

Comparative Analysis of Acute Physiological Responses between Short and Middle Distance Swimming Athletes with Physical Loading Test

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Abstract

Indonesia's swimming achievements are still far from that of other countries. Among other things, at the 2018 Asian Games, Indonesia did not succeed in getting a single medal. If not improved, Indonesia's swimming performance will get worse. One of the innovations is to identify the physical abilities and physiological responses of an athlete through a physical loading test. This study aims to analyze the differences in acute physiological responses between short and middle distance swimming athletes through continuous and interval high intensity physical test. The sample of males aged 14-18 years consisted of the short distance (n=12) and middle distance (n=12) swimmers. Participants did a high intensity physical test with an ergocycle for 21 minutes with a 7-minute warm-up and 3-minute cool down, intervally, and without resting for continuous test. The variables studied included resting pulse rate, blood lactate, leg and shoulder muscle strength, arm and leg power. Data collected in before (pre) and after (post) physical test. The results showed that the short distance swimmers had greater increase in lactate level and pulse rate in both physical tests. The leg power decreased significantly in the short distance swimmer when performed continuous physical test, whereas the middle distance swimmer when performed interval physical test. The conclusion of this study was to differ the leg power as acute physiology response for swimmers is more appropriate using continuous or interval high intensity physical test. Based on these results, training program for swimmer type can be developed. However, further research is still needed to enhance the swimmers performance.

Keywords: *Swimming; Athletes; Pulse; Lactate; Power; Health*

Introduction

The achievements of Indonesian swimming athletes are still far from that of other countries⁽¹⁾. It was proven at the 2018 Asian Games, Indonesia failed to get a single medal⁽²⁾. In fact, some Indonesian swimmers are predicted to win medals because they managed to be the best in the qualifying rounds several times. Swimming sports tend to use high intensity and good physicality is needed to win. Sports activity is one of the physical stressors that affect the homeostatic system, because it has an impact on physiological responses which are marked by an increase in stimulation of the body's

physical performance in the cardiorespiratory system⁽³⁾.

The swimming race from 50 m to 1,500 m is divided into 3, namely short distance 50-100 m, middle distance 200-400 m, and long distance 800-1,500 m⁽⁴⁾. To win in swimming, it takes practice, anthropometry, and strong physical abilities⁽⁵⁾.

Various attempts have been made to improve the performance of swimming athletes, one of which is the right training program that can improve the performance of swimming athletes. However, the efforts that have been made are still not getting maximum results, to

achieve glorious swimming sports. One of the reasons is that there is no known identification of physical ability which is a physiological response in short and middle distance swimming athletes. Therefore, this study was conducted with the aim of analyzing the differences in physiological responses between short and middle distance swimming athletes through continuous and interval high intensity physical loading tests. Physiological responses measured were variables which included lactate, leg muscle strength, shoulder muscle strength, arm power, leg power, and resting pulse rate.

Materials and Methods

This study has received approval from the Research Ethics Commission from the Faculty of Medicine, Airlangga University (No.90/EC/KEPI/T'KUA/2020), and was declared ethical in accordance with 7 WHO 2011 standards which refer to the 2016 CIOMS guidelines.

Research subject

This study was analytic observational design and cross sectional. The subjects in this study were athletes of short and middle distance swimming aged 14-18 years. The selected subjects were determined according to their specialization and swimming competition numbers which were grouped into the middle and short distance swimming groups. The middle distance swimming group was 12 person and the short distance swimming group was 12 person.

Physical Loading Test Protocol

All groups of short and middle-distance swimmers performed a continuous and interval high-intensity test in 31-minute using an ergocycle. The pattern of interval was a 7-minute warm-up, 21-minute core and 3-minute cool down.

