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The Effects of Sodium Bicarbonate and Sodium Citrate on Blood pH, HCO3-, Lactate Metabolism and Time to Exhaustion

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ABSTRACT

The purpose of this study was to compare the effects of sodium bicarbonate and sodium citrate in increasing lactate concentration, blood pH, $HCO3^-$, and time to exhaustion. Increased time to exhaustion is an advantage since the athletes can do more anaerobic work. Exhaustion could be delayed by increasing $HCO3^-$ to catch H^+ produced by lactate metabolism to form H_2O and CO_2. The design of this research was randomized pretest posttest control group design. Thirty badminton student players were randomly selected and randomly assigned to three groups. The first group (the control group) was given placebo, NaCl .9 g/dl, the second group was given sodium bicarbonate 300 mg/kg in 500 ml aqua, and the third group was given sodium citrate 300 mg/kg in 500 ml aqua. Blood pH and bicarbonate ion ($HCO3^-$) were measured through Opti Medical Blood gas Analyzer. Lactate was measured by Cobas Roche lactate Analyzer. Data was analyzed using Manova with .05 significant level. Blood pH of the groups taking sodium bicarbonate and sodium citrate were higher significantly against control group ($p<.05$), and sodium bicarbonate group was significantly higher than the sodium citrate group ($p<.05$). Blood lactate tests showed that sodium bicarbonate group and sodium citrate group gave significant difference vs control group ($p<.05$), whereas sodium bicarbonate did not differ significantly against sodium citrate ($p>.05$). Sodium bicarbonate is better than sodium citrate, although both were better than control ($p<.05$). Sodium bicarbonate is better than sodium citrate in increasing blood pH and time to exhaustion. The disadvantage of using sodium bicarbonate is that it can cause gastrointestinal problem and headache, so it is not advisable to be used by athletes who have the symptoms.

Key words: *blood pH, blood lactate, [HCO3-], time to exhaustion*

Introduction

Physical training not only has a good impact on health status but also on sport performance. Badminton is very popular in Indonesia. It needs kind of anaerobic performance. As a favorite game that can get gold medals in international events, badminton players are expected to have a good anaerobic performance. Effective and efficient training is sometimes not good enough to get maximal performance so that trainers finally turn to ergogenic aids that are not prohibited by Olympic Regulations.

In sport performance, fatique is a prominent factor that needs attention since it limits the ability of muscles to perform well. The causes of fatique is quite complex; namely central and peripheral fatique, lack of oxygen in muscle, homeostatic imbalance, changes in body as well as room temperature, substrate depletion or metabolite accumulation (Brooks & Fahey, 1984). Lactic acid, a byproduct of energy producing metabolism, could act as fatique indicator, although it is not the only cause of muscular fatique, accumulation of H+ ion from ATP hydrolysis would also cause muscular fatigue .

In general, fatique is caused by two factors, intracellular acidosis and changes in excitation-contraction coupling process. Recovery of excitation coupling proces is heavily influenced by external pH, since the decrease in pH as a consequence of increase in lactic acid production in muscle disturbs excitation-contraction coupling process (Allen, Westerblad & Lannergren, 1995). This situation happens in short duration sport activity with high intensity. Accumulation of H+ ion from lactic acid is then evacuated through plasma in adjacent surrounding.

Among many attempts to reduce muscular fatique, the use of sodium bicarbonate as buffer system enforcer could be applied, known as bicarbonate loading. Sodium bicarbonate or NaHCO3 has the ability to inhibit pH increase. Bicarbonate ions react with H+ to produce bicarbonate acid or H2CO3, soon being decomposed into H2O and CO2. Sodium bicarbonate consumed results in acute increase of bicarbonate level [HCO3–] and blood pH, therefore increasing buffering capasity of the blood against pH decrease. Increased buffering capasity would change intracellular environment and increase blood efflux of lactic acid and H+ out of the cells. Sodium bicarbonate or sodium citrate would decrease H+ ion level and lactate in muscle and postpone the decrease of intracellular pH that has negative impact on glycolysis in muscle. Since sodium bicarbonate is found in the body in limited amount, consumption of sodium bicarbonate 90 minutes before high intensity activity is expected to increase the availability of buffer and increase time of exhaustion.

