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THE EFFECT OF NASAL IRRIGATION ON TOTAL EXERCISE TIME, HEART RATE, AND BLOOD LACTATE DURING GRADED EXERCISE IN HEALTHY INDIVIDUALS

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ABSTRACT

Oral consumption of sodium bicarbonate is a popular yet uncomfortable ergogenic aid as gastrointestinal distress is commonly encountered with its usage. Nasal irrigation is the process of rinsing out one's nasal passageway with an isotonic saline solution consisting of sodium chloride and sodium bicarbonate. Therefore, the purpose of this study was to examine nasal irrigation as a possible sodium bicarbonate ergogenic aid and observe its effect on exercise performance. Twenty active male subjects performed two treadmill graded exercise tests without and with nasal irrigation. Heart rate, blood pressure, blood lactate, and ratings of perceived exertion were measured at rest, during the graded exercise test, and after a five minute passive recovery period. Total exercise time was also evaluated. Heart rate was significantly lower with nasal irrigation than without it during the first two minutes of the warm-up stage ($P<0.05$) and trended towards significance ($P<0.10$) during the first two minutes of stage one of the exercise test. Mean arterial blood pressure was significantly lower following the passive recovery period with nasal irrigation when compared to without it ($P<0.05$). Finally, total exercise time increased by ~1% from 16.99 ± 0.68 minutes without nasal irrigation to 17.19 ± 0.64 minutes with it. These results indicate that nasal irrigation prior to an acute bout of exercise may improve total exercise time and could potentially boost the post-exercise recovery period. It appears that nasal irrigation may be a safe alternative to the oral ingestion of sodium bicarbonate prior to exercise.

Keywords: sodium bicarbonate; exercise; nasal irrigation; ergogenic aid; heart rate

INTRODUCTION

Ergogenic aids are any external influences that can enhance exercise performance. One such popular and highly researched ergogenic aid is sodium bicarbonate. Across the literature, ingestion of sodium bicarbonate has been shown to improve performance in high intensity glycolytic exercises in several different sports including, but not limited to, swimming and sprinting (5, 9, 10, 17-20, 25, 26). Sodium bicarbonate can delay fatigue by postponing acidosis and preserving intramuscular pH (1, 8).

The body uses glycolysis to provide energy for muscular contractions (1). While glycolysis produces energy quickly, the total capacity of the pathway is limited by the gradual increase in hydrogen ions within the muscles (28). Hydrogen ions increase the acidity of the muscular environment and eventually inhibit energy transfer and the ability of the muscles to contract (28). When muscular contraction is limited, the individual is forced to decrease their exercise intensity (6, 12). The natural defense against acidity is the bicarbonate buffer system. During exercise, hydrogen ions bind with bicarbonate to form carbonic acid. Carbonic acid travels in the blood until it reaches the lungs where it quickly dissociates into water and carbon dioxide and carbon dioxide is blown off during expiration. So, it has been reasoned that increasing the body's extracellular buffering capacity, by increasing the bicarbonate reserve, will allow hydrogen ions to leave the exercising muscle at a faster rate; consequently, more hydrogen ions can be produced before the acidity within the muscle cells reaches a limiting level (7, 12). The advantage of sodium bicarbonate consumption would thus be a delayed onset of fatigue during exercise (2, 14, 26).

Individuals typically consume 300 mg/kg body weight of baking soda with 1 liter of water to increase their sodium bicarbonate reserve (5, 21). Unfortunately, severe gastrointestinal distress is often associated with this method and dose of sodium bicarbonate (30). Nasal irrigation (NI) is a process of washing out the nasal cavity and nasal sinuses with an isotonic saline solution squirted from a plastic bottle or a tea cup like-product called a neti pot. Interestingly, the salt water found in most NI solutions usually contains 0.9% non-iodized sodium chloride and sodium bicarbonate. While NI is typically used to treat chronic sinusitis (13), it may help to improve exercise performance if the solution is absorbed through the nasal turbinates, highly vascularized epithelial cells located in the nasal cavity proper (13).

To our knowledge, no one has examined the use of NI as a potential sodium bicarbonate ergogenic aid or its effect on exercise performance. Therefore, the aim of this study was to examine how NI would influence exercise performance, specifically heart rate, mean arterial blood pressure, blood lactate, ratings of perceived exertion, and time to exhaustion. We hypothesized that NI would improve total exercise time and result in lower cardiovascular parameters throughout the exercise bout due to an increased buffering capacity.

