ORIGINAL ARTICLE

The Changes in pH Levels, Blood Lactic Acid and Fatigue Index to Anaerobic Exercise on Athlete After $NaHCO_3$ Administration

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ABSTRACT

Introduction: Previous studies have revealed that sodium bicarbonate consumption prior to physical activity has a performance-enhancing effect on anaerobic activity. **Methods:** It was an experimental research using retest and posttest design. 36 healthy professional athletes were randomly assigned to either $NaHCO_3$ group (SBC=18) or placebo group (PLA=18). Respondents in SBC were given sodium bicarbonate solution at a dose of 0.4 gram/kg of bodyweight dissolved in 500 ml of aquades, while PLA group were given mineral water. Sixty minutes after NaHCO3 administration, both groups were assigned to anaerobic activity which was 300 m sprint test. pH level and lactic acid were measured 5 minutes after anaerobic activity, while fatigue index was measured 30 minutes after anaerobic activity. **Results:** Significant differences between SBC and PLA were found in pH level (p=0,000), blood lactic acid (p=0,000), and fatigue index (p=0,003). **Conclusion:** The administration of NaHCO3 was able to prevent a decrease in pH and an excessive increase of lactic acid and fatigue index as the result of anaerobic activity.

Keywords: Anaerobic activity, Blood lactic acid, Fatigue index, pH, Sodium bicarbonate

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INTRODUCTION

Aerobic and anaerobic exercise are two different type of exercise classified based on the interval, intensity, and muscle fibers involved (1). Anaerobic is a type of sports activities that increases the concentration of lactic acid in muscle cells. The increase of lactic acid causes a decrease of pH cells, a decrease in pH causes a decrease in reaction rate of catalyst and finally it decreases the ability of metabolism and ATP production (2). Anaerobic glycolysis exercise leads to excessive accumulation of lactic acid in the blood which results in disruption of muscle contraction (3). Accumulation of lactic acid and carbon dioxide can lower the force or power, speed, and cause fatigue (4). Previous study reported that the increase in lactic acid would be followed by an increase of fatigue index during an anaerobic (5).

In high intensity and short duration exercises, the fulfillment of energy requirement increases almost 100 times (6). Oxidative phosphorylation is not able to produce large amounts of energy in a short period of time, therefore, the fulfillment of energy requirement of this type of sport depends on the phosphagen system and anaerobic glycolysis (7). The phosphagen system can only provide energy for activities with a span of 10-15 seconds, thus, anaerobic glycolysis is the major metabolic pathway in high intensity exercise (7). However, this anaerobic glycolysis metabolic pathway produces by-product in the form of lactic acid (8). Increased reliance energy causes lactic acid accumulation. According to some researchers, lactic acid accumulation causes muscle fatigue that arises during the intense exercise (9).

Recovery from exercise or competition is an important component of the overall sports paradigm. And the most important thing from recovery is to support a better performance in the next exercise or competition (10). Recovery is useful for body adaptation after physical activity. Increased recovery time helps athletes in maintaining health and performance in order to increase opportunities to enter or undergo a competition favorably (11).

Strategies for optimizing recovery from exercise or physical activity depend on type of exercise, specific exercise, duration, intensity, and time between exercise sessions or competitions (12). Successful recovery involves many physiological and metabolic processes that act to prepare athletes for the next competition or exercise (12). Adequate recovery has been proven to result in the recovery of physiological and psychological processes, so that athletes can compete or train again at the appropriate level. Recovery from exercise and competition is very complex and usually depends on the nature of the exercise performed and other external stressors (13).

There are a number of popular methods used by athletes to improve recovery. Its use depends on the type of activity carried out, and the period until the next exercise session. Some popular recovery techniques for athletes include stretching, active recovery, compression sportswear, hydrotherapy, massage, good quality sleep, and nutrition. Nutrition is one of the best ways for athletes to do recovery, such as consuming balanced diet and drinks containing sodium bicarbonate. Consuming sodium bicarbonate has been proven to increase exercise tolerance, but its effect on intermittent sports with high intensity is obscure (14). Bicarbonate is an alkaline neutralizer, naturally regulating acid-base homeostasis in the body. Chemically, bicarbonate binds with hydrogen lactate ions to form water and carbon dioxide, and carbon dioxide dissolved in the blood will be released through the respiratory system (15).