Besides sodium bicarbonate, sodium citrate proved to be

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effective in increasing blood pH and carbonic acid level (Oopik, Saaremets, Timpmann, Medijainen & Karelson, 2004). Costill, Verstappen, Kuipers, Janssen and Fink (1984) stated that by consuming sodium bicarbonate, acidity in muscle was reduced so that fatigue could also be reduced. Consumption of sodium citrate was able to increase plasma volume by increasing sodium ion level in serum, therefore suppresing aldosteron activity (Oopik et al., 2004).

Badminton is an anaerobic activity. It is done with high intensity, high speed and power. So, the energy (Adenosine Tri Phosphate) is supplied through anaerobic glycolisis with a lot of lactic acid as a byproduct (Bahri, Joseph, Sigit & Yusanti, 2009). Once the anaerobic threshold is achieved when blood lactic acid was 4 mMol/L, fatique began to show up. Athletes should be trained in accordance with predominant energy so that fatique could be postponed until later (Purba, 2002).

Methods

The design of this study was pretest posttest control group design. Thirty badminton student players were randomly selected and randomly assigned to three groups consisted of 10 people. Subject characteristics; all sample were male with the age mean=21 years old. During pretest, blood lactate, blood pH, [$HCO3^-$], and time to exhaustion were measured. Time to exhaustion was measured from anaerobic threshold to the time they stopped running because of exhaustion. During posttest, the first group which acted as the control group was given 500 ml aqua, the second group was given sodium bicarbonate 300 mg/kg in 500 ml aqua, 90 minutes before treadmill testing, the third group was given sodium citrate 300 mg/kg in 500 ml aqua, 90 minutes before treadmill testing. Posttest was conducted at least 3 days after pretest to ensure complete recovery of the sample. Blood pH and bicarbonate ion were measured through Opti Medical Blood gas Analyzer. Lactate was measured by Cobas Roche lactate Analyzer. Time to Exhaustion was measured from anaerobic threshold (respiratory exchange ratio=1) to termination of the test because of exhaustion. Appropriate statistics was applied.

This study was approved in advance by Institutional Review Board of Surabaya State University. Each participant voluntarily provided written informed consent before participating.

Results

Kolmogorof-Smirnov test of Normality; .112 for blood pH, .102 for [HCO3-], .144 for [blood lactate], and .200 for Time to Exhaustion, so the data was normal. Homogeinity test using Box's test of equality of Covariance Matrices showed p=.805 (p>.05). It meant that the sample was normal and homogenous, so that parametric statistics could be applied.

Table 1. Blood lactate cocentration following of ingestion of placebo, sodium bicarbonate, and sodium citrate

group	group	Sig.	Mean
K1	K2	0.000*	K1=6.640 mEq/L
	K3	0.000*	
K2	K1	0.000*	K2=10.630 mEq/L
	K3	0.568	
K3	K1	0.000*	K3=10.140 mEq/L
	K2	0.568	

Legend: *: signifikant at p<.05; K1: control group; K2: sodium bicarbonate group; K3: sodium citrate group

Sodium bicarbonate and sodium citrate gave significant difference vs control group in blood lactate concentration, but sodium bicarbonate did not differ significantly against sodium citrate on increasing blood lactate.

Table 2. Time to Exhaustion following ingestion of placebo, Sodium bicarbonate, and Sodium Citrate

Group	Group	Sig.	Mean
K1	K2	0.029*	K1=3.400 minutes
	K3	0.017*	
K2	K1	0.029*	K2=6.890 minutes
	K3	0.020*	
K3	K1	0.017*	K3=6.120 minutes
	K2	0.020*	

Legend: *: significant at p<0.05

Sodium bicarbonate showed significant difference against sodium citrate (p=.020) and control (p=.029), with the best Time to Exhaustion in sodium bicarbonate (6.890 min), although sodium citrate also showed significant difference against control (p=.017).

Table 3. Blood pH following ingestion of plscebo, Sodium Bicarbonate, and Sodium Citrate

Group	Group	Sig.	Mean
K1	K2	0.000*	K1=7.428
	K3	0.048*	
K2	K1	0.000*	K2=7.635
	K3	0.000*	
K3	K1	0.048*	K3=7.355
	K2	0.000*	

Legend: *: significant at p<0.05

Sodium bicarbonate gave the highest blood pH compared with sodium citrate (p=.000) and control (p=.000), eventhough sodium citrate also increased pH significantly against control group (p=.048).

