rest × 3 set)
	The series begins with straight kicks,	Cooling down, PNF	1:2 HIIT Exercise Program
	1–3 reactions performance (10 × 2 set)	Pray	Perform one point (10 × 2 set)
	The series begins with straight kicks,		Perform one point + Slam (10 × 2 set)
	1–3 reaction patching + slam (10 × 2 set)		Cooling down
	Cooling down + Pray		Pray
4	Pray	Pray	Pray
	Dynamic Static Warm-up	Warm-up, PNF	Warm-up
	Skipping 10 min	Fun game ball	Interval workout jumping jacks, push up,
	Interval skipping (30'' slow 30'' fast 4')	1:1 HIIT Exercise Program	squat, Russian twist (30'' work
	1:1 HIIT Exercise Program	The slam	30'' rest × 3 set)
	The performance begins with a sickle kick,	Cooling down, PNF	1:1 HIIT Exercise Program
	then another attack (10 × 2 set)	Pray	The combination of a punch
	Cooling down		Slam (10 × 2 set)
	Pray		Cooling down + Pray

kicks, and successful moves according to the target and trajectory of the attack was calculated. It is similar to research on kickboxing [15] and taekwondo [16]. However, pencak silat differs from the findings of *muay-thai* fights, where the fighting phase is 60% of the total time and 40% is used for preparation (non-combat). It explains the differences in time movement activities during the combat phase in combat sports.

2.4 Data Analysis Technique

Quantitative data analysis techniques began with descriptive statistical analysis to describe specific endurance capacities and the contribution of technical performance during competition simulations based on pretest and posttest data. The determination of specific endurance capacity variables and the contribution of technical performance can be seen from the mean, standard deviation, variation, min, max, and sum related

to the description of this study. Next is inferential analysis to analyze sample data, and the results are used for the population to test the research hypothesis. Before testing the hypothesis (t-test), a data prerequisite test was carried out using the Shapiro-Wilk Test to determine whether the data obtained was normally distributed. The statistical hypothesis test is determined if the Sig. (2-tailed) is greater than the significance level of $p = 0.05$, so H_0 is accepted, and H_a is rejected. It means HIIT exercise protocol for specific endurance capacities and technical performance contributions during simulated matches have an influence. Conversely, if Sig. (2-tailed) is smaller than the significance level of $p = 0.05$, then H_0 is rejected and H_a is accepted. Then there is the influence of HIIT protocol training specific endurance capacity and contribution of technical performance during the simulation. After the prerequisite test was met, the final stage was the Pearson correlation test. The correlation test determines the strength and weakness of a relationship if the value is close to 1 or -1. If what is obtained is close to 0, then the relationship between the two variables is weak.

3 Result and Discussion

3.1 Result

After four weeks of implementing the exercise program, the results of the data analysis of the pre-and post-HIIT tests on specific endurance capacity and the technical performance contribution during the match simulation are presented in Table 2.

Table 2 shows an increase in posttest results on specific endurance capacity and contribution to technical performance during match simulations for UMS pencak silat athletes—the average score of each HIIT exercise evidences this. Specific endurance capacity is 48.85 and 59.81, with a difference of 10.99. The technical performance contribution is 5.15 and 8.69, with a difference of 3.54. Thus, it can be concluded that there is a change of 10.99 for the specific endurance capacity and 3.54 for the technical performance contribution during the match simulation. Before the data analysis test is carried out, it is necessary to test the analysis requirements. The analysis requirements test consists of a normality test presented in Table 3.

Table 2. Descriptive Research Results

Statistics	Specific Endurance		Technical performance	
	Pretest	Posttest	Pretest	Posttest
Mean	48.85	59.81	5.15	8.69
Std. Deviation	1.355.345	1.564.957	257.702	552.848
Variance	183.696	244.909	6.641	30.564
Min	24.7	31.3	0	0
Max	70	83.7	9	18
Sum	635.1	777.5	67	113

Table 3. Normality Test Analysis Result

Variable	P	Interpretation
Pretest Specific Endurance	0,965	Normal
Posttest Specific Endurance	0,904	Normal
Pretest Technical performance	0,592	Normal
Posttest Technical performance	0,643	Normal

Based on Table 3, the normality test criteria analysis accepts the hypothesis if the significant value is $\alpha = 0.05$. Thus, it is concluded that the sample is based on a normally distributed population. This conclusion signifies the implications of parametric statistical analysis that can be used to test the hypotheses proposed for testing the hypotheses are met. A homogeneity test using the Levene test with a value of $\alpha = 0.05$ is presented in Table 4.

