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Effect of Circulated Flow of Hydrotherapy on Reduction of Lactic Acid Levels in the Body after Physical Exercise

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Abstract The purpose of this study was to analyze the effect of circulating hydrotherapy on reducing lactic acid levels in the body. This study used a 2 x 2 factorial experimental design. Subjects were taken in this study by means of purposive sampling and then the subjects were divided into 4 groups. A total of 24 adult males aged 18-21 years participated in this study. Exclusion criteria in this study were having a history of lung disease and heart disease. Subjects took blood to measure lactic acid levels (Pre-test). Furthermore, the subject carried out the running-based Anaerobic Sprint Test (RAST) activity. Then the subject rested for 2 minutes. Each subject was given an intervention based on their respective groups for 10 minutes. Furthermore, the subject took blood to measure lactic acid levels (post-test). The statistical test used is the two-way Anova in the SPSS application. The results of this study indicate that there are differences in the effect of water temperature of 20ºC, with a water speed of 0.25 and 0.50 liters/second on the decrease in lactic acid levels. There is a significant difference in the effect of water at 37ºC, with a water speed of 0.25 and 0.50 liters/second to reduce lactic acid levels. There is an interaction between water temperature (20ºC, 37ºC) with a water speed of 0.25 and 0.50 liters/second on changes in lactic acid levels. It can be concluded that Circulated Flow of Hydrotherapy with the development of modified Water Temperature (WT), and Water Speed (WS) can both be used to improve recovery by lowering blood lactic acid levels in the body after physical activity.

Keywords Hydrotherapy, Recovery, Muscle Fatigue, Physical Exercise, Lactic Acid

1. Introduction

Physical exercise performed with high intensity will trigger energy deficiency and muscle fatigue [1]–[3]. Muscle fatigue becomes an obstacle during exercise because it causes dysfunction. In health, muscle fatigue is a decrease in the ability of a muscle to generate force and impair performance [4], [5].

The mechanism of muscle fatigue is considered to be a complex interaction phenomenon between central and peripheral factors [6]. Theoretically, a process in the central nervous system (CNS) that reduces nerve impulses to muscles causes a decrease in muscle strength known as central fatigue [7]. Increased blood lactate levels are believed to be a trigger for peripheral fatigue [8]. Currently, blood lactate is very popularly used as an indicator to predict fatigue and muscle performance after physical exercise [9], [10]. Excessive lactic acid will reduce the level of acidity (pH) in the muscles so that muscle contractions become weak and fatigue occurs. One study reported that increased lactate also contributes to ischemic pain by acting on sensory neurons that innervate muscles and thus impact performance during exercise [11].

It is necessary to find alternative solutions to overcome muscle fatigue. Advances in Science and Technology have helped human activities in various activities [12]–[14]. One of the popular tools in the medical world is hydrotherapy. Hydrotherapy is known as an alternative medicine to reduce pain by using water [15]. Hydrotherapy works by modulating body temperature such as sending cold or heat to the body. Previous studies have reported that hydrotherapy can reduce low back pain. In addition, a study reported that the combination of hydrotherapy and massage can increase Nerve Growth Factor (NGF) [16]. The hydrotherapy method can be applied in the rehabilitation process. However, the effect of modification of water flow and velocity has not been reported. The water used for hydrotherapy is predicted to have a different effect if it is still.

The purpose of this study was to analyze the effect of circulated flow of hydrotherapy on reducing lactic acid levels in the body.

2. Research Methods

Study Design

This study used a 2 x 2 factorial experimental design. Subjects were taken in this study by purposive sampling and then the subjects were divided into 4 groups. Group 1 (K1) is a group in a hydrotherapy bath with a water temperature of 20°C with a water velocity of 0.25 liter/s. Group 2 (K2) is a group in a hydrotherapy bath with a water temperature of 20°C with a water velocity of 0.50 liter/s. Group 3 (K3) is a group in a hydrotherapy bath with a water temperature of 37°C with a water velocity of 0.25 liter/s. Group 4 (K4) is a group in a hydrotherapy bath with a water temperature of 37°C with a water velocity of 0.50 liter/s.