Table 4. Blood bicarbonate concentration [$HCO3^-$] following ingestion of placebo, Sodium Bicarbonate, and Sodium Citrate

Group	Group	Sig.	Mean
K1	K2	0.045*	K1 = 24.310 mEq/L
	K3	0.009*	
K2	K1	0.045*	K2 = 27.980 mEq/L
	K3	0.008*	
K3	K1	0.009*	K3 = 22.870 mEq/L
	K2	0.008*	

Legend: *: significant at p<0.05

Sodium bicarbonate gave the highest buffering ability compared to sodium citrate (p=.008) and control (p=.045). Buffering ability of sodium citrate was also greater than control (p=.009)

Discussion

Requena, Zabala, Padial and Feriche (2005) stated that sodium bicarbonate and sodium citrate had ergogenic function because those supplements increased pH level, bicarbonate ion, and lactate concentration. Sodium bicarbonate and Na-citrate seem to be effective in activities with a sufficient duration to generate a difference in the hydrogen ion gradient, characterized by a very high intensity and involving large muscular groups. However, in activities of equally high intensity, but with longer duration, the results obtained have been conflicting and inconclusive.

McNaughton and Cedaro (1986) indicated that a dose of 0.5 g/kg body mass sodium citrate had no ergogenic benefit for exercise of either 10-s or 30-s duration, but exercise periods of 120 s and 240 s were significantly increased (p<.05) above the control and placebo conditions following sodium citrate ingestion. They suggested that a dose of 0.5 g.kg-1 body mass of sodium citrate could improve anaerobic exercise performance of 120-s and 240-s duration. Parry-Billing and MacLaren (2005) found in their study that pH increased significantly with sodium citrate supplement. Increased pH was possible with the role of sodium bicarbonate and sodium citrate as buffering agents that absorbed hydrogen ions and diverted into H2O and CO2 (McNaughton, Dalto, Tarr & Buck, 1997), so that pH did not fluctuate a lot.

Other benefit of using sodium bicarbonate and sodium citrate is that sodium could maintain body fluid, so it is favorable to the work of the heart (Zajac, Cholewa, Poprzecki, Waśkiewicz & Langfort, 2009). Graydon, Marsh, Kowalchuk and Thompson (2004) stated that metabolic effect caused by alkalosis related to the ability of NaHCO3 to maintain optimal pH would delay the onset of intracellular acidification during exercise with high intensity. Graydon et al. (2004) stated further that the induced alkalosis triggers an increase in glycolysis that eventually increase training capacity, proven by increased lactate level.

Billat, Bernard, Pinoteau, Petit and Koralsztein (1993) found that one factor related to time to exhaustion was increased blood lactate. In this study, sodium bicarbonate loading also significantly increased time to exhaustion by 3.49 minutes which meant that bicarbonate loading could increase anaerobic endurance, although the effect of sodium bicarbonate loading was not significantly different from sodium citrate loading. In other study, Hartono, Wiriawan and Ashadi (2014) found that supplement sodium bicarbonate and sodium citrate 21 g/500 ml aqua given 60 minutes before treadmill testing in badminton student players did not give any significant difference in time to exhaustion between sodium bicarbonate loading and sodium citrate loading, and control (p>.05), but blood lactate level was significantly higher in sodium bicarbonate and sodium citrate loading compared with control (p<.05). It could be concluded from this study that time for sodium bicarbonate or sodium citrate to go to extracellular level optimally is 90 minutes, and increased blood lactate was not linked with sport performance. Other possible cause was that the physical condition of the sample during treadmill test was not optimal. Zabala et al. (2011) studied the effects of sodium bicarbonate on performance of elite BMX cyclist and concluded that the induced alkalosis did not improve the Wingate test performance, Ratings of Perceived Exertion (RPE) and performance across three consecutive Wingate tests in elite BMX cyclists although the sodium bicarbonate modified acid-base balance significantly.

McNaughton, Curtin, Goodman, Perry, Turner and Showell (1991) studied the effects of sodium bicarbonate on 60 second of an anaerobic work and power output of cyclists on cycle ergometer. The results of this study suggest that sodium bicarbonate is an effective ergogenic aid when used for typically anaerobic exercise as used in this experiment, and this ergogenic property is probably due to the accelerated efflux of H+ ions from the muscle tissue due to increased extracellular bicarbonate buffering. McNaughton et al. (1997), and Parry-Billing and Maclaren (1986) stated that the use of sodium citrate is a better choice than sodium bicarbonate in that sodium citrate did not give any bad effects to gastrointestinal system as sodium bicarbonate loading. The side effects to gastrointestinal system could be headache, stomachache, and diarrhea

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