Based on Table 4, the homogeneity test results indicated by the Levene test analysis obtained a value of $p = 0.601 > \alpha = 0.05$ for specific endurance capacity and $p = 0.051 > \alpha = 0.05$ for technical performance contribution. Thus, the data obtained from the two variables show the distribution of data from the population with homogeneous variance so that the data meets the prerequisites for the hypothesis test of the difference in pre and posttest scores using the paired sample t-test presented in Table 5.

Based on Table 5, the mean value \pm SD of the specific durability data is 10.9 ± 13.9 with a p-value of 0.01 (< 0.05). Meanwhile, the mean \pm SD contribution to technical performance is 3.53 ± 3.45 with a p-value of 0.003 (< 0.05). It shows a significant increase in the average score of specific endurance and technical performance from the pre and post-test implementation of the HIIT exercise program, a 22% increase in specific endurance, and a 68% increase in technical performance. Furthermore, a Pearson correlation test was performed to determine the interaction between the variables (specific endurance and technical performance). The correlation test determines the

Table 4. Homogeneity Test Analysis Results

Variable	P	Interpretation
Specific Endurance	0,601	Homogenous
Technical performance	0,051	Homogenous

Table 5. Hypothesis Test Data for Pretest and Posttest

Variable	Mean	Std. Deviation	P
Specific Endurance	10,953	13,913	0,015
Technical performance	3,538	3,454	0,003

Table 6. Pearson Correlation Analysis Result

Variable		Post Specific Endurance	Post Technical performance
Pretest Specific Endurance	Pearson Correlation	1	0,264
	Sig. (2-tailed)		0,384
	N	13	13
Pretest Technical performance	Pearson Correlation	0,264	1
	Sig. (2-tailed)	0,384	
	N	13	13

strength and weakness of a relationship if the value is close to 1 or -1. If what is obtained is close to 0, then the relationship between the two variables is weak. The results are presented in Table 6.

Based on the data in Table 6, the p-value is 0.03 (<0.05), so the null hypothesis (H_0) is rejected. It can be concluded that there is no unidirectional relationship between specific endurance capacity and technical performance during match simulations, where the magnitude of the interaction between the two is 0.02, which tends to be close to 0 (weak).

3.2 Discussion

Analysis of specific endurance capacity and contribution of technical performance during the match simulation of UMS pencak silat athletes finds that the average pretest and posttest are 48.8538 and 59.8077 for specific endurance capacity and 5.1538 and 8.6923 for technical performance contribution. From these results, the experimental HIIT protocol consisting of 3 rounds of 2 min clean with a 1-min break with a duration of 3 times a week for four weeks can increase the number of kicks and punches during a match simulation. These results align with [17] research, which states that the HIIT program for eight weeks, three times a week with a duration of 60 min, improved the physical condition of STKIP Muhammadiyah Kuningan martial arts athletes. The results show that the percentage increase in the HIIT group is 5,119%, with an average pretest of 877,538 and an average posttest score of 922,462.

This research is supported by [18] findings, which find that short-duration HIIT programs employ specialized techniques during boxing-specific match simulation with a three-block, five-rep protocol of 30-s all-out effort with 1-min rest between blocks three times a week for four weeks. This result suggests that group interaction complied with the HIIT protocol to increase the number of strokes during the bout simulation. HIIT programs using boxing-specific techniques can promote better physical conditioning and action and increase activity during match simulation. The results show that the boxing-specific addition HIIT program effectively increases the number of punches during match simulation. This finding is proven by the results of short-duration HIIT protocol data using special boxing techniques on activities during match simulation with significant

values for the number of punches, with an increase of $51.1 \pm 39.4\%$ for the experimental group because the increase in anaerobic metabolism performance is not measured.

