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Sodium Bicarbonate Supplementation and Its Effect on Fatigue in a Maximal Bout of Exercise

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SODIUM BICARBONATE SUPPLEMENTATION AND ITS EFFECT ON FATIGUE IN A MAXIMAL BOUT OF EXERCISE

A Masters Thesis

Presented to

The Graduate College of

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Health Promotion and Wellness Management

By

Anthony J. Ramos

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SODIUM BICARBONATE SUPPLEMENTATION AND ITS EFFECT ON FATIGUE IN A MAXIMAL BOUT OF EXERCISE

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Anthony J. Ramos

ABSTRACT

The purpose of this study was to determine or assess if sodium bicarbonate ($NaHCO_3$) supplementation is a plausible method of delaying fatigue in a maximal effort bout of exercise. Fourteen, college aged, cardiovascular trained males participated in the study (Age- 21.38 ± 1.50y, Height- 180.46 ± 10.12cm, Weight- 79.15 ± 9.28kg). Sodium bicarbonate was compared with sodium chloride and a baseline. Following the initial meeting and tolerance test, participants completed 3 exercise trials which consisted of Day 1: Initial meeting & tolerance testing and Days 2, 3, and 4: Exercise Test Sessions 1-3. Data being collected was run time, RPE, pre exercise blood lactate, and post exercise blood lactate. The exercise test consisted of a maximal treadmill run test at 8 mph and 15% grade incline. The supplement was ingested 1.5 hours prior to the run. An analysis of variance test showed no significant different in run times, RPE, or pre exercise blood lactate. However, the study did find significant differences in post exercise blood lactate between sodium bicarbonate and sodium chloride, and sodium bicarbonate and the control. The study refutes sodium bicarbonate as an effective as ergogenic aid for this specific exercise domain.

KEYWORDS: sodium bicarbonate, blood lactate, lactic acid, maximal treadmill test, rating of perceived exertion

This abstract is approved as to form and content

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INTRODUCTION

Overview

In today's sports world, quality of performance is important for all levels of physical activity. Examples such as a soccer player being able to sustain a full 90 minutes of play or a hockey player performing at their best for an entire line shift, are limited by the ability of the individual to delay or resist fatigue while performing a sport specific skill. Muscular fatigue is a phenomenon that results in a decline of force generating capacity due to increases in lactic acid (Bird 399, Lavender 42). Lactic acid is a metabolic by-product that increases the intracellular acidity in muscles (Horsewill 567, McNaughton 100). When oxygen levels are normal in the body, carbohydrate breaks down into water and carbon dioxide. When oxygen levels are lower than the demand in the body, carbohydrate breaks down to be utilized as energy and makes lactic acid. With rising acid levels, muscle pH decreases, which then decreases the Ca^{2+} release in the muscles (Brooks 1, Mueller 1). Therefore, any mechanism that would increase muscle pH (i.e. decrease acidity) should delay fatigue or improve performance (Allen 287). The following study will examine the effects of buffering (increasing) muscle pH prior to maximal exercise with a sodium bicarbonate supplement.

Research Question

Does sodium bicarbonate buffering improve performance and delay the onset of muscular fatigue?

Hypotheses

Hypotheses for this study are as follows: Ingesting $NaHCO_3$ solution will delay fatigue in a maximal bout of exercise (Directional), ingesting $NaHCO_3$ solution will not delay fatigue in a maximal bout of exercise (Non-Directional), and ingesting $NaHCO_3$ will not have an association with fatigue in a maximal bout of exercise (Null).

Delimitations

This study's main focus was to explore the delay in fatigue in a maximal bout of exercise. Delimitations in this study began with the participants.

-Inclusion criteria for the participants were as follows:

-Male

-College aged (18-25y)

-Cardiovascular trained - Runs a minimum of 30 minutes at moderate-vigorous intensity, at least 3 days a week, for the past 6 months

-The controllable aspects of supplementation were (McNaughton 101): Baking soda ($NaHCO_3$) was used as the experiment treatment, Sodium Chloride (NaCl) was used as the placebo, and Crystal Light mixed with water was used as the control. The type of test was a maximal effort sprint on a treadmill for duration. The duration of testing was 2 weeks long:

-Day 1 involved an introduction to the study, demographics data collection, signing of informed consent, and $NaHCO_3$ tolerance test.