METHODS

Subjects

Twenty male subjects took part in this experiment. As a pre-requisite for inclusion, all subjects met the following criteria: 1) Recreationally active (exercised 3-4 times per week), 2) Non-smoker, 3) Absence of chronic asthma or allergies, 4) No upper respiratory illnesses in the past month, and 5) Non-snorer. Subjects were classified if they were a snorer if they knew that they snored or if another person had ever witnessed them snoring. The inclusion criteria helped to eliminate any subjects who had possible problems breathing through their nose. We wanted to minimize subject discomfort using the nasal irrigation device. All subjects completed an informed consent and Physical Health and Medical History Questionnaire prior to participation. This study was done in compliance with the Federal Requirements for Protection of Human Subjects and was approved by the West Chester University of Pennsylvania Human Subjects Committee Institutional Review Board.

Experimental Procedure

Two testing conditions were implemented for this study. In the control condition, subjects did not receive the NI treatment prior to exercise and in the experimental condition they did. The two trial conditions were randomized and separated by two weeks.

Nasal irrigation:

For the NI testing condition, subjects were given a warm 8 ounce isotonic solution of 0.9% non-iodized sodium chloride and sodium bicarbonate. Fifteen minutes prior to the exercise test, subjects were instructed to place the tip of the bulb of the nasal irrigation device onto one of the external nasal openings and gently squeeze with just enough pressure so that the solution could trickle out of the opposing nostril. In order to ensure that each nostril received equal treatment, subjects were instructed to gently squirt for five seconds into the nasal cavity before squirting in the opposing nostril. This process was repeated until the 8 ounce bottle was completely empty of solution. NI was performed 15 minutes prior to the start of the exercise test to allow the NI solution enough time to be absorbed by the nasal turbinates and lessen any nasal edema.

Exercise protocol:

A modified Astrand treadmill protocol was used for the graded exercise test. Under the regular Astrand protocol, stages are two minutes in length. In the modified protocol used for this study, however, stages were three minutes in length. Stages were extended by 1 minute each to be similar to a normal treadmill workout routine. The exercise test started with a three minute warm-up stage which consisted of a 0% incline gradient at 3 miles per hour. The official time of the test started immediately following the warm-up stage. During the duration of the test, speed on the treadmill was kept at a constant rate of 5 miles per hour. The incline of the treadmill started at 0% for Stage 1, and increased by 2.5% at every stage thereafter. Subjects were instructed to engage in the treadmill test until maximal volitional fatigue was reached. Verbal encouragement was given to the subjects during the graded exercise tests to ensure maximal effort. Once the subjects indicated, either verbally or by raising their hand, that they could no longer continue the exercise test, the time of the exercise test stopped and the treadmill speed was brought down to 3 miles per hour at a 0% incline gradient for an active cool down. Following the active cool down, the subjects sat quietly for a 5 minute passive recovery period.

Measurements

Resting Measurements:

Subject's height, weight, resting heart rate, resting blood pressure, and resting blood lactate were measured before each experimental condition and subsequent exercise test. Furthermore, subjects completed a subjective pre-questionnaire regarding their current level of energy and clarity of breathing. This questionnaire was asked in the control condition and following the administration of NI in the experimental condition.

Exercise Measurements:

During each stage of the exercise test, heart rate measurements were taken every minute using a heart rate monitor (Polar Electro Inc, Lake Success, NY), including during the warm-up, cool down, and passive recovery period.

Blood pressure was taken using a sphygmomanometer and stethoscope during the second minute of each stage during the exercise test including the cool down and at the conclusion of the passive recovery period (24).

Blood lactate was measured with a lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA) following stages 2 and 4 of the exercise test, during the second minute of the cool down, and at the conclusion of the passive recovery period. Blood lactate was only collected at these times to study sodium bicarbonate as an alkalizing agent to help minimize subject discomfort and ensure subject retention.
Subjective difficulty of the exercise test was measured using Borg's Rating of Perceived Exertion (RPE) 15 point, 6-20 scale. Subjects were asked RPE during the final minute of each stage during the exercise test and during the final minute of the active cool down.
The same questionnaire was completed at the conclusion of the exercise test with the addition of two questions. The additional post exercise questions asked the subjects to rate the difficulty of the exercise routine and to rate their feeling post exercise test versus after a typical endurance workout.