Table 1. Characteristics of the high intensity loading test

	Kontinu	Interval
Work Ratio	--	1:1
Warm up (minutes)	7	7
Working Duration (seconds)	1260	180 between intervals
Recovery intensity	Passive	Passive
Recovery duration (seconds)	--	180 between intervals
Repetition	1	4
Cooling down	3	3
Total Duration (Minutes)	31	31

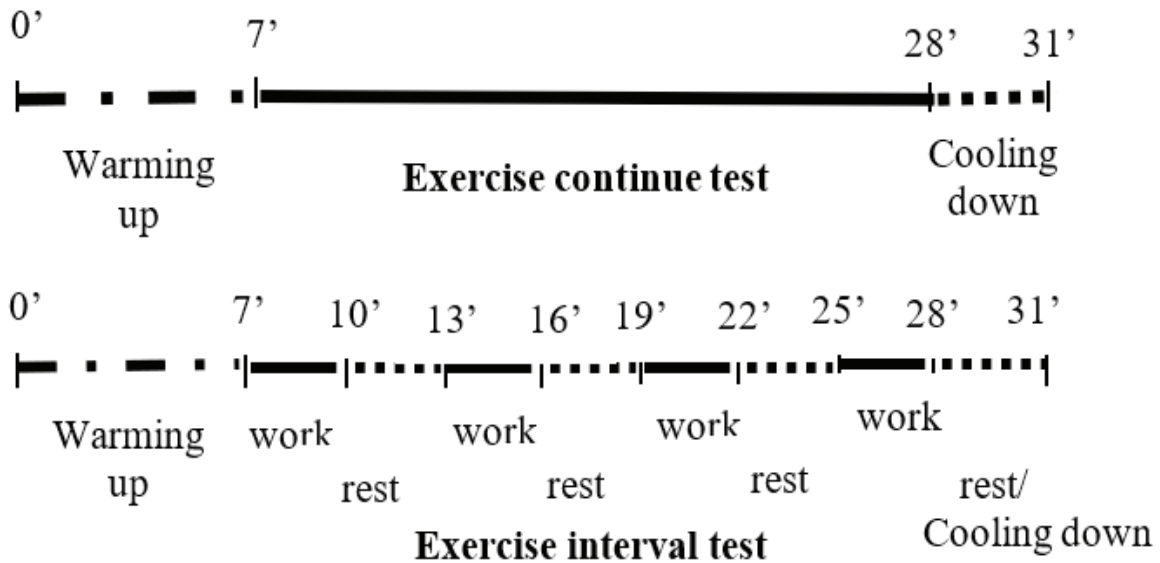


Figure 1. Exercise test

All athletes in short and middle distance swim was fasting for \pm 8-10 hours (drinking water was still allowed), before the physical test was carried out, resting pulse rate, blood lactate, leg muscle strength, shoulder muscle strength, arm power, and leg power were measured, and Leg Power as a pre-test. Then, the subject were given a sweet solution and rest for 30 minutes. Subsequently, continuous and interval physical tests were accomplished. Afterward, blood lactate, leg muscle strength, shoulder muscle strength, arm power, and leg power, and resting pulse rate were measured as a post-test.

Lactic acid measurement

Lactic acid measurements were carried out on capillary blood through a transcutaneous puncture on the medial side of the tip of the middle finger⁽⁶⁾. Measurement of lactic acid was carried out before the loading test as a pretest. And immediately after the loading intervention at 32 and 36 minutes. Measurement of lactic acid using the Accutrend plus, Roche, Germany. Lactic acid analysis results were recorded in units (mmol/L).

Measurement of Shoulder and Leg Muscle Strength

Measuring the strength of the shoulder muscles was measured by pulling the expending dynamometer

with both hands and the results will appear in Kg.

The measurement of leg muscle strength was measured by pulling the leg dynamometer with both hands using the leg muscle strength and the results appeared in Kg units.

Arm and Leg Power Measurement

Measuring arm power was done with a 3 kg medicine ball, which was measured by sitting on a chair with the chest part held with a rope to stabilize, then a medicine ball was pushed forward horizontally with both hands. The unit was watts.

The measurement of foot power was done with the DF jump tool which was measured by standing on the mattress then jumping as high as possible. The unit was watts.

Pulse Rate

Pulse rate measurement was in resting condition and using a polar connected to the iPad-4 which is measured before (pre-test) in beat per minute (Bpm).

Data analysis

The Statistical Package for the Social Sciences

(SPSS) software was used for data analysis. Data was presented in tables. The paired T test or Wilcoxon Signed Ranks Test was to examine the difference of before and after physical test. The independent T test or Mann Whitney was to evaluate the difference between physical loading test (continue and interval high intensity) and between swimmers (short and middle-

distance).