The results of the analysis of specific endurance HIIT exercises and technical performance find that (mean \pm SD) for specific endurance abilities has an average of (10.9539 ± 13.91334), while for technical performance contribution has an average of (3.53846 ± 3.45484). These results in the simulation of pencak silat show no significant increase. These results are similar to [19] who found an increase in second and third-round stroke count after the intervention. The results show a significant effect of time group interaction on cumulative punching force during round 1 ($F_{1, 16} = 4.61$; $p = 0.047$), round 2 ($F_{1, 16} = 7.5$; $p = 0.015$), round 3 ($F_{1, 16} = 15.29$; $p = 0.001$) and total hitting force for three rounds ($F_{1, 16} = 35.2$; $p = 0.001$). Improved hitting underlies the ability to maintain punching frequency and power during simulation because aerobic capacity is associated with an athlete's ability to perform repetitive, all-out activities. This relates to performance because getting the right shot requires a high frequency of attack movements during the game, in line with the results of field measurements of punches and kicks made by [13]. It is explained that many women's wushu fighting patterns use punches and kicks, respectively 48.2% and 46.9%, and the remaining 4.8% are throws. The athlete applied 11 ± 8.67 strokes, 10.7 ± 5.63 kicks, and 1.1 ± 1.6 throws per round. Sanda Putri wushu athletes use more punches and kicks (flashing motor action) to reduce throwing action. This is supported by applying throwing techniques that wushu athletes widely use to collect high scores to win matches.

HIIT training, on the other hand, can increase specific endurance capacity and technical performance contribution during match simulation in pencak silat. This is evidenced by the correlation value of 0.264, which means a correlation exists between specific endurance and technical performance in UMS pencak silat athletes. This agrees with [20], who explained that the protocol for calculating Vo^2_{max} , in healthy and untrained adults, had a good correlation with the male laboratory protocol $r = 0.95$; rwft son $r = 0.93$; 1,000 m and for women $r = 0.83$; rwft women $r = 0.74$; 20m. Investigations can be recommended to calculate the selected tests in the same population and compare their predicted results. These results are corroborated by [21], which found that hemoglobin (HB) and Vo^2_{max} are correlated. The ability to enter oxygen into the lungs and take oxygen to provide energy is a function of oxygen to transport carbon dioxide through respiration. This is evidenced by a correlation value of 0.484, which shows a correlation between HB and Vo^2_{max} but not high. The results show that considering a physiological relationship between HB levels which function as a binder of O^2 and CO^2 in respiration and oxidation with O^2 input expressed as Vo^2_{max} , it cannot be ascertained that the higher the HB, the higher the Vo^2_{max} .

After four weeks of training, HIIT can best contribute to specific endurance capacity and technical performance in a pencak silat competition simulation in the sparring category. Endurance is the most important element for pencak silat athletes to maintain and repeat their training. According to [22], endurance is maintaining and repeating without compromising maximum strength at high speed. HIIT is used to build endurance and requires repeated, high-intensity training, particularly in martial arts. The physical demands of pencak silat are the most complex branch of the sport [23]. Athletes with high metabolic conditions can maintain endurance and develop techniques. Combat

sports are HIIT exercises that require athletes to develop their stamina to the maximum, repeated to fight their opponents. Pencak silat is a martial arts sport with full-body contact characteristics, which requires athletes to have sound technical quality to support competitive performance [24]. This makes technical performance a vital part of pencak silat to support match performance. In addition, pencak silat athletes with suitable endurance components will reduce the risk of injury to these athletes [25]. Limitations in this study related to the lack of physiological measurements during training sessions and tests, particularly in specific endurance tests that would help characterize the type of HIIT protocol. Another limitation is the small sample size, one being an athlete in transition.

4 Conclusion

This study concludes that training with the pencak silat-specific HIIT protocol (3 rounds of 2 min clean with 1-min pause) applied for four weeks proves to be effective for increasing specific endurance capacity and technical performance during simulated pencak silat in the match category. The designed training considers the need for work and rest ratios, which can be used as a guideline for determining the time protocol for the HIIT training phase. In addition, the demands of technical performance during matches can be a modality in determining actions during periods of high-intensity action. Although there is no interaction between specific endurance and technical performance, the positive value is that the specially designed HIIT protocol involving pencak silat techniques can affect these two variables. However, the implementation of this HIIT program is still limited to small groups, so further identification is needed to investigate the effect of this particular HIIT on physical fitness in a more general group. This HIIT protocol can be recommended as a new training model to increase specific endurance capacity and technical performance, particularly in pencak silat. Professionals can modify the HIIT protocol according to the training stages and targets.

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