Statistical Analysis

All results are presented as mean values ± standard error of mean. The data was analyzed using Student's two tailed t-tests of equal variance. Differences between experimental conditions for heart rate, mean arterial blood pressure, blood lactate, RPE, and total exercise time were examined. Statistical significance was set at the level of $P < 0.05$.

RESULTS

Subject Demographics

Subject demographics are displayed in **Table 1**.

Table 1 - Subjects Demographics

Subjects (n)	*Age (years)*	*Height (cm)*	*Weight (kg)*
20	21.8 ± 0.3	181.8 ± 1.6	83.3 ± 2.6

Data represent mean ± SEM.

Heart Rate

Heart rate (HR) response during the graded exercise test was evaluated without nasal irrigation (CON) and with nasal irrigation (NI). There were no significant differences in resting heart rate (76 ± 3 bpm; Control vs. 78 ± 4 bpm; NI) between the two experimental conditions. Interestingly, HR was significantly lower with NI during the first (P = 0.0002) and second minutes (P = 0.0328) of the warm-up stage (3.0 mph, 0% grade) than without it. Furthermore, there was a trend for HR to be significantly lower with NI (P = 0.07) during the first two minutes of stage 1 (5.0 mph, 0% grade) during the graded exercise test (**Figure 1**). Following stage 1, there were no significant differences in HR with or without NI for the rest of the graded exercise test including the cool down stage. Lastly, recovery HR was similar (104 ± 4 bpm; Control vs. 108 ± 2 bpm; NI) between the two experimental conditions.

Blood Pressure

Mean arterial blood pressure (MAP) during the incremental exercise test was not significantly different between the control and NI trials (**Table 2**). However, MAP was significantly lower (93 ± 1.1 mmHg; Control vs. 87 ± 2.7 mmHg; NI) for the experimental group at the conclusion of the five minute recovery period following the exercise test (P = 0.0478).

Figure 1. Mean heart rate through 5 stages of the graded exercise test for control versus nasal irrigation. Minutes 1-3: Warm-up, Minutes 4-6: Stage 1 (5 mph; 0% incline), Minutes 7-9: Stage 2 (5 mph; 2.5% incline), Minutes 10-12: Stage 3 (5 mph; 5% incline), Minutes 13-15: Stage 4 (5 mph; 7.5% incline), and Minutes 16-18: Stage 5 (5 mph; 10% incline). Data represent mean ± SEM. *Significantly decreased versus Control (P < 0.05)

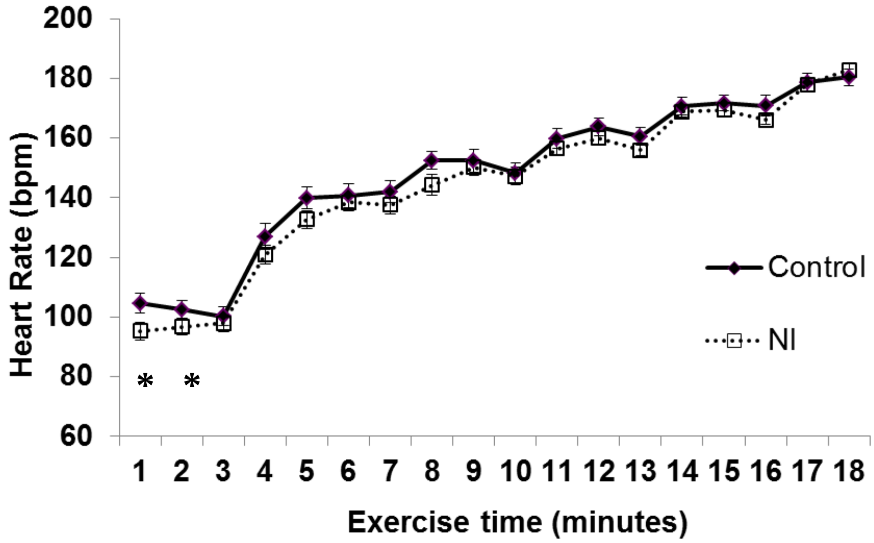

Table 2. *Mean Arterial Pressure (mmHg) throughout the Graded Exercise Test*

	Rest	Warm Up	Stage 1 (0%)	Stage 2 (2.5%)	Stage 3 (5%)	Stage 4 (7.5%)	Cool Down	Recovery
Control	92 ± 1.8	95 ± 1.5	97 ± 1.8	97 ± 1.9	98 ± 1.9	99 ± 1.9	93 ± 2.0	93 ± 1.1
NI	92 ± 2.0	94 ± 1.5	99 ± 1.8	101 ± 2.2	100 ± 1.8	99 ± 2.0	94 ± 1.8	87 ± 2.7*