Results

The analyzed data were compared between before and after continuous physical loading test, and compared between the short-distance and middle-distance swimmers (tab. 2). The same was done for the interval loading test (tab. 3).

Table 2. The averages of variables before & after continuous high intensity exercise test

Variable		short-distance	middle-distance	sig. between group (p)
		(mean±SD)	(mean±SD)	
Lactate (mmol/L)	Pre	3,3±1,4	3,45±1,13	0,796
	Post	5,3±1,8	5,01±1,47	0,734
	Delta	2,0±1,2	1,56±0,76	0,520
	sig. between pre & post in each group (p)	0,001*	0,000*	
Leg muscle strength (Kg)	Pre	123,4±33,0	113,1±45,4	0,567
	Post	108,9±27,4	113,5±41,2	0,772
	Delta	-14,5±20,6	0,4±16,4	0,364
	sig. between pre & post in each group (p)	0,053	0,933	
Shoulder muscle Pull strength (Kg)	Pre	25,6±6,8	22,0±9,5	0,342
	Post	23,3±7,1	20,0±9,3	0,385
	Delta	-2,3±5,0	-2,0±3,56	0,939
	sig. between pre & post in each group (p)	0,181	0,109	
Arm Power (Watt)	Pre	163,2±36,9	168,2±44,8	0,791
	Post	154,2±35,3	160,4±48,4	0,748
	Delta	-9,0±18,0	-7,8±25,2	1,000
	sig. between pre & post in each group (p)	0,150	0,357	
Leg Power (Watt)	Pre	522,9±114,7	456,7±130,2	0,243
	Post	489,0±112,7	427,5±169,2	0,351
	Delta	-33,9±35,8	-29,2±75,9	0,880
	sig. between pre & post in each group (p)	0,015*	0,254	

Variable		short-distance	middle-distance	sig. between group (p)
		(mean±SD)	(mean±SD)	
Pulse rate (Bpm)	Pre	81,7±7,4	84,4±10,5	0,515
	Post	172,6±10,1	165,3±6,7	0,702
	Delta	90,9±7,8	80,9±12,9	0,052
	sig. between pre & post in each group (p)	0,000*	0,000*	

*signifikan (p <0,05) antara pre dan postest

** signifikan (p <0,05) antara kelompok jarak pendek dan jarak menengah

The results of the different test with a significance level (p <0.05) in Table 2, it can be concluded that there was a significant differences before and after continuous loading on middle and short distance swimming athletes on the variables of oxygen saturation, blood lactate, and pulse rate. In leg power, after continuous loading, significant differences between pre and post-test were only found in short-distance swimming athletes.

Table 3. The averages of variables before & after high intensity interval exercise test

Variabel		short-distance	middle-distance	sig. between group (p)
		(mean±SD)	(mean±SD)	
Lactate (mmol/L)	Pre	6,0±1,6	5,9±1,6	0,951
	Post	16,1±2,8	12,8±2,4	0,240
	Delta	10,1±3,24	6,9±2,9	0,052
	sig. between pre & post in each group (p)	0,000*	0,000*	
Leg muscle strength (Kg)	Pre	118,0±24,0	96,4±31,5	0,145
	Post	123,6±31,8	95,0±27,9	0,077
	Delta	5,6±22,9	-1,4±7,7	0,673
	sig. between pre & post in each group (p)	0,511	0,627	
Shoulder muscle Pull strength (Kg)	Pre	20,1±3,1	20,1±7,3	1,000
	Post	20,3±4,4	18,1±6,4	0,453
	Delta	0,2±2,3	-2,0±2,4	0,081
	sig. between pre & post in each group (p)	0,882	0,150	
Arm Power (Watt)	Pre	148,4±18,6	144,0±22,8	0,684
	Post	149,6±30,8	133,9±24,2	0,276
	Delta	1,2±21,0	-10,1±16,7	0,002
	sig. between pre & post in each group (p)	0,875	0,127	

Variabel		short-distance	middle-distance	sig. between group (p)
		(mean±SD)	(mean±SD)	
Leg Power (Watt)	Pre	470,2±108,5	474,4±104,4	0,938
	Post	459,7±112,8	371,7±100	0,121
	Delta	-10,5±35,6	-102,7±39,1	0,248
	sig. between pre & post in each group (p)	0,430	0,000*	
Pulse rate (Bpm)	Pre	80,5±9,9	83,3±7,5	0,540
	Post	181,6±6,0	178,4±7	0,337
	Delta	101,1±6,3	95,1±7,6	0,092
	sig. between pre & post in each group (p)	0,000*	0,000*	