Tools

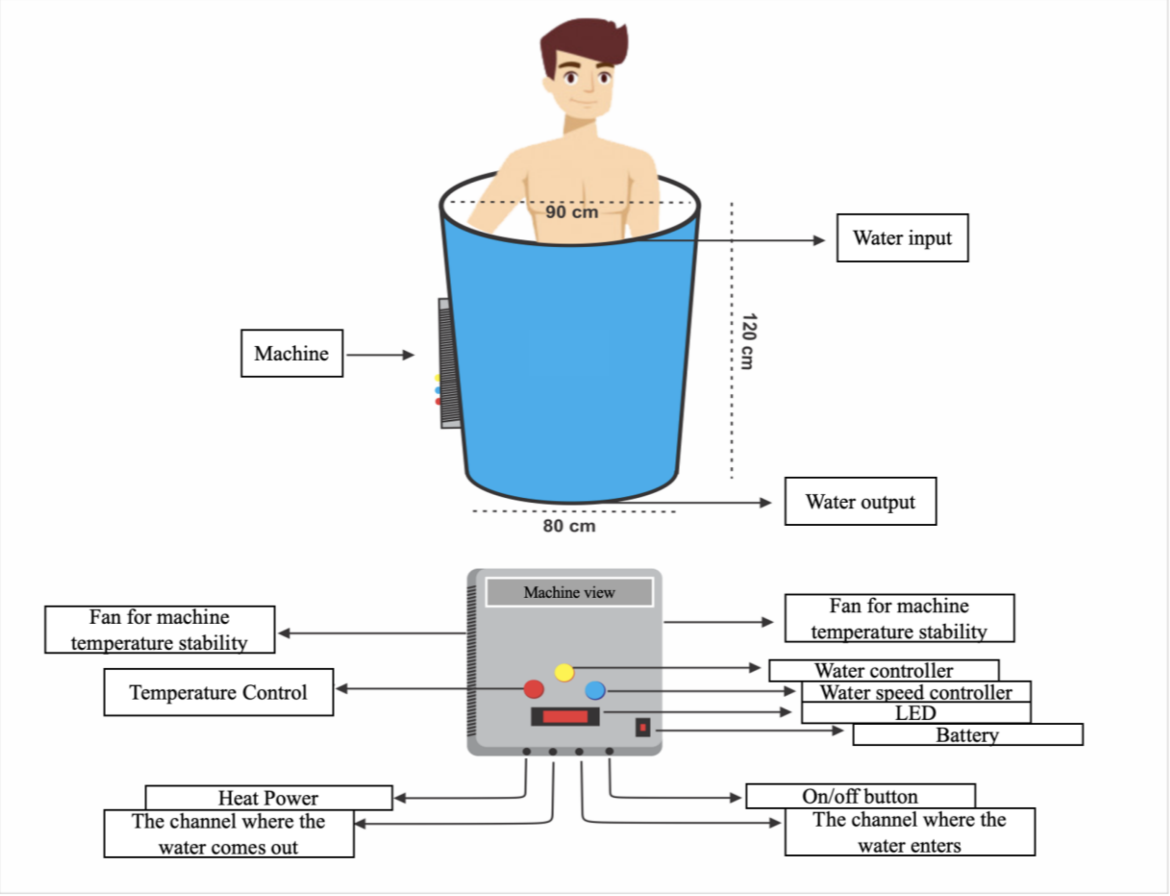

Figure 1. Hydrotherapy device

Subjects

A total of 30 adult men aged 18-21 years participated in this study. The exclusion criteria in this study were having a history of lung disease and heart disease.

Procedure

i). The first preparation is preparing the administration which includes research permits, and permits for facilities and infrastructure.
ii). Furthermore, preparing research subjects based on inclusion and exclusion criteria.
iii). After the subjects were selected based on the inclusion and exclusion criteria, the subjects were asked to fill out informed consent.
iv). Subjects were divided into 4 groups using random sampling.
v). Furthermore, blood samples were taken to measure lactic acid levels (Pre-test).
vi). After taking the pre-test blood, the subjects carried out the Running Based Anaerobic Sprint Test (RAST).
vii). Then the subject rested for 2 minutes.
viii). Then the subjects were given intervention based on their respective groups for 10 minutes.
ix). Finally, the subjects took blood to measure lactic acid levels (Post-test).

Statistical analysis

The data analysis technique used in this study was using SPSS version 20.0 software for windows, namely two-way Analysis of Variance (ANOVA) at a significance level of = 0.05. Furthermore, to compare the mean pairs of treatments, the Newman Keuls Range test was used. Considering that the research data analysis was carried out using ANOVA, before arriving at the use of ANOVA, it was necessary to test the requirements, which included the normality test and the homogeneity of variance test. The technique used in the normality test is Kolmogorov Smirnov and the technique used in the homogeneity test of variance is the Barlett test. After the normality test and homogeneity of variance were tested, the requirements for using ANOVA in data analysis were met.