Data represent mean ± SEM. *Significantly decreased versus Control (P < 0.05)

Blood Lactate

Blood lactate levels were measured at rest, during stage 2 (5.0 mph, 2.5 % grade), stage 4 (5.0 mph, 7.5% grade), cool down (3.0 mph, 0% grade), and recovery period following the incremental exercise test. There were no statistical differences in blood lactate with or without NI (**Table 3**).

Table 3. *Blood Lactate (mmol/L) throughout the Graded Exercise Test*

	Rest	Stage 2 (2.5%)	Stage 4 (7.5%)	Cool Down	Recovery
Control	2.2 ± 0.2	4.6 ± 0.9	7.0 ± 1.0	11.6 ± 1.0	9.4 ± 0.8
NI	2.7 ± 0.4	6.0 ± 1.0	5.5 ± 0.9	12.0 ± 0.8	11.7 ± 1.4

Data represent mean ± SEM.

Ratings of Perceived Exertion

Throughout the entire graded exercise test, ratings of perceived exertion (RPE) were recorded. No statistical differences in RPE with or without NI were found (data not shown).

Total Exercise Time

Total exercise time excluding warm-up and cool down were compared between the two trial conditions. Without NI, subjects exercised for a total of 16.99 ± 0.68 minutes. With NI, subjects exercised for a total of 17.19 ± 0.64 minutes. While the increase in total exercise time was not statistically significant, subjects saw a 1.17% increase in total exercise time with the use of NI prior to exercise (**Figure 2**). Furthermore, in a post hoc analysis examining the subgroup of the exercise times that did improve (N=10) with NI, total exercise time was significantly longer with NI (16.93 minutes) than without (15.99 minutes) (P = 0.0003) (**Figure 3**).

Figure 2. Total exercise time for control versus nasal irrigation. Data represent mean ± SEM. With NI, subjects saw a 1.17% increase in total exercise time.

