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The Time Course for Changes in Plasma [H+] After Sodium Bicarbonate Ingestion

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Numerous studies have demonstrated that induced alkalosis through ingestion of a sodium bicarbonate ($NaHCO_3$) solution can enhance performance during maximal-intensity exercise of varying durations, as well as maintain performance during high-intensity intermittent exercise.[1-3] Several studies have investigated the effect of dose ingested on subsequent exercise performance. For example, Horswill et al[4] demonstrated that doses of less than 0.2 g/kg were ineffective in improving performance during 2 minutes of maximal cycle exercise, whereas Wilkes et al[5] improved run performance of similar duration using a dose of 0.3 g/kg. Most studies have used a dose of 0.3 g/kg, and this seems to be the largest that can safely be consumed without an unacceptable risk of side effects of gastrointestinal distress. Although there is some consensus with regard to the optimal dose of $NaHCO_3$ that should be ingested, the timing of ingestion in relation to the start of exercise seems to vary from study to study. Matson and Tran[6] conducted a meta-analysis and found that studies that produced a large effect size in terms of improved exercise performance were associated with larger doses (0.278 ± 0.60 g/kg) and produced greater decreases in preexercise plasma $[H^+]$ and greater increases in $[H^+]$ after exercise than in studies that used lower doses (0.236 ± 0.70 g/kg). Because it appears that the magnitude of the induced change in plasma $[H^+]$ determines the success or lack thereof of $NaHCO_3$ as an ergogenic aid, it is necessary to establish the time course for changes in plasma $[H^+]$ after ingestion of the most commonly reported dose. This will allow identification of the optimal time of ingestion in relation to the subsequent maximum change in plasma $[H^+]$ and thus the timing of the commencement of exercise.

Methodology

Ten healthy participants (7 male, 3 female, age 28 ± 1.6 years) agreed to perform the experimental procedures. All provided informed consent, and all procedures used were approved by the institutional ethics committee.

The participants reported to the laboratory at 10 AM after an overnight fast on 2 separate occasions separated by a minimum of 7 days. Capillary blood for determination of plasma $[H^+]$ was taken immediately on arrival at the laboratory, and all analyses were performed using a Compact 3 blood-gas analyzer (AVL

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Medical Instruments, Stone UK). Blood was sampled using glass capillary tubes containing 6 IU Na-heparin and 9 IU Li-heparin per 100-μL tube volume (AVL Medical Instruments). Several studies have demonstrated that arterialized capillary blood gives a true picture of acid-base status.[7] To ensure that the peripheral capillary beds were arterialized, each participant's hand was immersed in a water bath at ~50°C for approximately 1 minute before sampling. The first drop of blood was wiped away, and one end of the tube was held flush with the wound so that the blood traveled directly from the tissue to the capillary. This procedure was repeated before all subsequent sampling.

Over the course of the next 30 minutes participants consumed a solution of 0.3 g/kg $NaHCO_3$ or $CaCO_3$ in 400 mL of plain water in 3 equal doses taken at 0, 15, and 30 minutes. Subjects were encouraged to drink ad libitum during this period and throughout the rest of the experiment. Prior pilot work had revealed that spreading the dose in this manner appeared to result in fewer incidents of gastrointestinal disturbance than giving the dose in a single bolus. The treatments were administered in a double-blind fashion, and the order was randomized. After the treatment solution had been consumed, a further blood sample was taken and then repeated at 30-minute intervals for the next 180 minutes.

Differences in plasma [H^+] in the period after $NaHCO_3$ and $CaCO_3$ ingestion were identified using a 2-way repeated-measures analysis of variance (ANOVA) followed by the Bonferroni post hoc test. All statistical analyses were performed using Graphpad Prism Version 4, and statistical significance was set at the $P < .05$ level.