3. Results

Normality Test Results lactic acid levels

Table 1. Result of normality test of lactic acid level

Data	Group	Shapiro-Wilk	
		n	P
Pre-test lactic acid levels	K1	6	0,249
	K2	6	0,830
	K3	6	0,101
	K4	6	0,584
Post-test lactic acid level 1	K1	6	0,582
	K2	6	0,139
	K3	6	0,137
	K4	6	0,504
Post-test lactic acid level 2	K1	6	0,587
	K2	6	0,069
	K3	6	0,094
	K4	6	0,529

Based on the normality test in Table 1, the data on lactic acid levels Pre-test, post-test 1, and post-test 2 on K1, K2, K3, and K4 show that the data ($p>0.05$) means that the data is distributed normally.

Descriptive statistical results of mean, standard deviation and homogeneity test of lactic acid levels

Based on Table 2 below, the average descriptive data and homogeneity test of lactic acid levels were $p>0.05$, indicating that the data were homogeneous variables. The homogeneity test of lactic acid both pre-test, post-test 1 and post-test 2 in all groups showed significant results.

Table 2. Mean, standard deviation, and homogeneity test results of lactic acid levels

Variable	$\bar{X}$ ± SD (mMol/l)		p
	Water Temp	Water Speeds	
Pre-test	2,16 ±0,70	2,46 ±0,71	0,240
Post-test 1	11,16 ±0,50	11,46 ±0,51	0,226
Post-test 2	5,93 ±1,40	5,95 ±2,38	0,220

Paired t test of blood lactic acid (mMol/l) at K1, K2, K3, K4

Table 3. Blood lactate paired test

Group	Variable	p (sig)
(K1)	Pre-test – Post-test 1	0,000
	Pre-test – Post-test 2	0,037
	Post-test 1 – Post-test 2	0,012
(K2)	Pre-test – Post-test 1	0,000
	Pre-test – Post-test 2	0,016
	Post-test 1 – Post-test 2	0,000
(K3)	Pre-test – Post-test 1	0,000
	Pre-test – Post-test 2	0,026
	Post-test 1 – Post-test 2	0,010
(K4)	Pre-test – Post-test 1	0,000
	Pre-test – Post-test 2	0,000
	Post-test 1 – Post-test 2	0,000

Table 3 illustrates that all variables obtained p value <0.05. This shows that there is a significant difference.

Multivariate test results

Table 4. Multivariate Test Results

Effect		p (sig)
Intercept	Pillai's Trace	0,000
	Wilks' Lambda	0,000
	Hotelling's Trace	0,000
	Roy's Largest Root	0,000
Group	Pillai's Trace	0,000
	Wilks' Lambda	0,000
	Hotelling's Trace	0,000
	Roy's Largest Root	0,000

*P<0.05 there is a significant effect

Results of post hoc test variable lactic acid test

Table 5. Post Hoc Test Results

Variable	Group		p (sig)
Lactic acid	K1	WT-WS	0,025
	K2	WT-WS	0,027
	K3	WT-WS	0,003
	K4	WT-WS	0,001

*P<0.05 there is a significant difference

4. Discussion

Lactic acid levels after recovery method Water Temperature (WT) 20ºC with Water Speeds (WS) 0.25, 0.50 l/s (K1, K2)

Based on the descriptive analysis of lactic acid after recovery using the Water Temperature (WT) method with Water Speeds (WS) of 0.25 and 0.50liter/second for 15 minutes, the results were post 1 (10.15±1.41 mMol/l), and post 2 (5.15±1.00 mMol/l). It is observable this result has decreased from the results of the previous post-test after doing submaximal physical activity. In addition, if we look at the results of the paired t-test, (post-test 1 – post-test 2) in the group (K1, K2), we also get a significant value, namely p = 0.012 for K1 and p = 0.000 for the group 2. This means that there is a significant difference in lactic acid levels between before and after recovery (post-test 1 – post test 2).

Physiologically, the Water Temperature (WT) 20ºC method with the addition of 0.25 and 0.50 l/s Water Speeds causes local arteriolar and venular vasoconstriction. This vasoconstriction is caused by reflex action of smooth muscle arising from stimulation of the autonomic nervous system and the release of epinephrine and norepinephrine [17]. However, if the cold continues to be given for 15 to 30 minutes there will be a vasodilation phase that occurs intermittently for 4 to 6 minutes. This period is known as the hunting response. The hunting response occurs to prevent tissue damage due to tissue anoxia [18].

Especially for blood vessels, cold hydrotherapy will cause a vasoconstriction effect, which is the shrinking of blood vessels due to contraction of the muscle walls of blood vessels. Reduction of the caliber of blood vessels will reduce the amount of blood flowing in the area. This effect is very useful for reducing swelling in blood vessels. However, if this cold therapy continues to be carried out there will be a reversal effect in the form of enlargement of blood vessels due to muscle relaxation of blood vessels. This effect is known as the Hunting Response [19].