-Days 2, 3, and 4 were a randomized testing days (baseline, experiment, control).

-All testing days were separated by at least a minimum of 48 hours of rest, and no more than 72 hours.

Limitations

-Time commitment for research and participant(s).

-Participants had control of diet and activity outside of study.

-Participants had control of their physical performance during the study.

-Participants may have decreased in effort given throughout study.

-Participants recruited may have not accurately represented desired population of study.

-Participants may have falsified level of fitness prior to study.

-Availability of facility.

Assumptions

-Participants will keep a consistent diet and activity level throughout testing.

-A maximal treadmill sprint is an acceptable method of fatiguing muscles.

-Strenuous exercise is a valid method to raise acid levels in muscles.

-Participants will comply with researchers and complete study to its entirety, to the best of their ability.

-Participants will represent the desired population.

-The researchers will complete proper training and instruction.

-Every trial will be properly managed and monitored by a trained professional.

Key Variables

Independent: Sodium Bicarbonate, Sodium Chloride, and Baseline trials

Dependent: duration of sprint, blood lactate levels, RPE

Definitions

Glucose – $C_6H_{12}O_6$; sugar

Adenosine Triphosphate (ATP) – a high-energy molecule stored in cytoplasm and nucleoplasm of every cell, and used for anything that requires energy for operation.

Glycolysis – the first stage in cellular respiration, constituting most of the catabolism of carbohydrate.

Pyruvic acid - $C_3H_4O_3$; intermediate compound in the metabolism of carbohydrates, fats, and proteins.

Acetyl CoA – molecule used to convey carbon atoms from acetyl group to Kreb's cycle to be oxidized for energy production.

Hypoxia – state in which the body or a specific region is deprived of oxygen.

Body Weight – Body weight is significant in this study because it pertains to the individualization of the amount of $NaHCO_3$ a participant receives.

pH Scale – pH Scale is a standard set to determine the acidity or basicity of a substance. The scale ranges from zero (0) to fourteen (14); Water has a pH very close to seven, and moving down the scale means more acidic, moving up the scale means more basic.

Serum – Serum is a substance in blood that contains electrolytes, antibodies, antigens, hormones, any outside substances, and proteins that aren't used for blood clotting.

Alkalosis – serum pH is higher than normal (7.45 and higher).

Maximal Treadmill Exercise Test – This exercise test has a wide variety of forms, but is designed to bring a participant to volitional fatigue.

Bicarbonate – Naturally occurring substance in the body produced by the kidneys to eliminate hydrogen and acidity in the blood.

Bicarbonate Buffering system – used to maintain the pH of blood.

Sodium Bicarbonate ($NaHCO_3$) – baking soda

Blood Lactate – Through the Glycolytic energy system, the end product of glycolysis is pyruvic acid, which then is either pushed through the Kreb's cycle or turned into lactic acid ($C_3H_6O_3$). Lactic acid can then accumulate causing muscular fatigue. Lactic acid is produced when it releases its hydrogen ions and combines with sodium or potassium; leaving an end result of lactate. Resting lactate levels typically range from 0.8-1.5 mmol/L.

Sodium Chloride (NaCl) – Sodium chloride is commonly known as table salt. Sodium chloride will be used in this study as the placebo in order to mimic the saltiness of the $NaHCO_3$ solution.

Crystal Light – Powdered mix will be used to give the $NaHCO_3$ and the NaCl solutions flavor. Crystal Light was chosen because of the absence of sodium keeping the integrity of the sodium in both solutions and will serve as the control.

Significance of Study

One of the greatest limiting factors to athletic or sport performance is fatigue. Muscular fatigue, whether it is minute or maximal, is directly related to decreasing performance capacity. Reducing muscular fatigue can be a benefit to any individual presented with a task that requires a physical demand. The less muscular fatigue an individual encounters, the better they may be able to perform in terms of intensity and duration (Bird 401, Duncan 358, Mueller 10). Understanding methods to prevent or slow down the onset of fatigue can be advantageous for athletes at all levels (Seip 81). This study is focused on investigating whether $NaHCO_3$ is a plausible method delaying the onset of fatigue, therefore increasing performance.

