

High Intensity Interval Training Method and The Flexibility Effects on Increasing VO_{2max} and Lactate Threshold

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Abstract—The volume of exercise in swimming is usually very high when compared to the relatively short competition time, the flexibility of one component of the physical condition, the HIIT method that has high intensity, repetition, and short rest period, have been shown to improve performance in a relatively short training period. This study aims to look at the effects of a combination of HIIT method and the flexibility of shoulder & hip on increasing LT and VO_{2max} . This study is using experimental method with the randomized pre-test–post-test control group design on 16 competitive swimmers This study trial was carried out for 3 weeks. The 12 min Cooper Test (swimming) is used to get VO_{2max} (yd) data, while the 7×200 m Step Test is used to get the LT data. Measurement were made twice (baseline/0 week and 3rd week). The results of this study show that HIIT method and the flexibility of shoulder & hip increased significantly ($p<0.05$) on VO_{2max} (38.69 ± 33.19), and the LT in the control group increased significantly ($p<0.05$). However, there was no significant increase on ($P>0.05$) LT (0.73 ± 0.89) in the experimental group. The combination of HIIT method and the flexibility of shoulder & hip can increase VO_{2max} .

Keywords—HIIT, Lactate Threshold, VO_{2max}

I. INTRODUCTION

Producing outstanding athletes cannot be done and achieved instantly, but it must be done through Long Term Athlete Development (LTAD), physiological framework aimed to managing focus, volume, intensity, and the type of training applied to athletes during adolescence to adulthood [1]. This swimming branch establishes extraordinary physical demands in both training and competition, such as muscle strength, aerobic endurance, anaerobic endurance, neuromuscular skills, coordination, and flexibility [2]. In all sports, the flexibility component is included as the main performance and as an integral part of the training program at the time of conditioning [3]

Swimmers may be able to practice swimming from 10,000 to 14,000 meters (6 to 8 miles) per day, 6 or 7 days a week. That distance of swimming is tantamount to 16,000 changes

per week or around 2500 strokes per day. The stroke movement is carried out continuously [4] When participating in a race, swimmers can go down several times and sometimes back to back because usually in Indonesia when holding swimming championships between clubs or schools, the championship is only held for one or two days.

Swimming branches such as freestyle, butterfly, backstroke, and breaststroke require good flexibility. This limits the extent to which limbs do repetitive swimming movements, giving maximum effect without removing extra energy and being efficient. In swimming, the dominant component of physical condition is endurance. In swimming, endurance is an important prerequisite for swimming performance [5]. According to Maglishco [24], the energy supply used during swimming comes from aerobic and anaerobic metabolism [6]. Maximum aerobic capacity which often called VO_{2max} classified as one of the physical factors that determine achievement. There are factors in aerobic endurance performance: maximum rate of oxygen consumption (VO_{2max}), Lactate Threshold (LT), and swimming economy (C) that is the cost of oxygen to produce swimming speed or cycling power output [7]. These factors serve as a useful framework for a comprehensive examination of the effects of aerobic training on endurance performance [8]. Blood lactate and lactate threshold (LT) have become important in the diagnosis of endurance performance [9].

The HIIT method exercises with high intensity intervals, slight repetitions, and short rest periods [10]. HIIT has the characteristics of the main part of the training session, the intensity for each interval is set at 92% of the best personal time [11]. or 80%, 90% to 100% of VO_{2max} [8]. Studies show that high intensity interval training for 5 weeks improves VO_{2max} (+10.2) and lactate (20,1) [11]. The study says that the short-term period (for 2-4 weeks) in the HIIT method can increase the maximum rate of oxygen consumption (VO_{2max}) [12].

II. MATERIALS AND METHODS

A. Participants

This study is using experimental method with the randomized pre-test – post-test control group design on 16 competitive swimmers (5 males and 11 females) (age = 13.5 years old, blood pressure = 117.5/80 mm Hg). Exclusion criteria included: (1) Participants are athletes who train at the Tirtamerta Club in Bandung; (2) Participants are included in the Age Groups 3 and 2; (3) Participants are athletes who have participated in Olimpiade Olahraga Siswa Nasional (O2SN), Indonesia Open Aquatic Championship (IAOC), Kejuaraan Daerah (KEJURDA); (4) Participants are swimming athletes who have undergone intensive training for (\pm) 4 years; (5) Participants are willing to take the test and training program proposed by the researcher; (6) Participants have no history of respiratory disease, etc.