*significant ($p < 0.05$) between pre and postest

**significant ($p < 0.05$) between the short-distance and middle-distance groups

In Table 3, the results of different tests with a significance level ($p < 0.05$), were found at before and after loading intervals for middle and short distance swim athletes, on variables of oxygen saturation, blood lactate, and pulse rate. The significant difference after the interval loading test in leg power was only in the middle-distance group.

Tabel 4. The averages of variables on short-distance swimmers

Variable		Physical testing		sig. between group (p)
		Continue	Interval	
		(mean±SD)	(mean±SD)	
Lactate (mmol/L)	Pre	3.3±1.4	6.0±1.6	0.002**
	Post	5.3±1.8	16.1±2.8	0.000**
	sig. between pre & post in each group (p)	0.001*	0.000*	
	Delta	2±1.2	10.1±3.24	0.000**
Leg muscle strength (Kg)	Pre	123.4±33.0	118.0±24.0	0.705
	Post	108.9±27.4	123.6±31.8	0.307
	sig. between pre & post in each group (p)	0.053	0.511	
	delta	-14.5±20.6	5.6±22.9	0.068
Shoulder muscle Pull strength (Kg)	Pre	25.6±6.8	20.1±3.1	0.052
	Post	23.3±7.1	20.3±4.4	0.304
	sig. between pre & post in each group (p)	0.181	0.882	
	Delta	-2.3±5.0	0.2±2.3	0.225
Arm Power (Watt)	Pre	163.2±36.9	148.4±18.6	0.317
	Post	154.2±35.3	149.6±30.8	0.773
	sig. between pre & post in each group (p)	0.150	0.875	
	Delta	-9±18.0	1.2±21.0	0.285

Cont... Tabel 4. The averages of variables on short-distance swimmers

Variable		Physical testing		sig. between group (p)
		Continue	Interval	
		(mean±SD)	(mean±SD)	
Leg Power (Watt)	Pre	522.9±114.7	470.2±108.5	0.336
	Post	489.0±112.7	459.7±112.8	0.591
	sig. between pre & post in each group (p)	0.015*	0.430	
	Delta	-33.9±35,8	-10.5±35,6	0.187
Pulse rate (Bpm)	Pre	81.7±7.4	80.5±9.9	0.772
	Post	172.6±10.1	181.6±6.0	0.040**
	sig. between pre & post in each group (p)	0.000*	0.000*	
	Delta	90.9±7.8	101.1±6.3	0.008**

*significant (p <0.05) between pre and postest

**significant (p <0.05) between the short-distance and middle-distance groups

The response difference of short distance swimmers between continuous and interval physical test can be seen in Table 4. Lactate levels and pulse rates were less increasing and the differences between before and after physical test were also lower for continuous physical test than interval physical test. The decrease in leg power after continuous physical test showed a significant more decreasing, whereas after the interval physical test, the leg power decrease was not significant.

Tabel 5. The averages of variables on middle-distcance swimmers

Variable		Physical testing		sig. between group (p)
		Continue	Interval	
		(mean±SD)	(mean±SD)	
Lactate (mmol/L)	Pre	3.45±1.13	5.9±1.6	0.001**
	Post	5.01±1.47	12.8±2.4	0.000**
	sig. between pre & post in each group (p)	0.000*	0.000*	
	Delta	1.6±0.76	6.9±2.9	0.001**
Leg muscle strength (Kg)	Pre	113.1±45.4	96.4±31.5	0.392
	Post	113.5±41.2	95.0±27.9	0.935
	sig. between pre & post in each group (p)	0.933	0.627	
	delta	0.45±16.4	-1.4±7.7	0.775
Shoulder muscle Pull strength (Kg)	Pre	22.0±9.5	20.1±7.3	0.652
	Post	20.0±9.3	18.1±6.4	0.582
	sig. between pre & post in each group (p)	0.109	0.150	
	Delta	-2±3.56	-2±2.2	0.866
Arm Power (Watt)	Pre	168.1±44.8	144.0±22.8	0.616
	Post	160.4±48.4	133.9±24.2	0.683
	sig. between pre & post in each group (p)	0.357	0.127	
	Delta	-7.8±25,2	-10.2±16.7	0.990