Results

Plasma [H^+] was lower after $NaHCO_3$ than $CaCO_3$ at all points after ingestion (see Figure 1). This difference reached statistical significance ($P < .05$) at 30, 60, 90, and 120 minutes. The size of the difference between the 2 conditions increased

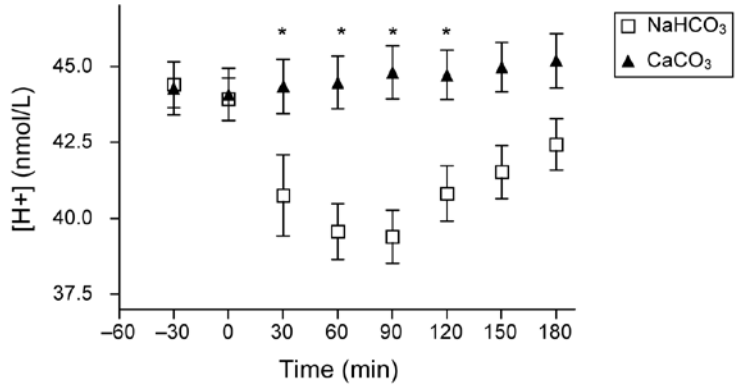

Figure 1 — Changes in plasma [H^+] during 180 minutes after ingestion of $NaHCO_3$ or $CaCO_3$. *$P < .05$.

until 90 minutes before decreasing again. By 150 minutes the difference between the 2 treatments did not reach statistical significance, although $[H^+]$ was still lower after $NaHCO_3$ 180 minutes after ingestion. The largest difference between the 2 treatments occurred at some point between the 60th and 90th minutes after ingestion (4.90 and 5.41 nmol/L, respectively).

Discussion

Matson and Tran[6] have suggested that enhanced exercise performance is associated with a larger decrease in $[H^+]$ before exercise after $NaHCO_3$ ingestion. If the treatment is consumed over a 30-minute period to reduce the risk of gastrointestinal disturbance, then in order to maximize the decrease in $[H^+]$ the optimal timing of ingestion in relation to the commencement of exercise would appear to be between 90 and 60 minutes beforehand. The magnitude of the change in $[H^+]$ induced in this study is relatively small, however. Ninety minutes postingestion, the mean $[H^+]$ was 39.40 nmol/L. In their meta-analysis, Matson and Tran[6] found that in 19 studies that produced a large effect size, mean postingestion pH was 7.43 ($[H^+]$ of 37.2 nmol/L). Despite variability in the individual responses to $NaHCO_3$, only 1 participant in the present study displayed lower plasma $[H^+]$. It is interesting to note that preingestion $[H^+]$ for this participant was 41.37 nmol/L, whereas mean preingestion $[H^+]$ for all other participants was 45.02 ± 1.25 nmol/L. In terms of the magnitude of the change in $[H^+]$ in response to $NaHCO_3$ ingestion, the difference between the highest and the lowest measured values was 5.05 nmol/L in this participant and 5.96 ± 2.25 nmol/L in the others. This would suggest that the basal plasma $[H^+]$ before ingestion might have been more important than the actual individual response to $NaHCO_3$ in determining whether or not the preexercise $[H^+]$ is at a level at which performance enhancement can be expected. In the current study, participants were required to report to the laboratory in a fasted state; this was an attempt to minimize the influence of the process of digestion on whole-body acid-base status.

Greenhaff et al,[8] however, demonstrated that a 4-day period of dietary manipulation influenced preexercise acid-base status. This suggests that in addition to considering the dose and timing of $NaHCO_3$ in relation to the commencement of exercise, researchers or coaches interested in experimenting with the use of $NaHCO_3$ should also consider controlling the composition of the diet in the days before exercise performance.

In the current study, $CaCO_3$ did not result in any significant change in plasma $[H^+]$ in the following 180 minutes. This would therefore suggest that $CaCO_3$ could be acceptable for use as a placebo in experimental trials in which $NaHCO_3$ ingestion is used to try to alter blood acid-base status before exercise.

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