LITERATURE REVIEW

Energy

In humans, glucose is a primary source of energy utilized by most cells. Glycolysis (glycol – sugar; lysis – breaking), by definition, is the metabolic pathway that converts glucose ($C_6H_{12}O_6$) into pyruvate ($C_3H_4O_3$) and in the process releases/provides energy. A limiting factor in the end result of glycolysis is whether sufficient oxygen is present to utilize oxidative metabolism; this will impact both the yield of adenosine triphosphate (ATP) and how quickly ATP will be utilized (Zoladz 897).

There are three energy systems used to produce ATP; Phosphocreatine (PC), Glycolytic, and Oxidative. The utilization of each of these three systems is determined by duration and intensity of work/exercise (Lindh 519). The ATP-PC is primarily utilized during short duration and high intensity bouts of work/exercise. ATP stores are used for energy for a few seconds at maximal intensity, and the phosphocreatine is utilized as a support for about 10 seconds afterwards as ATP declines and an individual begins to shift into the Glycolytic energy system.

As more energy is required to sustain a task, the glycolytic, medium duration and medium intensity, takes over. Glycolytic energy system can be used in both a “fast” or “slow” capacity. When oxygen is present, glycolysis is “slow” to accumulate lactate. When oxygen is removed, glycolysis is more rapid (Brooks 791). The level of exertion is the limiting factor on whether the individual will be subject to fast or slow glycolysis. As the ATP-PC system fatigues, lactic acid begins to accumulate resulting in a loss of power and an increase in muscular fatigue. Fast glycolysis will generate more power, but the byproduct of pyruvic acid converts into lactic acid, which results in the onset of muscular fatigue (Seip 82, Shelton 1). In contrast, during slow glycolysis, the intensity or “power” level is a lower demand, allowing the pyruvic acid to be converted into Acetyl CoA, which can then enter the Kreb’s Cycle, resulting in more ATP to be produced and avoiding a greater fatigue (McNaughton 100, Seip 83). Around 60 seconds and further, the high duration and low intensity oxidative energy system is the main source of energy.

Cellular respiration is a progression happening within cells that releases metabolic energy stored in glucose molecules. Aerobic Respiration has three main stages (Aerobic Glycolysis, Krebs Cycle, Electron Transport Chain). By consuming oxygen in this form of cellular respiration, the end result of glucose metabolism is carbon dioxide, water, and 38 ATP (energy) molecules (Lindh 520, Zoladz 900).

Temperature is also crucial to energy production and optimal performance in humans. The normal or ideal *in vivo* temperature ranges are 36-40ºC (Kelso 1). When the values stray outside of those ranges, cellular activity becomes impaired (Kelso 1). Heat is produced by muscles contracting and as a by-product of cellular metabolism, both are elements of exercise.

Carbonate and pH

The standard reference for the level of hydrogen in an aqueous solution is pH or “power of Hydrogen”. The pH scale goes from zero (0) to fourteen (14) with seven (7) being stable/neutral. The closer it gets to 14, the more alkaline or basic the pH. The closer it gets to 0 is the more acidic the pH. When carbon dioxide is dissolved into water, carbonic acid (H_2CO_3) is formed. Carbonic acid is an acid that has an important duty with maintaining our body's pH. In humans, normal blood pH is between 7.35 and 7.45, making it slightly alkaline.

During exercise, acid levels begin to rise in skeletal muscles resulting in a decreased absorption of proteins, minerals, and other nutrients; thus leading to a larger inefficiency with performance (Mueller 10). Therefore, a more acidic environment is created when we perform at elevated levels. Furthermore, increased acidity can be damaging and harmful to our bodies. It is believed that buffering the body's pH with an alkaline substance can minimize pH changes, and in return, change the overall effect of performance.

Specific Studies

Sodium Bicarbonate.

Sodium bicarbonate ($NaHCO_3$) typically consumed mostly in two circumstances: First, it can be used to treat metabolic acidosis and can be used to improve athletic performance (Wahl 2013). Second, in treating metabolic acidosis, there is a continued fall in bicarbonate levels in the body thus causing a lower pH. Sodium bicarbonate is the agent most commonly prescribed for in treating the deficit. In theory, when used for athletic performance, promoting alkalosis in the body will promote a longer process to reach an acidic state (Yunoki 540). Thus, promoting a delayed fatigue. Previous research suggests consuming $NaHCO_3$ 1.5 hours prior to exercise will give the best results in terms of buffering (Sobrero 130). An optimal dosage is reported as 0.3g/kg; with anything over 0.3g/kg having reports of negative side effects (Duncan 359, Hultmen 1, Jourkesh 403, Pasman 225, Maughn 1, Seip 82, Snyder 27, Sobrero 130, White 83).