B. Study Design

All participants were divided into two groups (experimental and control) and this study was conducted for 3 weeks, 3 days a week. The High Intensity Interval Training (HIIT) method and the flexibility of shoulder & hip with high intensity of 80%, 90% to 100% of VO_{2max} or 92% of personal best time, repetition, and short rest period, and also the flexibility of 2-3 repetitions with the duration of 12 seconds per set. Experimental group and control group conducted continuous training method with the intensity of 85% and rest for 30 seconds.

C. Exercise method Protocol

- **Exercise High Intensity Interval Training (HIIT) Protocol**
The HIIT method in swimming has repetition intervals of 10-15 times with a distance of 20 meters, an intensity of 92% of the best personal time, and a total of 30 minutes, by emphasizing technical skills such as quality, efficient strokes, start, reversal, etc. [11]. 16 repetitions, a distance of 25 meters, the intensity is maximum with a break between 30 seconds repetition, recovery between sets is 3 minutes [10].
- **Exercise Flexibility Protocol**
2 x 3 repetitions of PNF Stretching (Proprioceptive Neuromuscular Facilitation), intensity is at the maximum tolerance point / to slightly exceed the pain point (go beyond pain). Each stretch is carried out for 12 seconds with a duration of 10-20 minutes.
- **Exercise Continuous Training Protocol**
This continuous training method is carried out by swimming 1500-2000 meters with moderate intensity (60-80% maximum heart rate (HRmax) [13]. High intensity is usually carried out at an intensity that represents 85% to 95% of the athlete's HRmax [14]. The duration of training varies between 15-60 minutes.

D. Measured Variables

- **Testing (Cooper 12-min Swimming) Protocol**
The 12-min Cooper Test (Swimming) is used to get VO_{2Max} data (yard), a 5-min warm-up, at the conclusion of 12 min, the total distance covered was measured to the nearest yard by means of a tape measure that was placed at the edge of the pool adjacent to the swimming lanes. After completing the 12-min swim, the swimmer's Heart rate was taken for 6 sec, and the time it took him to find and begin counting his pulse was recorded. Radial pulse was taken by each participant at the conclusion of the 12-min swim because the majority of the swimmers completed the time allotment in the middle of the pool. When the swimmer heard the whistle indicating the conclusion of the 12 min, he stood where he was and began taking his pulse by looking at a peach clock on the edge of the pool.
- **Testing (Lactate Profiling Protocol)**
This 7 x 200 m step test is used to provide information about aerobic fitness or endurance of swimmers. This test is carried out in a swimming pool with a distance of 50 meters, this test protocol can provide some information such as; cardiovascular (heart rate), metabolic (blood lactate), and mechanical (stroke rate and stroke count). Before the participant conducts a warming up that has been determined, each swimmer counts the individual target time based on the personal best time, then personal best time + 0.05. This 7 x 200 m swimming speed is the slowest with an intensity of 60% -70% to the fastest intensity (80% <), in this test every step (per 200 m) is 30 seconds. Swimming in the seventh step (last) is done to the maximum and functions as a measure of maximum training performance. For this 7 x 200 m test swimmers streamline their movements when they push (start), go down, and underwater. Emphasis on "speed" (time) or "even split" and the target time is given before each swim. The time for each split is 100 m and a total of 200 m is recorded with Seiko Stopwatch. The stroke rate is measured by determining the time of three complete stroke cycles on the third lap, and the number of strokes (strokes per 50 m) is determined on the fourth lap of every 200 m effort (Table I). Immediately after each swim, heart rate measured by the Polar Sports tester (Polar FT7), and ratings of perceived exertion (RPE). Finally, swimmers came out of the pond and 25m capillary blood samples were taken from the fingertips and analyzed for lactate concentration using Accutrend plus [15].