Cont... Tabel 5. The averages of variables on middle-distance swimmers

Variable		Physical testing		sig. between group (p)
		Continue	Interval	
		(mean±SD)	(mean±SD)	
Leg Power (Watt)	Pre	456.7±130.2	474.4±104.4	0.187
	Post	427.5±169.2	371.7±100	0.703
	sig. between pre & post in each group (p)	0.254	0.000*	
	delta	-29.2±75.9	-102.7±39.1	0.059
Pulse rate (Bpm)	Pre	84.4±10.5	83.3±7.5	0.759
	Post	165.3±6.7	178.4±7	0.964
	sig. between pre & post in each group (p)	0.000*	0.000*	
	Delta	80.9±12.9	95.1±7.6	0.027**

*significant (p <0.05) between pre and postest

**significant (p <0.05) between the short-distance and middle-distance groups

Middle distance swimming athletes responded to continuous and intervals physical test can be seen in table 5. Lactate levels and pulse rate presented less increased and the difference was also lower between before and

after continuous test compared to interval physical test. The leg power variable had a significant greater decrease between the pre- and post-interval physical test in middle-distance swimmers (fig. 2).

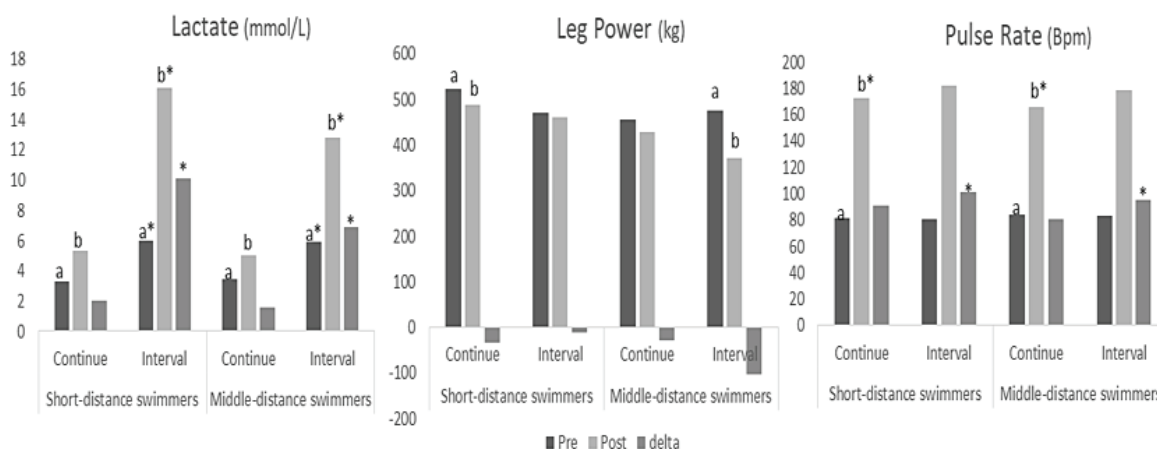


Figure 2. The three variables with the significant difference in each groups after physical loading test.

a & b: sig. diff. between pre & post within group (p<0.05)

*: sig. diff compared to the continue physical test in the same group (p<0.05)

Discussion

The results of the study of athletes in moderate and short distance swimming showed significant differences in pre-post oxygen saturation variables. This is because during exercise the sympathetic and parasympathetic nervous systems have an effect on an increase in heart rate which affects oxygen transport and the strength of heart contraction, thereby increasing peripheral vasodilation to the blood flow to active skeletal muscles so that during exercise there will be an integrated control of blood pressure which is controlled by reflex through the autonomic nervous system⁽⁷⁾. Another physiological response that occurs is an increase in oxygen diffusion capacity several times between resting and maximum work. previously blood flow through the pulmonary capillaries flows very slowly and even stops in a resting state. so when the body performs maximum work activities continuously or at intervals it will increase blood flow, through the lungs which causes the capillaries to diffuse maximally, so that athletes need more oxygen which is higher⁽⁸⁾.