Side Effects.

Unfavorable side effects have been reported with $NaHCO_3$ supplementation with the most common being gastrointestinal (upset stomach, gas, bloating, diarrhea, etc.). Also, frequent use could possibly lead to cardiac arrhythmias, apathy, irritability, and muscle spasms. In very rare instances, gastrointestinal ruptures have also been reported (Duncan 358, Hultmen 1, Pasman 226, Snyder 27).

Exercise.

Previous research has studied a large range of modalities while testing $NaHCO_3$ supplementation. Understanding it's effects under different exercise protocols is important to understanding how and why $NaHCO_3$ will benefit performance, if there were to be benefits.

When exploring the effects of $NaHCO_3$ in long duration endurance exercise, researchers sought out to determine whether $NaHCO_3$ has a positive effect on total work output. A double blind study, which involved twelve trained athletes running a 1500-meter run, consumed 0.3g/kg of $NaHCO_3$ (Bird 399). The results indicated that $NaHCO_3$ buffering does have an ergogenic effect on runs lasting 1500 meters (Bird 403). Another long duration method explored was long distance swimming. A group of eight swim-trained participants ingested 0.3g/kg of $NaHCO_3$ prior to testing. The exercise test was a 1000-meter swim and data collection was duration of the swim. Results showed statistically significant changes in swim speed suggesting $NaHCO_3$ as an effective buffer to improve swim performance (Mueller 1).

Studies containing a higher intensity and shorter duration mode of exercise were also explored to examine the effects of $NaHCO_3$ in such environments. In studies containing sprint methods of exercise (swimming and cycling) 0.3g/kg of $NaHCO_3$ was ingested 1.5 hours prior to testing. In a study involving eight trained cyclists performing high intensity cycling until failure, time to exhaustion increased by 23.5% with $NaHCO_3$ supplementation (Stevens 616). Similar results were found with sprint swim performance in regards to $NaHCO_3$ buffering (Horsewill 569).

Researchers have also examined the effects of $NaHCO_3$ on anaerobic methods of exercise, specifically bench press and back squat (Duncan 358). In a double blind, randomized design, eight resistance-trained men performed the movements until failure at 80% of 1-repetition max. The results of this study suggest that $NaHCO_3$ can enhance resistance-training performance using the repetition to failure protocol (Duncan 361).

Previous research suggests short to medium duration, medium to high intensity, endurance type exercise produces the best results in regard to the $NaHCO_3$ being useful (Bird 403, Duncan 366, Hultmen 1, McNaughton 1, Jourkesh 413, Pasman 230, Maughn 1, Stevens 621).

Lactate Measuring.

Towards the end of glycolysis, the Nicotinamide Adenine Dinucleotide (NAD) and Hydrogen (H^+), creating $NADH^+$, and the pyruvate ($C_3H_4O_3$) molecules are the important factors in lactate production. $NADH^+$ molecules shuttle H^+ to the inner membrane of the mitochondria of the cell. During strenuous exercise, however, the pyruvate molecules shuttle directly into the mitochondria. The energy demand is higher than what is currently available during strenuous exercise. This manifestation causes a slight back up in the electron transport chain, which then causes $NADH+H^+$ to contribute a hydrogen molecule to pyruvate. With this happening, the pyruvate converts to lactate. The body is constantly producing lactate, not only at specifics times (Hultmen 1)

Lactate is the end result of NADH+H+ releasing hydrogen ions, which in turn combine with sodium or potassium (McNaughton 101). With the neutral pH maintained in the body, most lactic acid found in the body will be present in the form of lactate. In the "non-exercising" individuals, the lack of oxygen can be the cause of many health problems in terms of a more acidic cellular environment, or acidosis. There is metabolic (kidneys) and respiratory (lungs) acidosis, both in which refer to the inability to keep pH in balance. Symptoms of acidosis can vary from rapid breathing to even death. In contrast, "exercising" individuals will be subject to a more acidic environment, however it is to be expected that levels will rise shortly after, causing less concern of health risk. Resting lactate measurements typically are within the range of 0.5-2.2 mmol/L (Horsewill 567, Sherman 9, Zoladz 899). Irregular or high amounts in a non-exercising individual means that tissues are not being delivered enough oxygen (Roth 1).