Anerobic glycolysis will generate lactic acid due to incomplete breakdown of glucose (16). The higher level of lactic acid in the blood will engage a decrease in blood pH which then cause physical fatigue and alter physical appearance. Moreover, prolonged physical activity or high intensity exercise will trigger the formation of lactic acid (9). When exercise occurs, anaerobic fatigue may develop as a result of lactic acid accumulation (17). Lactic acid in muscle cells causes lactic acidosis so that the neuromuscular junction stops the nerve stimulation to the muscle fibers, consequently, the muscles are unable to contract (18).

Acidic status in the blood (low pH) can cause interference with various cellular muscle mechanisms such as decreased aerobic resistance due to inhibition of aerobic enzymes, poor movement coordination due to inhibition of creatin phosphate formation, decreased fat oxidation rate due to increased urea levels (19). A method that can be used to slow down the occurrence of fatigue due to lactic acid that accumulates in the body during physical activity is providing alkaline fluids such as sodium bicarbonate drinks. Sodium bicarbonate ($NaHCO_3$) is an alkaline that has the ability to damage and oxidize acids in food ingredients. This happens because $NaHCO_3$ is the weakest sodium alkali and has a pH of 8.3 in aqueous solution (19).

Some literatures also explain that drinks containing sodium bicarbonate can neutralize low pH levels during exercise or physical activity, thus it can alleviate the lactic acid production during exercise (20). Sodium bicarbonate is a strong base that quickly reacts with H^+ and NaOH quickly release acid molecules in solution. Alkali is a molecule generated by the formation of one or more alkali-sodium metals such as potassium and lithium (19). The acid solution will be removed by this alkaline molecule because it can react quickly with H^+. Normal pH level of the liquid in human body ranges from 7,34 to 7,40 (21). If the pH is out of this range, the mechanism of homeostasis will improve buffer process, and consequently it will set a new pH level (19).

A pH level beyond 7.4 is categorized as alkaline, and previous studies revealed that sodium bicarbonate drink is one of the high alkaline-containing liquids that that causes blood become more alkaline at a low pH or acidic (3). Consuming sodium bicarbonate is an effort to reduce the body acidity due to the physical activity, especially in doing exercise, thus, the acidic condition or decrease in pH can be reduced to postpone the risk of fatigue as a result of lactate ions and H^+ ions accumulation (3).

Therefore, the authors are interested to analyze the effect of $NaHCO_3$ on pH levels, blood lactic acid, and fatigue index after anaerobic activity. The aim of this research is to investigate whether the administration of $NaHCO_3$ can withstand the decrease in pH level and fatigue index as well as an increase in blood lactic acid due to anaerobic activity so that this treatment can delay fatigue and improve athletic performance, especially athletes in intermittent sports such as badminton (22)

MATERIALS AND METHODS

This research was an experimental research with a pre and post control group design. A total of 36 PBSI Jombang (Badminton Association of Indonesia in Jombang district) athletes were employed as the research subject with inclusion criteria aged 16-20 years old, male, having normal weight and BMI, and agreed to participate in this study and followed all the protocols. All participants were informed about the research purpose, procedures, and any potential risks that may develop as side effects. The research subjects were then randomly divided into two groups (PLA and SBC) with a total of 18 people in each group (See Fig. 1 below).

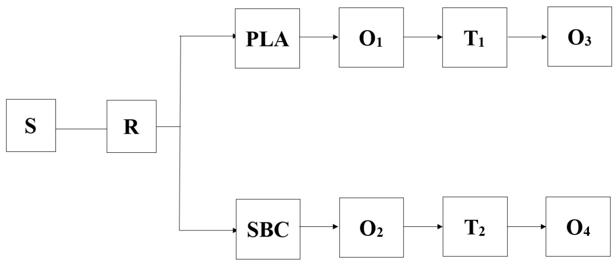

Fig. 1 : Research Design

Remarks:
S : Sample
R : Randomization
PLA : Placebo group
SBC : Treatment group (with NaHCO3)
T1 : Mineral water
T2 : NaHCO3 with dose 0,4 gram/kg bodyweight in 500 ml mineral water
AA : Anaerobic activity
O1 : Pretest of PLA (pH levels, blood lactic acid, fatigue index)
O2 : Pretest of SBC (pH levels, blood lactic acid, fatigue index)
O3 : Post-test of PLA (pH levels, blood lactic acid, fatigue index)
O4 : Post-test of SBC (pH levels, blood lactic acid, fatigue index)

The research data were obtained from tests on blood pH, blood lactic acid and anaerobic fatigue index conducted 2 times (pretest and posttest). Blood pH was measured with a pH meter 1-STAT tool and lactic acid was measured using a lactate meter Roche Cobas Accutrend Plus GCTL Meter. Blood pH and lactic acid was employed by taking blood from the respondent's fingertips and then dripping on the instrument. Whereas, the measurement of anaerobic fatigue index used RAST-test (Running-based Anaerobic Sprint-test) (23).