Blood lactate was found to be a significant difference in pre-post between the two groups of athletes in middle and short distance swimming because when doing stressful activities the body experiences a lack of oxygen to break down glucose in the blood especially at high intensity it can reach 15-25 mM^(7,9). This is because the production of lactic acid is higher than its destruction (cleaning) when given high intensity loading⁽¹⁰⁾. So that a person experiences fatigue after exercise and will cause an increase in lactic acid up to 10 times during exercise⁽¹¹⁾.

Continuous and interval loading on leg muscle strength did not produce a significant difference between pre-post because athletes who have good physical abilities and are trained must have the capacity and strength ability to manage their energy sources properly⁽¹²⁾. The interval loading test resulted in a significant reduction in leg strength in the middle distance swimmer group. The middle-distance swimmer group who had the dominant aerobic muscle ability, was unable to quickly restore

ATP energy during interval loading. The dominance of red muscle cells which need oxygen to reproduce ATP cannot work optimally due to the lack of oxygen supply at the interval. Meanwhile, the short distance swimmer group who had the ability of anaerobic muscles was used to it and was able to work optimally at intervals. This is what causes a greater decrease in leg power in the middle distance swimmer group than the short distance swimmer during the interval loading test⁽¹³⁾ proved that middle distance swimmers experienced a decrease in strength after the interval compared to continuous training.

The continuous loading test resulted in a significant reduction in leg strength in the short swimmer group. The group of short distance swimmers who have dominant anaerobic muscle ability, are not able to consistently produce ATP energy during continuous loading. The dominance of white muscle cells which are only able to work for a short time and are unable to produce ATP is due to the low number of red muscle cells so that the muscles cannot work optimally. Meanwhile, the middle-distance swimmer group who has the ability of aerobic muscles (red muscles) is accustomed and able to work optimally when continuous⁽¹⁴⁾. This is what causes a greater decrease in leg power in the short distance swimmer group than in the middle distance swimmer during the continuous loading test.

The variables of shoulder muscle strength and arm power did not show a significant difference in the pre-post that when doing continuous physical loading tests and intervals using ergocycle, this was because the athlete did not experience significant muscle fatigue during loading⁽¹²⁾, so that he did not give the effect of fatigue, especially on the shoulder muscles.

Leg power shows a significant difference in pre-post short distance swimming athletes because short distance swimmers are more dominant anaerobic and have less aerobic capacity which tends to exercise for a short time⁽¹⁵⁾. So that when given a long or continuous workload, there is an increase in muscle blood flow during strenuous physical exercise which results in increased muscle

workload⁽⁸⁾. Intermediate distance swimmers have red muscle that tends to be aerobic. which is more dominant in moderate sports for a relatively long time ⁽¹⁵⁾. So that when given a load. the activity tends to be high. there is an increase in muscle blood flow during heavy physical exercise and results in increased muscle workload⁽⁸⁾. In continuous and short distance athletes. it does not make a significant difference because intermediate distance swimmers tend to have high aerobic metabolism and a cardiorespiratory system that can maintain moderate power for a relatively long time ⁽¹⁵⁾. So that when given continuous loading the physiological response in the body is not so excessive. Short-distance swimming tends to produce much greater instantaneous strength for a short period of time. sufficient to complete a 50 or 100 meter race ⁽¹⁵⁾. So that when given the physiological response in the body is not so excessive.

The middle distance swimmer group enjoyed and found it easier to load than the short distance swimmer group. This can be due to rest intervals which aid in energy recovery. The middle distance swimmer group had better energy recovery abilities during rest. because it had red muscle cells that were more dominant than the short distance swimmer group ⁽¹⁶⁾.

On the pulse rate variable in the two groups of athletes in the middle and short distance swimming athletes showed a significant difference in pre test and post test. Due to an increase in muscle blood flow during physical work. the body responds with an increase in oxygen demand as indicated by a much higher pulse rate frequency than at rest. Oxygen consumption and cardiac output also increase during exercise. Also. it is known that exercise will stimulate the sympathetic nerves and the result is an increase in pulse rate⁽⁸⁾.

The continuous physical loading test had a greater increasing lactate levels and pulse rate, and more decreasing leg power in short distance than middle distanceswimmers. The short distance swimmers, when compared between types physical loading test (continuous and interval), it was found that lactate levels and pulse rates increased more after doing interval

loading. This had a similar pattern to middle distance swimmers, where the leg power of middle distance swimmers had a greater decrease than short distance swimmers after doing interval physical loading test (fig. 2).