Lactate is one predictor for fatigue, and as a limiting factor it can vary greatly from person to person (Roth 1). Lactate threshold is an effort level an individual can reach and continue performing without slowing down. Lactate threshold (LT) is determined by the onset of blood lactate buildup. Lactate threshold can be influenced by two factors; Respiratory Exchange Ratio (RER) and economy. VO_2max, is the volume of oxygen a person can utilize in one minute of maximal physical exertion. By running an exercise test, a value you will discover is the RER, which is the ratio between how much CO_2 is produced with how much O_2 is consumed. The point when CO_2 production exceeds O_2 utilization is the anaerobic threshold. In numerical terms, Lactate threshold is reached as soon as RER reaches 1.0. Economy of exercise refers to the level of efficiency the individual can perform the given movement. A lactate threshold varies from person to person, as it increases with mode of training. Athletes who train regularly under short duration and high intensity environments will attain a higher lactate threshold for exercise in similar conditions, likewise for athletes whose training modes and settings differ. Lactate threshold may also regress as well with the absence of exercise.

Oxygen utilization changes a muscle chemically and uses pyruvate for aerobic energy, which in turn is not needed for lactate production in anaerobic conditions. With more oxygen utilization, oxygen delivery becomes more efficient. With this, total pyruvate production decreases which leads to anaerobic capacity decreasing.

A high lactate threshold in an individual should be desired for the fact that they can sustain a given task at a higher intensity; however, lactate clearance is the body's ability to remove the lactate being produced and transport it to other tissues (muscles, cells, etc.) that can utilize lactate as a fuel source. With a greater ability to clear lactate, the rate of accumulation will be lower which will result a lower circulating blood lactate and intramuscular lactate levels (McNaughton 100). The high ability for lactate clearance aids in recovery from strenuous activity (McNaughton 100).

One of the most common methods for collecting and measuring blood lactate is via a finger stick. Collecting and analyzing whole blood prior to exercise, during, and within 5 minutes post exercise can best determine the increase of lactate in the blood for the time the muscles were under stress (Davidson 2, Horsewill 568). A common purpose of testing blood lactate is to pinpoint a concentration, and quickly report the measurement to the athlete to determine if the training intensity is where it needs to be (Siegler 2551).

Previous research suggests that lactate analyzers can reliably measure lactate within a single trial and a day-to-day basis (Bishop 1, Davidson 2, Zoladz 904).

Considerations for Study Design based on Literature:

Type of Test.

This project used a maximal treadmill test. This was chosen because speed and incline could be adjusted to more accurately and efficiently induce muscular fatigue in participants.

Experiment vs. Control.

Sodium bicarbonate was the experiment condition, NaCl was the placebo and Crystal Light® was the control. The placebo was chosen to simulate the saltiness of $NaHCO_3$, whilst not giving any type of ergogenic effect if a psychological factor came into play while ingesting a supplement.

Dosage.

Previous research suggests ingesting 0.3g of $NaHCO_3$ per kg of body weight, 1.5 hours prior to exercise would properly induce alkalosis, buffer blood bicarbonate and is optimal for performance benefits (Duncan 358, Hultman 1, Jourkesh 405, Pasman 227, Maughn 1, Roth 23, Snyder 30, Sobrero 130, White 90). Dosage for NaCl supplementation has been suggested as 8.0 g not dependent on subject's body weight (Price 978).

Blood Lactate.

Lactate levels decrease rapidly following exercise. Lactate measurements were performed pre-exercise and immediately post to ensure proper observation of lactate shuttling capacities and metabolic stress encountered from the given exercise (6, 35).

METHODS

Participants

Nineteen participants were recruited and were cardiovascular trained, college-aged males, with no history of cardiovascular, pulmonary or orthopedic complications during exercise. Participants of the Missouri State University campus community were recruited by email, by word of mouth in Foster Recreation center, and by instructors in the Department of Kinesiology. Participants were on a cardiovascular training program for the past six months, lasting at least 30 minutes of moderate-vigorous intensity, at least three days a week. Fourteen of the original nineteen completed the study to its entirety.

Sampling

Sampling was performed on a non-probability, volunteer basis on the Missouri State University campus and surrounding areas. We looked for delimitations listed in Chapter 1 to ensure proper participants are attained.