The procedure for carrying out the RAST-test was done by asking the respondents to perform six 35-meter sprint, with 10 seconds break for each sprint, then the time was recorded. Next, speed (distance/time), acceleration (speed/time), force (weight x acceleration) and power (force x speed)were calculated (24). The fatigue index is calculated using RAST calculator as follows:

$$\text{Fatigue index} = \frac{\text{Maximal Power - Minimal Power}}{\text{Total time of 6 sprints}}$$

Before taking the pretest data, respondents were asked to fast for 8 hours while still consuming mineral water and checking their health condition both pulse and blood pressure. Besides, respondents were also asked questions about their medical history, eating habit and physical activity carried out during the last 3 days. 30 minutes after the pretest, respondents consumed sodium bicarbonate solution at a dose of 0.4 gram/kg of bodyweight for the treatment group (SBC), and drank mineral water for the placebo group (PLA) (14). Sodium bicarbonate was dissolved in 500 ml of aqua water (25). To avoid vomiting, sodium was given in 3 stages: 60 minutes, 45 minutes and 30 minutes. After 60 minutes of consuming sodium bicarbonate or mineral water, the research subjects conducted anaerobic activity by running 300 meters (26)(27). Bloods were drawn after 5 minutes of conducting anaerobic activity to re-measure pH and lactic acid (posttest) (28). 30 minutes after anaerobic activity, the subjects were measured their anaerobic fatigue index by doing the RAST posttest.

Data were analyzed with statistical software and were presented as mean values and standard deviation (SD). Paired t-test was performed to compare pH level, blood lactic acid, and fatigue index before and after $NaHCO_3$ administration. Independent t-test was performed to compare between groups. The tests were all two-tailed and p<0,05 was considered statistically significant.

RESULTS

Thirty-six healthy athletes were participated in this study. The mean values and standard deviation of physical characteristic (age, height, weight, and BMI) in both groups are shown in Table I. For PLA group, the mean value of age, height, weight, and BMI were 17,56 ± 1,29, 168,89 ± 2,81 cm, 60,56 ± 3,85 kg, and 21,22 ± 0,94, respectively. For SBC group, the mean value of age, height, weight, and BMI were 18,44 ± 1,25, 167,00 ± 4,56 cm, 63,00 ± 3,85 kg, and 22,61 ± 1,40, respectively.

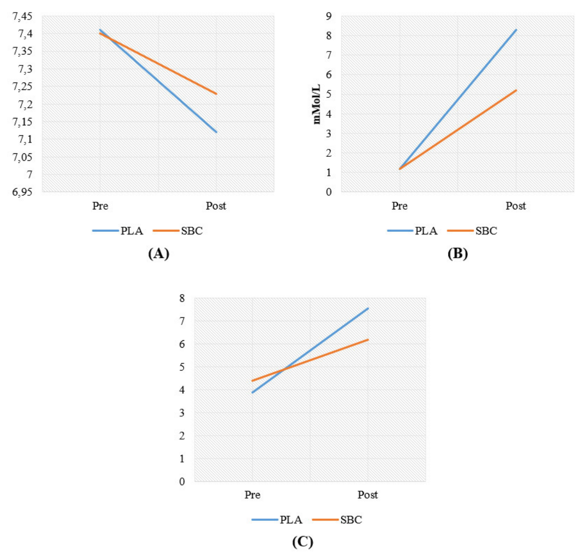

Fig. 2 : The changes in pH levels (A), blood lactic acid (B); and fatigue index (C) after anaerobic activity in control (PLA) and treatment (SBC) group.

Fig. 2 shows the changes in pH levels, blood lactic acid, and fatigue index after respondents in both groups performed running exercise. Both groups experienced a significant decrease in pH levels, but the PLA group decreased more sharply. A significant increase was found in blood lactic acid and fatigue index, with PLA group experience a sharper increase than SBC.

Table I : Baseline characteristic of respondents in both group

Group	Mean ± SD			
	Age	Height (cm)	Weight (kg)	BMI
PLA	17,56 ± 1,29	168,89 ± 2,81	60,56 ± 3,85	21,22 ± 0,94
SBC	18,44 ± 1,25	167,00 ± 4,56	63,00 ± 3,85	22,61 ± 1,40

PLA = mineral water + anaerobic exercise
SBC = group of $NaHCO_3$ + anaerobic exercise intervention

Table II shows the changes in pH levels, blood lactic acid and fatigue index in the PLA and SBC groups. Paired sample t-test results showed that data before (pre) and after (post) intervention was significantly different p<0,05. It can be concluded that anaerobic exercise affected pH levels, serum lactate and fatigue index in both PLA and SBC groups.