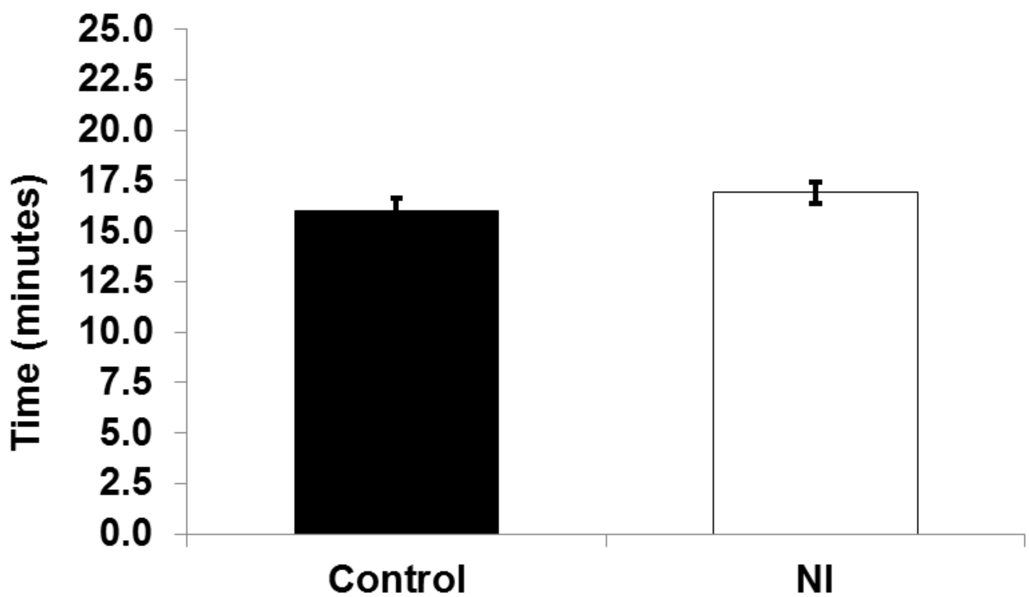

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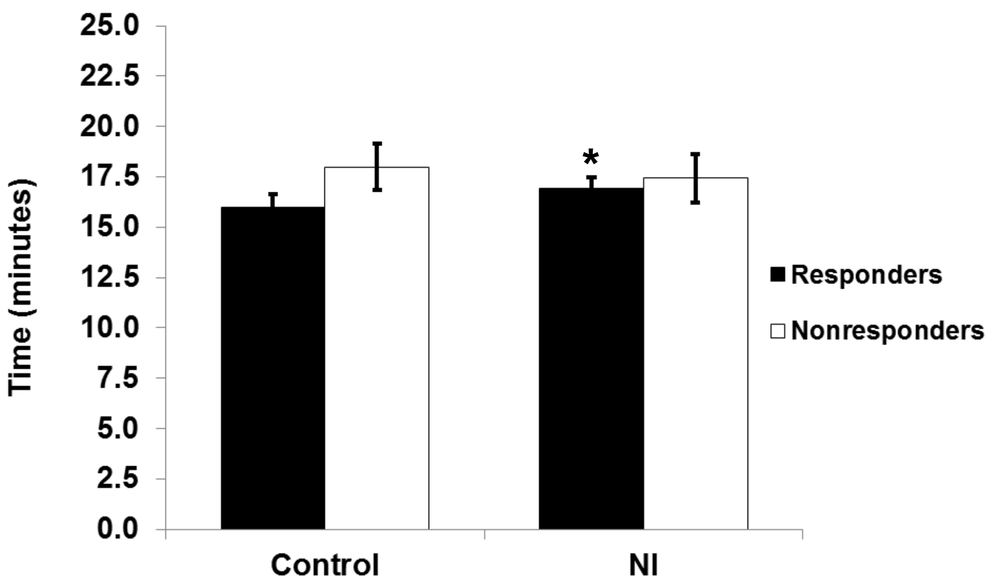
Figure 3. Total exercise time for a subgroup of subjects (n=10) that responded to nasal irrigation (responders) as compared to a subgroup of subjects (n=10) who do not respond to nasal irrigation (nonresponders). In the responders group, total exercise time increased ~5.88%, Control = 15.99 ± 0.63 minutes versus NI = 16.93 ± 0.53 minutes. Data represent mean ± SEM. *Significantly increased versus Control Responder (P<0.001).



DISCUSSION

This study is the first investigation known by the authors that has examined NI as a potential ergogenic aid for exercise. The main finding of this study was that total exercise time increased from 16.99 minutes without NI to 17.19 minutes with NI. This increase represents a 1.17% increase in total exercise time for the NI trials. Although the numbers are not statistically different, a 1% increase in total exercise time could benefit the everyday exerciser who hopes to perform the most efficient workout. There are two possible explanations as to why total exercise time increased in the NI trials. One reason may be metabolic alkalosis brought on by sodium bicarbonate and the other may be more inspired air was available. It is also possible that a combination of the two contributed to the results.

This study agrees with previous studies that have shown an improvement in total exercise time when sodium bicarbonate was orally ingested (3, 25). In a meta-analysis by Carr et al., the authors noted about a 1-2% increase in total exercise time across 59 studies (3). This corresponds with the 1.17% increase that was found in the present study. In this study, subjects all exercised for longer than 10 minutes and some still saw a positive improvement in time with nasal irrigation. When sodium bicarbonate is orally ingested, the typical dosage is 300 mg/kg body weight (5, 21). This dosage is larger than what was presented nasally. The total amount of sodium bicarbonate administered in the 8 ounce bottle was only 4.4 grams. Since little to no information is available regarding exercise and NI, it is unclear, however, how much of the sodium bicarbonate was nasally absorbed and what the minimal dosage would be in order to observe more favorable results in exercise time. We believe that all of the sodium bicarbonate in this study was absorbed though the nasal turbinates located in the nasal cavity proper. The turbinates of the nasal cavity are lined with respiratory mucosas that are comprised of stratified ciliated columnar epithelium. It is here in the mucosa that fluid is permeable (23). However, since blood sodium bicarbonate levels were not measured in this preliminary study, further studies are needed to explore these questions.

When total exercise time was examined in subjects who experienced improved times with NI (n=10), their total time was significantly longer. Similarly, when the total exercise time of those subjects who exercised longer without nasal irrigation (n=10) was examined, they too performed longer. This may suggest that subjects may be grouped as those responding to NI and those not responding to NI.