Methods

Once participants were recruited, the first meeting was located in the Exercise Physiology lab (Rm. 121) in McDonald Arena located on Missouri State University campus. A sample testing schedule is shown in Figure 1.

Day 1 – Pretest:

Participants were informed of risks and procedures as detailed in an informed consent form (This project is in accordance with the federal government regulations 45

CFR 46 Federal Policy for the protection of Human subjects. Prior approval for this project was obtained from the Missouri State University Institutional Review Board on (November 12, 2014: IRB approval #15-0194). The participants were given a full description of what the exercise test is, how long the study will be, when to consume the experiment or control drink, and when and where they will need to be and on what days. In addition, anthropometric data were also recorded: height (cm), weight (kg), and age (y). The amount of $NaHCO_3$ given was based on the individual's body weight (0.3g/kg body weight, references). A $NaHCO_3$ tolerance test was given to ensure the individual did not experience any adverse or undesirable effects. If the individual felt that they could not perform a maximal sprint due to the effects of the $NaHCO_3$, the individual would be dropped from the study as a participant.

Days 2, 3, and 4 – Exercise Tests #1, #2, #3

A minimum of 48 hours and no longer than 72 hours rest period was applied between testing days. Three trials were used for data collection – baseline, experiment, and control, and all three were randomized using by a random drawing. All trials were held at the same time of days to ensure consistency. Participants asked to refrain from participating aerobic exercise for 24 hours prior to testing; otherwise participants were allowed to partake in aerobic exercise outside of testing. Prior to testing, participants were also asked to restrict consumption of food and drink besides water, medicine besides prescribed and tobacco.

The supplementation of $NaHCO_3$ was baking soda. Participants ingested 0.3g/kg body weight for the $NaHCO_3$ trial. For the placebo trial, participants ingested a NaCl solution. Participants ingested 8.0g of NaCl. The two supplements were given to ingest

1.5 hours prior to the treadmill test. Each solution was mixed with one packet of Crystal Light flavor mix in one 500mL water bottle. Participants were allowed to drink water after consumption.

For each protocol, pre-workout whole blood samples were taken to establish baseline values. Blood samples were taken by finger stick, similar to testing blood glucose, which requires a relatively small amount of blood each time (~0.5mL). The area was first cleaned by an alcohol swab, allowed to air dry and then a manual finger stick was performed with a lancet. The first drop of blood was wiped away using a clean gauze pad and the next 1-3 drops of blood were collected on an analytical test strip. Lastly, another clean gauze pad was placed on the site with slight pressure until the bleeding stops. After completion of the exercise sessions, blood samples were taken immediately post-exercise. Techniques to limit biohazard exposure included: utilizing rubber gloves, eye protection and lab coats; properly disposing of lancets in a sealed sharps container; and properly disposing of any other items that come into contact with blood.

For each exercise trial, participants completed a 5-10 minute walking or jogging warm up on the treadmill prior to completing the test. The maximal test entailed a fast paced sprint on a treadmill at eight (8) miles per hour (12.87 kilometers per hour) and a 15% grade incline.

Rating of Perceived Exertion (RPE) was taken after the sprint was completed during the cool down. Cool down was a light walk for 3-5 minutes.

Days 2, 3, and 4 all consisted of the same protocol, with the only difference being the substance consumed:

Exercise Trials

- Participant arrived in Exercise Physiology lab (MCDA 121) 1.5 hours prior to exercise testing
- Participant consumed one of the following randomly assigned solutions: Sodium chloride (0.8g), $NaHCO_3$ (0.3g/kg), and plain Crystal Light (baseline).
- Participant(s) came back 1.5 hours post consumption
- Finger stick sample was taken at rest
- Participant warmed up.
- Participant performed exercise test
- Duration was taken using a stop watch
- Finger stick sample was taken immediately post test
- Participant cooled down
- RPE of total maximal sprint was taken
- Participants were asked about comments from the trial

Analysis

Descriptive statistics was performed on height, weight, and age. A one-way Analysis of Variance (ANOVA) with LSD post-hoc analysis was used to determine differences in blood lactate, total sprint RPE and duration of sprint. Alpha level for significance was set at $p < .05$. All data and information regarding performance was withheld from the participants until the study was completed.