Table II : Effect of anaerobic exercise on the changes of pH levels, blood lactic acid and fatigue index

Group		pH levels Mean ± SD	sig.	Blood lactic acid (mg/dl) Mean ± SD	sig.	Fatigue index (watt/s) Mean ± SD	sig.
PLA	pre	7,41 ± 0,02	0,000*	1,20 ± 0,57	0,000*	3,89 ± 1,20	0,000*
	post	7,12 ± 0,01		8,26 ± 1,16		7,55 ± 1,77	
SBC	pre	7,40 ± 0,02	0,000*	1,21 ± 0,35	0,000*	4,38 ± 1,29	0,000*
	post	7,22 ± 0,02		5,17 ± 1,19		6,17 ± 0,66	

*significant difference at α=0,05
PLA= mineral water + anaerobic exercise
SBC= $NaHCO_3$ + anaerobic exercise

To find out the difference in the effect of $NaHCO_3$ administration on pH levels, blood lactic acid and fatigue index, the difference between the pre and post data in the PLA group and the SBC group was calculated using an independent sample t-test.

The results of the independent sample t-test are presented in Table III. The results of the independent sample t-test showed the value of p <0,05 on the pH level variable (p = 0,000), blood lactic acid (p = 0,000), and fatigue index (p = 0,003). These results indicated that there were significant differences between the PLA group and the SBC group at pH levels, blood lactic acid and fatigue index after anaerobic exercise. Thus, it can be concluded that there was an influence of giving $NaHCO_3$ on pH levels, blood lactic acid and fatigue index after anaerobic exercise.

DISCUSSION

The Effects of anaerobic exercise on pH levels, blood lactic acid and fatigue index

Based on the results of the statistical tests in this study, anaerobic exercise was able to influence the pH levels, serum lactate and fatigue index (see Table II). These results are in line with research conducted by Rashidi, Salehian, & Vaezi (2013) that blood lactate levels increased after 5 minutes of anaerobic activity. Increased blood lactate was caused by the active anaerobic glycolysis system in the muscles during anaerobic activity resulting the production of lactic acid (29). The lactic acid from metabolism result in the muscle then was secreted into the blood. It caused the decrease of blood pH and the blood become acidic. The decreased blood pH would disrupt the activity of glycolytic enzymes and muscle contraction, consequently, it would cause fatigue and decreased performance (30).

Anaerobic activity is a high intensity exercise with a short duration and fueled by energy sources that are metabolized without oxygen (31). Energy in anaerobic exercise is obtained from the ATP-PC system and anaerobic glycolysis (32). ATP-PC system and anaerobic glycolysis causing lactic acid production (27). The examples of anaerobic exercises are sprint, bicycle racing, weight-lifting (33). 300 meters run is anaerobic activity because it is a high intensity in a short duration exercise (34).

Anaerobic activity metabolism causes the production of lactic acid in the working muscles (8). The part of produced lactic acid is released into the blood, consequently it reduce blood pH and disturb the acid-base balance (35). Lactic acid is a three-carbon biomolecule with a carboxyl group and a hydroxyl group. It is the final product of the anaerobic glycolysis process produced by red blood cells and active muscle

Table III : Differences in pH levels, blood lactic acid, and fatigue index after anaerobic exercise in the PLA group and SBC group

Group	Δ pH levels Mean ± SD	sig.	Δ Blood lactic acid (mg/dl) Mean ± SD	sig.	Δ Fatigue index (watt/s) Mean ± SD	sig.
PLA	0,291 ± 0,03	0,000*	-7,061 ± 1,31	0,000*	-3,658 ± 1,87	0,003*
SBC	0,183 ± 0,02		-3,961 ± 1,17		-1,791 ± 1,65	

*significant difference at α=0,05
PLA= mineral water + anaerobic exercise
SBC= $NaHCO_3$ + anaerobic exercise

cells (36). Lactic acid is a strong acid, and consequently it will dissociate into lactic and H+. The increase of H^+ ions will decrease pH and cause acidosis (4).

The discussion of acidosis during the intense exercise has been explained as a result of lactic acid production, causing proton release and formation of sodium lactate. This biochemical event is called as lactic acidosis (37). Other theories reveal that acidosis is not the only way to decreases the speed of observed contraction during fatigue (38).