Conclusion

The continuous and interval high intensity physical loading tests with ergocycle in short and middledistance swimmers increase blood lactate and pulse rate. The short distance swimmers have greater increase of blood lactate level and pulse rate in both physical test. The leg power examination for short distance swimmers is more appropriate to continue high intensity physical loading test, whereas for middle distance swimmers is interval high intensity physical loading test. Based on these results, training program for swimmer type can be developed. However, further research is still needed to enhance the swimmers performance.

Ethical Clearance: Taken from the Research Ethics Commission from the Faculty of Medicine, Airlangga University (No. 90 / EC / KEPI (T`KUA / 2020).

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References

1. Nurcahyo. Hubungan Kemampuan Power Tungkai,

- Power Lengan, Dan Kapasitas Aerobik (VO2 MAX) Dengan Prestasi Renang Gaya Bebas 50 Meter [Internet]. Universitas Pendidikan Indonesia. 2013. Available from: <http://repository.upi.edu/2944/>
2. Olympic Council of Asia. Official Result Book: Swimming [Internet]. Palembang; 2018. Available from: https://www.ocagames.com/orb/files/4/59/AG2018_OfficialResultBook_Swimming_v1.0.pdf
 3. Sugiharto. Fisiologi Olahraga Teori dan Aplikasi Pembinaan Olahraga. Malang: Universitas Negeri Malang; 2014.
 4. Lubkowska W, Wiazewicz A, Eider J. the Correlation Between Sports Results in Swimming and General and. *J Educ Heal Sport*. 2017;7(12):222–36.
 5. Ince G, Turkeri C. Physical Fitness And Anthropometric Profiles Of The Turkish Special Athletes National Swimming Team. *Sport Sci*. 2016;9(2):83–91.
 6. Alsamir Tibana R, Manuel Frade de Sousa N, Prestes J, da Cunha Nascimento D, Ernesto C, Falk Neto J, et al. Is Perceived Exertion a Useful Indicator of the Metabolic and Cardiovascular Responses to a Metabolic Conditioning Session of Functional Fitness? *Sports*. 2019;7(7):161.
 7. Kenney. L. W. et al. 2012. *Physiology of sport and exercise*. 6th ed. USA: Library of Congress Cataloging-in-Publication Data; 2012. 642 p.
 8. Hall JE, Guyton AC. *Guyton and Hall Textbook of Medical Physiology*. 13th ed. Vol. 53, *Journal of Chemical Information and Modeling*. Philadelphia: Elsevier; 2016. 160 p.
 9. Goodwin ML, Harris JE, Hernández A, Gladden LB. Blood lactate measurements and analysis during exercise: A guide for clinicians. *J Diabetes Sci Technol*. 2007;1(4):558–69.
 10. Aminudin. Perbandingan Efek Pemanasan Aktif dan Pemanasan Pasif Terhadap Kadar Glukosa Darah dan Kadar Asam Laktat pada Aktivitas Fisik Submaksimal [Internet]. Universitas Airlangga. 2014. p. 22–72. Available from: <http://repository.unair.ac.id/39507/>
 11. Sun S, Li H, Chen J, Qian Q. Lactic acid: No longer an inert and end-product of glycolysis. *Physiology*. 2017;32(6):453–63.
 12. Foss M, Keteyian S. *Fox's Physiological Basis for Exercise and Sport*. 6th ed. New York: McGraw Hill; 1998.
 13. Billy Andrianto E, Dimyati M. The Effects of Exercise Method and Arm Strength on 200 Meters Freestyle Swimming Achievements. 2019;278(YISHPESS):468–71.
 14. Vasile L. Endurance Training in Performance Swimming. *Procedia - Soc Behav Sci*. 2014;117:232–7.
 15. Riewald S, Rodeo S. *Science of Swimming Faster*. United States of America: Sheridan Books; 2015.
 16. Connolly LJ, Bailey SJ, Krstrup P, Fulford J, Smietanka C, Jones AM. Effects of self-paced interval and continuous training on health markers in women. *Eur J Appl Physiol*. 2017;117(11):2281–93.