RESULTS

Nineteen cardiovascular trained college aged males from Missouri State University student body were recruited and volunteered to participate in this study. Two participants dropped due to unfavorable side effects during the tolerance test, two participants dropped due to scheduling complications, and one participant dropped due to level of difficulty of exercise protocol. Fourteen participants (Age – 21.38 ± 1.50y, Height – 180.46 ± 10.12cm, Weight – 79.15 ± 9.28kg) finished the study. There were no significant differences in run time to failure for any of the conditions (Run Time: $NaHCO_3$ – 68.46 ± 14.24 seconds, NaCl – 66.97 ± 14.23 seconds, control – 67.94 ± 15.01 seconds). There were also no significant differences in RPE for any of the conditions (RPE: $NaHCO_3$ – 15.23 ± 1.96, NaCl – 15.69 ± 1.79, control – 15.46 ± 1.66). There were no significant differences in lactate levels prior to testing ($NaHCO_3$ – 1.63 ± 0.99 mmol/L, NaCl – 1.83 ± 1.01 mmol/L, control – 1.79 ± 0.94 mmol/L). While there were no differences in post exercise lactate levels NaCl and the control; there were significant differences ($p < 0.05$) with post exercise lactate levels between the $NaHCO_3$ and NaCl, and the $NaHCO_3$ and the control. ($NaHCO_3$ – 13.67 ± 1.87 mmol/L, NaCl – 11.64 ± 1.86 mmol/L, control – 12.05 ± 1.71 mmol/L).

Participants gave comments referring to; Supplement having terrible taste, what they thought the supplement was, their time in relation to another trial, how they felt during and after in relation to another trial. All data and information regarding performance was withheld from the participants until the study was completed.

DISCUSSION

This study has demonstrated that ingestion of $NaHCO_3$ does not have an effect on time to failure or RPE during a maximal treadmill sprint. The results of the current study did confirm that blood pH was lower when $NaHCO_3$ was ingested, although did not have an effect on lactic acid or the onset of fatigue. In previous studies in which induced alkalosis did succeed in delaying fatigue, shorter bouts of high intensity exercise were generally used (Hultmen 1, McNaughton 99, Jourkesh 405, Pasman 230, Maughn 1, White 93). It is thought that in this specific study, the speed and elevation was not set difficult enough to fatigue participants fast enough. If this study were to increase the level of intensity, the shorter duration may have yielded results favoring the $NaHCO_3$ due to the faster rate of declining muscular force. Therefore, the longer duration and relatively lower intensity of running in the current study may explain while $NaHCO_3$ did not yield the same positive results. As lactic acid begins to accumulate with medium to high intensity the ATP-PC system switches over to fast glycolysis.

Another difference in previous studies is the mode of exercise. Previous research utilized types of exercise such as cycling, swimming, track running, wrestling, and weightlifting. While the mode of exercise isn't likely a large factor of why the $NaHCO_3$ did not delay fatigue in this specific study, it does vary from other studies in which it did. When an athlete is considering $NaHCO_3$ supplementation for performance, it is probable that the individual is considering it for in-play situations. Without risking performance for a game or event that may matter, most studies are testing the experiment during the training period with hopes of a positive effect to transfer over to game play. The difference between game play and training for supplementation could alter the outcome based on the individual's state of mind.

Potential Limitations

There were some potential limitations to the current study design that may have limited the effectiveness of $NaHCO_3$ prior to running. The sample size of fourteen may have not been large enough. It is also possible that the test population may not represent the desired population accurately, meaning using specific athletes for specific athletic events could result in an outcome that the specific athlete could utilize. A larger sample size may have added to the results in favor of the $NaHCO_3$. Heart rate and blood pressure were not recorded during the study. These two variables could have provided a more sound reading on how hard the individual was working during each trial as opposed to RPE alone.

Diet and activity was not directly controlled and diet could have affected the results largely by a few different ways. The participant may have had an inconsistent diet, the participant may have eaten or drank something within the 1.5 hour buffering period pre-exercise, and/or the participant may have had a large amount of sodium ingested which can act as added sodium to the experiment. When testing to understand the effect of $NaHCO_3$, it is important to focus solely on the $NaHCO_3$ and what it is doing to performance. Diet itself can be a performance enhancer so we must emphasize consistency in order to minimize the compromise of the $NaHCO_3$ effects. Also, a major factor pertaining to diet may be the macronutrient content the individual consumes the day's prior and day of testing. If the individual is carbohydrate depleted, different energy systems will be used to complete the task. Without consistency across the board of participants, reasoning for results could lie with diet.