Lactate produced by muscles due to the effects of epinephrine will be metabolized in the liver through the process of gluconeogenesis to produce glucose (Cori cycle). Gluconeogenesis produces energy of 2 ATP for each glucose molecule that becomes lactate. And one molecule of lactate will use 6 ATP to form one molecule of glucose from lactate. The Cori cycle shows the ability of liver cells to use ATP via beta-oxidation of free fatty acids to produce glucose [20], [21].

Researching on fatigue recovery in swimming athletes is by comparing the temperature between cold (20 ℃) and hot (40 ℃), the results are both able to recover fatigue. Many articles show that cold water immersion is more effective in recovering sports at a temperature of 10-15 ° C for a duration of 5-10 minutes [22].

In a cold state, the hypothalamus will regulate the skeletal muscles for active vasoconstriction. This will cause a person to shiver and increase body temperature. At the same time, the adrenal glands will secrete the hormones adrenaline and noradrenaline, while the thyroid will secrete the hormone thyroxine, all of these hormones aim to increase body temperature by increasing the body's metabolism. Increased body temperature makes blood circulation smoother so that the supply of glucose and oxygen in the muscles is met for energy processes, this will help the recovery process of muscle fatigue [23].

Lactic acid levels after recovery method Water Temperature (WT) 37ºC with Water Speeds (WS) 0.25, and 0.50 l/s (K3, K4)

Based on the descriptive analysis of lactic acid after recovery using the Water Temperature (WT) 37ºC method with Water Speeds (WS) 0.25 and 0.50 liters/second for 15 minutes, the results were post 1 (11.25 ± 1.21 mMol /l), and post 2 (5.65±1.10 mMol/l) hence, these results have decreased from the previous post-test results after doing submaximal physical activity. In addition, if we look at the results of the paired t test (post-test 1 – post-test 2) in the group (K3, K4), we also get a significant value, namely p = 0.090 for K3 and p = 0.160 for Group 4. This means that there was a significant difference in lactic acid levels between before and after recovery (post-test 1 – post-test 2).

Recovery carried out with hot temperatures (37 ℃), does not directly affect the decrease in lactic acid accumulation in the blood due to exercise, but the increase in temperature acts as a factor that can cause vasodilation and improve enzymes in the metabolism of energy ATP formation.

During recovery with the Water Temperature (WT) 37ºC method with Water Speeds (WS) 0.25, and 0.50 l/s, the body supplies sufficient oxygen so that it can be used for metabolic processes in the muscles together with pyruvic acid through the cycle process kreb in a number of electron transport [24]. From the Krebs cycle and the electron transport system, energy will be obtained which is used to synthesize ATP which has been used during exercise. Thus, the amount of lactic acid formed during the process of anaerobic glycolysis is not lost from the body, until oxygen is available again, lactic acid is converted into ATP or energy. After sufficient energy is available in the muscles, the state becomes fresh and ready to do the exercise again, and with active recovery can shorten the recovery time [10].

A study reports that increased body and muscle temperature during exercise will affect metabolism and muscle function [25]. The study was conducted using rats that were trained with a treadmill in different environments, cold acclimatization would increase muscle mitochondria and cytochrome-C oxidase levels were measured [26]. Changes in temperature can affect mitochondrial levels in various ways, for example, changes in body temperature during exercise can increase oxygen supply from the blood to muscle mitochondria, substrate utilization, plasma epinephrine concentration, blood pressure and oxygen consumption in producing ATP. Biochemical reactions will involve mitochondrial respiration depending on the availability of oxygen. Increased oxygen delivery and use during exercise will improve mitochondrial respiration, therefore increasing temperature during exercise can increase muscle mitochondrial levels [27].

An increase in temperature in addition to increasing the supply of oxygen to the blood, can also improve the performance of enzymes (Lactate dehydrogenase, pyruvate carboxylase) which play a role in the ATP formation process because an increase in temperature of 10 ℃ causes the activity to be twice as large (Q10=2). At the optimum temperature, the reaction proceeds most rapidly. Enzymes in the human body have an optimum temperature of around 37 ℃ [28]. The heat that arises in the human body is the result of muscle activation, assimilation of food and vital processes that support the basal metabolic rate [29].

Comparison of lactic acid levels after recovery with the method Water Temperature (WT) 20ºC and 37ºC

The results of the manova test using the tests of between-subjects effects analysis to determine the difference in lactic acid levels between the control groups, K1, K2, K3 and K4 obtained significant results with p value = 0.001. The results of the analysis showed that recovery significantly affected lactic acid levels in the control group, K1, K2, K3 and K4.