Given that sodium bicarbonate is an alkalizing agent, blood lactate levels are often measured when it is consumed (22, 30). When excess sodium bicarbonate is present in the blood and lactic acid is being produced by the exercising muscle, an increased pH gradient is created (6). As a result, the hydrogen ions (from the disassociation of lactic acid into hydrogen and lactate) flow out of the muscle and into the blood (6). Since hydrogen ions leave the cell, intramuscular pH is preserved and more work can be performed prior to the onset of fatigue (6). In the present study, blood lactate levels for the control trials were lower than that of the NI trials, with the exception of the measurement at stage 4, which cannot be explained. The higher blood lactate findings when sodium bicarbonate is ingested are parallel with that of other studies (21, 22, 25). Since blood lactate levels were higher with NI, it is conceivable that alkalosis may have been achieved. Blood bicarbonate levels and blood pH, however, were not measured in this study so further investigation is required to fully elucidate the role of NI on blood bicarbonate and pH levels.

Another possible explanation as to why total exercise improved with NI is that more air would be able to be inspired due to a decrease in nasal edema. This effect is similar to a nasal dilator and could work by increasing minute ventilation and possibly oxygen consumption (4, 11). When a larger nasal passageway was created by a nasal dilator, Macfarlane and Fong found a reduction in breathing effort as well as an improvement in peak aerobic performance in field tests (16). However, research by Case et al. and Trocchio et al. found no statistical differences ($P<0.05$) in VO_2 when nasal dilators were used (4, 27). The respiratory system is unlikely to deter exercise performance given that healthy lungs exceed the demand for gas exchange, however, a reduction in breathing effort may lead to a perception of an easier workout and hence longer workout sessions. Since nasal flow was not measured in the present study, more research is required to include that possible benefit of NI on exercise.

Another interesting finding of the present study was a significant difference in heart rate at the beginning of the exercise test. During minutes one and two of the warm-up, heart rate was significantly lower with nasal irrigation than when compared to without it. Furthermore, heart rate trended towards significance during minutes one and two of the first stage of the graded exercise test. The findings of our study conflict with that of Price and Simons (2010) as they reported no significant differences in heart rate with sodium bicarbonate consumption (21). Contradictory to both, Yunnoki et al. reported higher heart rates for subjects ingesting sodium bicarbonate during exercise and during recovery, although significance was not reached (29). The mechanism as to why heart rate was lower at the beginning of the exercise test is not clear. It is possible that NI improved ventilation and hence the heart did not need to pump blood as fast to deliver oxygen rich blood to the working muscles during the early stages of the exercise test. It would be important for future studies to measure oxygen consumption with and without NI during exercise. During the recovery period, mean arterial blood pressure was significantly lower with NI than without it. Most studies examining the effects of the oral ingestion of sodium bicarbonate do not typically report blood pressure, so the mechanism is not clearly understood.

Gastrointestinal (GI) distress, such as vomiting and diarrhea, are common with sodium bicarbonate ingestion (30) and therefore could cause an unfavorable outcome to individuals and athletes that use it before exercise. With NI, the sodium bicarbonate bypasses the GI tract because it is absorbed through the highly vascularized epithelial cells of the nasal turbinates in the nasal cavity proper (13). Subjects in our study did not report any GI distress.

A major limitation to this study was the lack of a placebo group. A placebo was difficult to administer because the subjects would have been able to decipher from a placebo, such as water, and the saline solution. Additionally, water could not have been used as a placebo irrigation solution because it has been shown to cause damage to the nasal epithelial cells (15). As a result of no placebo, this study could not be blinded. Therefore, although the subjects were never told of any possible ergogenic benefits, the subjects knew the difference from the experimental condition and the control condition. While the two trials were randomized, subjects could have expected better results with NI and improved exercise time as a result. Future studies should use a saline solution containing no sodium bicarbonate as a placebo.

CONCLUSION

In summary, our study was the first to examine NI as a possible ergogenic aid for aerobic exercise performance. With NI, total exercise time increased by 1%, heart rate was significantly lower during the warm-up, and MAP was significantly lower during recovery. Additionally, no GI distress was reported after NI. This study suggests that NI may improve aerobic exercise time to exhaustion and may be an alternative to orally ingesting sodium bicarbonate. Further studies on NI and its effects on exercise parameters are warranted. Future studies should examine blood pH levels, blood bicarbonate levels, and nasal flow following NI.

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