The pH change in the muscles that become acid will inhibit the work of glycolysis enzymes, consequently, it will disrupt the chemical reactions in the cell (39). It causes the reduction of energy produced so that the muscle contraction gets weaker and eventually, and finally the muscles will experience fatigue. Low pH levels will inhibit the performance of the enzyme phosphofructokinase which plays an important role in fulfilling muscle energy, so that it will cause muscle fatigue (40).

From the above theories it can be concluded that anaerobic exercise could increase the index of fatigue due to the acid-base imbalance in the blood or it is called as experiencing metabolic acidosis. Metabolic acidosis was caused by an increase in lactic acid in the blood that leads to decrease in blood pH and disruption the performance of glycolytic enzymes to produce energy used in muscle contraction.

The effect of $NaHCO_3$ administration on pH levels, blood lactic acid and fatigue index

This study found that there was a significant difference of pH levels as well as blood lactic acid with p-value of zero and fatigue index (p = 0.003). The results of this study indicated that the administration of $NaHCO_3$ affected the pH levels, serum lactate and fatigue index after anaerobic exercise. In accordance with Hartono & Sukadiono (2017) which stated that the administration of sodium bicarbonate and sodium citrate at a dose of 300 mg/kg in 500 ml aqua was able to increase blood pH and the time duration to fatigue after performing anaerobic exercise (25). In line with research by Kupcis et al. (2012) that there was an increase in blood pH and a decrease in lactic acid after sodium bicarbonate was given to the rowing athletes but there was no increase in their performances (41). Krustrup in his study stated that the administration of sodium bicarbonate at a dose of 0,4 g kg^{-1} body weight could increase the results of Yo-Yo IR2 performance by 14% higher than the placebo group (14). These results indicated that administration of sodium bicarbonate was able to increase fatigue resistance.

Sodium bicarbonate has an ergogenic effect that can improve performance in swimming, rowing, middle-distance running, sprinting and boxing (42–44). However, the administration of sodium bicarbonate 70-90 minutes before competing does not improve the performance of rowing athletes (41). Sodium bicarbonate is the monosodium salt of carbonic acid with alkalinizing and electrolyte replacement properties (45). After dissociation, sodium bicarbonate forms sodium ions and bicarbonate. This ion formation will increase plasma bicarbonate levels and act as buffer in excess concentrations of hydrogen ion, thereby increasing blood pH (45). Sodium bicarbonate that enters the body will cause metabolic alkalosis which is good for buffering lactic acid. However, consumption of sodium bicarbonate can cause discomfort in the stomach as it emits a lot of carbon dioxide (46). The side effect of sodium bicarbonate consumption is a decrease in cardiac output and impaired lactate clearance by the liver (47).

When someone does exercise, the body will produce lactic acid (48), therefore, the body needs additional sodium bicarbonate to buffer lactic acid. Continuous training can cause mineral deficiency and sodium bicarbonate deficiency (electrolytes lost through sweat or urination) which can cause latent tissue acidosis, pain, edema, hyponatremia and death (15). The administration of alkaline sodium bicarbonate is a good treatment and it is commonly used in overcoming the problem of acidosis (49). Sodium bicarbonate increases hydroxyl ions or electron levels through increased alkalinity to cells that protect metabolic acids (15). Nanang et al. (2018) in his research revealed that giving pH 9 alkaline water could prevent fatigue due to high lactic acid and low pH after submaximal exercise. Sodium bicarbonate that is absorbed by the body immediately binds with pyruvate molecules to form oxaloacetate and malate, strong binding occurs by bicarbonate against hydrogen ions, so that it leads to functioning bicarbonate, and LDH enzyme does not work optimally (50).

Lactate level in the SBC group was lower because bicarbonate was a buffer against lactic acid. Biochemically the role of bicarbonate is a binding of H^+ ions in intracellular fluid and extracellular fluid to form carbonic acid (H_2CO_3) Furthermore, carbonic acid in the blood fluid will be brought to the respiratory system into H2 O and CO2. Water and carbon dioxide will then be excreted during the respiratory process. Bicarbonate will combine with pyruvic acid in muscle cells to form malate, then it will directly enter the Krebs's Cycle (50). The fatigue index of the SBC group was also lower because the level of lactic acid was also low due to the administration of sodium bicarbonate which was buffered against lactic acid.

CONCLUSION

There was a decrease in pH level, as well as an increase in lactic acid and fatigue index after anaerobic exercise. The administration of $NaHCO_3$ was able to prevent a decrease in pH and an excessive increase of lactic acid that led to a decrease in the fatigue index values. However, the dosage given should be considered for sodium bicarbonate has side effects such as headache, stomachache, and diarrhea.

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