TABLE I. AN EXAMPLE OF AN INDIVIDUALIZED PROTOCOL FOR THE 7X200-M STEP TEST

STEP	TARGET 200 M TIME (in seconds)	1 st 100 M Split time (in seconds)	2 nd 100 m split time (in second)	Actual 200 m time (In Second)	Avg. 100 m	HR (bpm)	La (mM)	SR (Strokes Rate)	SC (Strokes per 50 M)	RPE
1	3.25	107	103	210	105	142	2.7			
2	3.20	100	101	201	100.5	154	2.9			
3	3.15	96	99	195	97.5	157	3.1			
4	3.10	96	95	191	95.5	163	3.2			
5	3.05	97	90	187	93.5	182	3.4			
6	3.00	92	92	184	92	193	5.8			
7	2.55	83	87	170	85	197	6.7			

TABLE II. A TYPICAL SET OF RESULT FROM THE 7X200-M STEP TEST

Swim No	Approximate % of Target Time	Approximate HR Below Max bpm	Example (PB: 2.45) (min: sec)
1	70	60	3.25
2	75	50	3.20
3	80	40	3.15
4	85	30	3.10
5	90	20	3.05
6	95	10	3.00
7	100	maximum heart rate	2.55

Differential from the swimmer’s personal best time was used to estimate the time for the final swim (No. 7) (1:50 PB time 1 0:05 5 1:55 target time). Working in reverse order from the seventh and final swim, 5 s were added for each subsequent interval to establish the full test protocol.

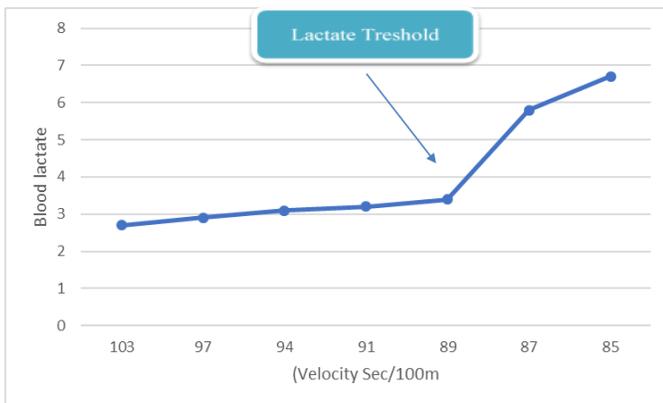


Fig. 1. Result of blood lactate deflection point in determining Lt

- Testing (The Flexibility of Shoulder & Hip (cm), Blood Pressure (mm Hg), BMI (Kg/m²)) Measuring flexibility with sit and reach, and shoulder flexibility [16]. Measuring blood pressure using a Digital Sphygmometer, while for the Body Max Index (BMI) using the Karada Scan tool, Omron

E. Statistical Analysis

Data analysis using SPSS 21.0. Data were analyzed by calculating the average and standard deviation (SD) of each group. Differences from each group were found using the Independent Sample T-Test.

III. RESULTS AND DISCUSSIONS

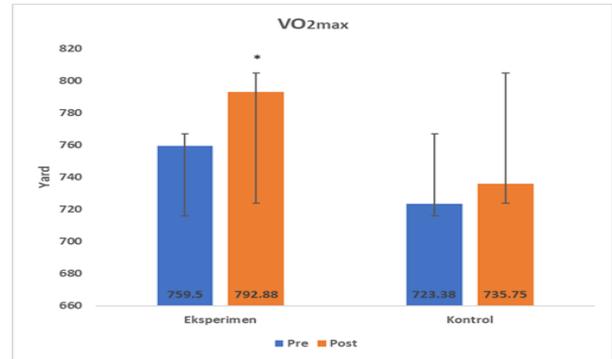


Fig. 2. Result of VO₂max

Figure 2 The results obtained after the VO₂max (yard) test (Cooper 12-min swimming test) increased in the HIIT experimental group with pre-test (759.50) and post-test (792.88). VO₂max results in the continuous training control group did not have a significant increase, pre-test (723.50) and post-test (735.75).