Because the results of the Manova test showed a significant value, then a post hoc test was carried out using the Bonferroni test on the lactic acid variable. The Bonferoni test was carried out because the homogeneity test of variance showed a homogeneous value with a p value of 0.123. In addition, this bonferroni test was conducted to determine whether there was a significant difference in the lactic acid variable between the control group, the K1, K2, K3, and K4 groups. The results of the Bonferroni test on the lactic acid variable showed that there was a significant difference between the control group and the K1 group (p=0.025), the control group with K2 (p=0.027), the control group with K3 (p =0.003), and the control group with K3 (p=0.003), control with K4 (p=0.001). If $p<0.05$, it can be concluded that the variance of the data group is different, but on the contrary, if $p>0.05$, it can be concluded that the variance of the data group is the same. In the table of Bonferroni test results, it can be seen that the significance of all variables is <0.05. So it can be concluded that group variants have different roles and inter-group linkages with unequal values of relatedness.

This is because the K1 and K2 groups experienced vasodilation as a result of the hunting response due to the administration of cold water for 15-30 minutes. While in groups K3 and K4, giving hot water affects the body by vasodilation of blood vessels, providing nutrients and oxygen to cells, increasing blood supply, and accelerating healing.

The mechanism of giving heat to the body will give a signal to the hypothalamus through the spinal cord. When heat-sensitive receptors in the hypothalamus are stimulated, the effector system issues signals that initiate sweating and peripheral vasodilation. Changes in blood vessel size are regulated by the vasomotor center in the medulla oblongata of the brain stem, under the influence of the anterior hypothalamic so that vasodilation occurs [30].This situation will increase the flow (circulation) in the blood and lymph vessels. Increased circulation will affect the smooth supply of oxygen which will help recycle lactic acid into an energy source. With the availability of re-energy from lactic acid, it will restore fatigue which has an impact on returning performance to normal [31].

Lactic acid formed during physical activity is converted into pyruvic acid and broken down into CO_2 and H_2O in the mitochondria. Lactic acid can diffuse out of the muscle cells, which is blood that can be used by other muscles. Lactic acid is carried to the liver and converted into liver glycogen for storage. Lactic acid is formed in the muscles during exercise and converted in the liver through gluconeogenic processes [20].

The liver is the most important organ in the lactate clearance process and plays a role of 40-50% in daily lactate metabolism [32]. The uptake of lactate by the liver occurs through the monocarboxylate transporter system, while the metabolism of lactate in the liver occurs through oxidation reactions or the process of gluconeogenesis. Lactate metabolism is highly dependent on the physiological condition of the liver, so the impaired liver function will affect lactate metabolism but rarely causes a significant increase in lactate levels. Many studies have shown that in the non-hepatic phase during liver transplantation, there is a slight increase in lactate levels. This shows that besides the liver there are other organs that also play a role in lactate metabolism. The half-life of lactate elimination from the blood ranges from 10-15 minutes. Lactate elimination in trained people is faster than in untrained people [20].

Restoration of blood and muscle lactic acid in strenuous exercise to a normal state takes 1-2 hours. Recovery will be faster if it ends with active recovery with 50% VO2Max intensity compared to passive recovery. Active recovery will reduce lactic acid levels more quickly because in active recovery blood flow is still high which can accelerate the diffusion of lactic acid out of the muscle for immediate oxidation [10]. This statement is supported by the results of [33], that lactic acid in the blood gradually decreases according to the decrease in time.

The results of the lactic acid bonferroni test showed that there was a significant difference between the (WT) Water Temperature 20ºC (K1, K2) group and the (WT) Water Temperature 37ºC (K3, K4) group. This is because the recovery in the 20ºC and 37ºC groups removes lactic acid through the same pathway with a different mechanism, namely vasodilation of blood vessels, thereby accelerating the transportation of lactic acid to the liver which will then be converted into glucose through the Cori cycle.

5. Conclusion

Circulated Flow Of Hydrotherapy with modified development of Water Temperature (WT), and Water Speeds (WS) both can be used to improve recovery by lowering blood lactic acid levels in the body after physical activity. Water Temperature (WT) with a temperature of 37ºC will recover lactic acid levels better with the addition of 0.50 l/s Water Speeds (WS) compared to 0.25 l/s. However, with a Water Temperature (WT) of 20ºC, it will be maximized with a Water Speeds (WS) of 0.25 l/d to restore the body's lactic acid levels.

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