Activity level outside of the trials was also in control of the participant. The participant could have fatigued themselves prior to the running trials, and therefore their performance would have been negatively impacted. The specific settings for speed and treadmill grade may have had an effect. The specific speed and grade was chosen based on previous research and trial and error. Once all the participants were able to complete a trial, it was thought that the protocol may not have been difficult enough.

The side effects from $NaHCO_3$ ingestion may have had an impact on results as well. It is known from previous literature, and from participants in this study, that there is gastrointestinal distress when consuming $NaHCO_3$. The GI distress may have been different from person to person and could have been more tolerable to some while running at a maximal effort.

It is also possible that there may have been a psychological factor in this study. It was noted in the comments after each trial, that a few participants knew which supplement they were taking based on taste. Due to the tolerance test given on Day 1, participants may have known when they were consuming the $NaHCO_3$. If an individual takes something that is supposed to make them better, they might try a little harder. In this case, there were no significant differences that claim $NaHCO_3$ as effective. However, participants may have mistaken the NaCl, the placebo, for the $NaHCO_3$ due to its salty taste. This may be grounds for why the NaCl results were higher than expected, but not significantly different.

As lactate being a focus of the study, lactate threshold from person to person must be recognized as a possible reason for ineffective outcomes. One participant may have specific training compared with another participant that yields a higher lactate threshold. Lactate threshold depends on type of athlete. This study recruited all possible volunteers that met the requirements, when previous studies recruited teams with similar attributes from athlete to athlete.

Conclusion

Sodium bicarbonate, by previous literature, seems to have a possible ergogenic quality for short term, high intensity events. As for events lasting long enough to exit the anaerobic stage of cellular metabolism, where most lactic acid is formed, results aren't as likely. Based on this specific protocol, these results suggest there were no significant differences in the information that would be most practical for an athlete to utilize; however, it was found that buffering with an alkaline substance such as $NaHCO_3$ can alter lactate levels.

Directions for Future Research

Future research needs to consider a change of study design. Possible changes include:

1. Exercise protocol to determine if certain amounts of $NaHCO_3$ have an effect on maximal efforts on different percent grades and speeds, and a study with a larger sample size is needed.
2. A monitored diet and activity for each individual throughout study is recommended.
3. A study design similar to this also needed to be expanded along a longer timeline.

4. Finally, a study in which the comparison is a proven ergogenic aid would be sensible. By both substances being considered as ergogenic, despite the fact that there was no difference within this study, researchers can understand how much of an ergogenic effect $NaHCO_3$ has as compared to something that is already proven to boost an athlete in a certain direction.

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APPENDICES

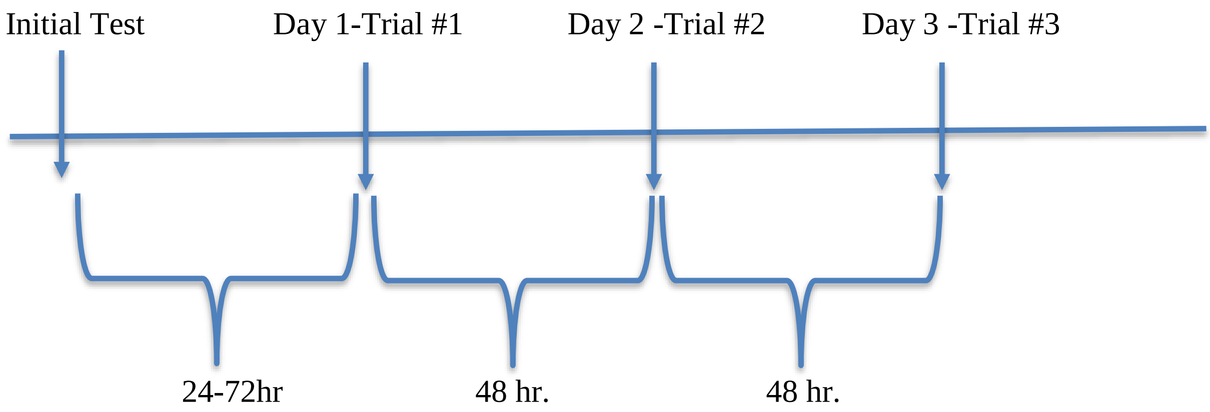

Figure 1 – Timeline of Events