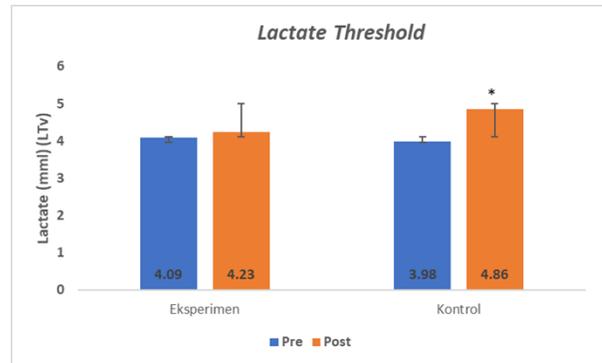


Fig. 3. Result of blood lactate treshold (mmol)

The figure 3 there was no significant increase in the Lactate Threshold (LT) (mmol) experimental group, pre-test (4.09) and post-test (4.23). In the Continuous Training (CT) control group there is a significant increase in Lactate Threshold (LT), pre-test (3.39) and post-test (4.86).

This study aims to see the effects of a combination of High Intensity Interval Training (HIIT) method and the flexibility of shoulder & hip and Continuous Training (CT) on increasing Lactate Threshold (LT) and VO₂max (yard) for the 3 weeks training period. The results of this study are in line and some

are not in line with the hypothesis. The results of this study show that the combination of HIIT method and the flexibility of shoulder & hip giving a greater increase to VO_{2max} , but there was no significant increase in the (CT) group.

The reason HIIT method and the flexibility of shoulder & hip made a greater contribution was strengthened by a statement in previous study which said that this could increase VO_{2max} in short time (2-4 weeks). Because the total time available for training is often limited to athletes, it is important to determine which HIIT methodologies are more effective in increasing VO_{2max} in short time, and high intensity, proven to be more effective, and there is a significant increase in endurance performance ($p < 0,05$) [16–18]. The research conducted [18] revealed that with a two-week HIIT training conducted at an intensity of 80% -95% resulting in an increase in VO_{2max} from 7 to 12%, depending on age, subject fitness level and duration of exercise, and an increase in body composition. The HIIT program is related to physiological adaptation for swimmers. This method has a large positive effect on the physiological aspects and performance of athletes [11].

According to [19] in his study that PNF stretching had a significant effect on speed when kicking the ball, increasing the range of motion in the leg joints, active dorsal flexion, right and left ankles, and active hip flexion (right and left) ($p < 0,05$). In another study, a comparison was made between static stretching and PNF in 18 rugby players at hip, step frequency, these parameters improved when doing PNF stretching exercises for five weeks, the frequency of exercise four times per week produced 7, 6%, 1.6% , 9.1% and 4.3% [20]. In PNF stretches found there were significant results in limb mobility, number of flutter kicks in swimming, training in the PNF stretching method performed with the frequency of exercise three times a week, ten minutes duration and seemed to help swimmers aged 12-15 years to improve mobility and performance [20]. A greater and more significant increase in LT occurs in the Continuous Training method. As for [13] his research report that a continuous training program effectively changes lactate and can cause a large increase in LT. The LT in HIIT method and the flexibility of shoulder & hip did not provide a significant increase. The failure of an LT increase in the experimental group might also be related to the specifics of the 7 x 200 m test procedure in assessing sprint swimming performance. This 7 x 200 m protocol which requires a 200 m repetition may not suit some sprint swimmers who practice specifically for shorter 50 and 100 m events. One alternative that can provide the appropriate results is the maximum anaerobic lactate test which performs four times the maximum swim (all out) 50 m interspersed with rest 10 [21]. Swimming events ranging from 50 to 1500 m, several different testing protocols may be very necessary so that the desired results are achieved, and to meet the various needs of sprint swimmers at distances of 50-100 m, distances of 200-400 m, and distances of 800 - 1500 m swimmers and the set test on butterfly and backstroke should comprise 5 x 200 m repeats. for freestyle and backstroke the test will be 7 x 200 m. In this protocol,

you must have standardized preparation conditions, such as in the micro and previous training sessions. The warming up procedure must be trained and considered so that the body's condition is ready for the test, and athletes maintain weight during [21]. Athletes who are tired and have significant depletion of glycogen tend to show different blood lactate profiles [22].

IV. CONCLUSIONS AND SUGGESTIONS

This study shows that exercise uses High Intensity Interval Training (HIIT) method and the flexibility of shoulder & hip has a positive effect and gives greater results on VO_{2max} , and the Continuous Training (CT) method gives better and greater results to the Lactate Threshold (LT).

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