

Responses to sodium bicarbonate supplementation in repeat sprint activity are individual

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Abstract. The aim of this study was to determine the individual effects of acute sodium bicarbonate (NaHCO₃) supplementation on elite short track speed skating relay race simulation. *Material and Method.* Double-blinded balanced, cross-over investigation required two teams of 4 athletes from the Australian National Short Track Speed Skating Program to participate in 2 simulated relay races 72 h apart. Each athlete performed 7 maximal speed skating sprints at a work:rest ratio of ~1:4. Each athlete ingested either 0.3g.kg⁻¹ per body mass of NaHCO₃ or lactose placebo (P) 75 min prior to each race. Plasma blood lactate concentration (Bla) was recorded 10min pre- and 2 min post- race simulation. Race lap times and changes in Bla were log transformed and analyzed using paired sample t-tests between NaHCO₃ and P. Data were also, analysed to evaluate individual response. Magnitudes of differences between conditions were interpreted using effect sizes (ES) and 90% confidence limits (CL). *Results.* Post-race simulation, Bla concentration demonstrated a very large increase from baseline for both groups. P demonstrated substantially faster performance for overall (ES: 0.98, CL: -0.13 to 1.82), mean lap (ES: 1.59, CL: 0.22 to 2.95), and fastest lap time (ES: 1.26, CL: 0.02 to 2.50) compared to NaHCO₃. Interpretation of the individual analysis indicates that NaHCO₃ results in a greater magnitude of individual variation for total (ES: 1.05, CL: -0.40 to 1.54), mean (ES: 2.04, CL: 0.71 to 2.79), and fastest lap time (ES: 1.85, CL: 0.64 to 2.54) than P. *Conclusion.* These findings indicate responses to acute NaHCO₃ supplementation may be individual.

Key words: short track,, sodium bicarbonate, repeat sprint.

Introduction

Sodium bicarbonate (NaHCO₃) supplementation prior to lactic anaerobic based exercise has been proposed to improve performance through a delay in the onset of fatigue through higher pre- pH levels. By starting exercise in a state of induced alkalosis, it may take a greater time until pH falls below an optimal physiological range thereby limiting exercise performance (1, 2). In this paradigm, the relationship between decreased pH and fatigue is assumed to be cause-effect, which has since been questioned in the literature (3-6). Despite evidence indicating that falling pH is not a limiting factor within the muscle during exercise (7), several studies (8-12) as well as recent reviews (13, 14) have still reported NaHCO₃ supplementation as an ergogenic aid, mostly through the greater sustainability of exercise intensity over protocols heavily dependent on lactic anaerobic energy.

Despite the findings of NaHCO₃ as an ergogenic aid in some investigations, in contrast others have reported no relationship (15-18). Of the several exercise protocols testing NaHCO₃ supplementation as an ergogenic aid, one modality specifically under debate is repeated maximal efforts involving large muscle groups with incomplete inter-set rest.

In line with scientific research debating the mechanism underlying NaHCO₃ as an ergogenic aid, findings related directly to a performance benefit have also been inconclusive with several investigators reporting a performance benefit (9, 19, 20) and others reporting no advantage (21-23). While several factors related to methodological discrepancies could account for the current lack of consensus as it pertains to NaHCO₃ supplementation as an ergogenic aid, perhaps this disagreement is more appropriately attributed to

the manner in which data has been previously analyzed. Of the relevant literature reviewed, all evaluated the data as a mean response to NaHCO₃ supplementation thereby masking a possibility that response is individual-dependent. Should differences in human physiology exist leading to wide variation in performance changes between individuals, these individual responses may be overlooked by mean-based statistical approaches. Considering the potential over-generalizations made in the statistical analysis of previous works intending to quantify the effects of NaHCO₃ supplementation as an ergogenic aid, it is necessary to consider an investigation that statistically intends to elicit an understanding of the individual ergogenic response. This investigation was designed with the intent of quantifying the effects of NaHCO₃ supplementation on elite short track speed skating relay race time-trial performance; and second, to determine if the effects of NaHCO₃ elicit individual responses possibly overlooked by traditional mean-based statistical analysis.

Material and Method

Eight athletes (7 male and 1 female) from the Australian National Short Track Speed Skating Team (Age 21.13 ± 1.63years, Height 174.63 ± 2.44cm, Weight; 76.3 ± 2.3Kg), were recruited for this investigation. Subjects were all accustomed to simulated maximal short track speed skating relay race training during regular national team training sessions. All provided informed consent and testing was approved by the institutional ethics committee, which conformed to the guidelines provided by the Declaration of Helsinki pertaining to research using human subjects.

Experimental Design. This study utilized a randomized, counterbalanced, and double blinded experimental design. Subjects were grouped onto one of two relay teams by the national team head coach. Each team performed two experimental sessions separated by 72 h. Both experimental sessions occurred at the same time of day.

Training for the 24 h prior to each session was similar in type, volume, and intensity. Subjects were asked to keep a consistent diet between 24 h periods prior to each session.

During each experimental session, each team ingested either supplement (NaHCO₃) or placebo (P) tablets. The experimental supplement (Sodibic, Aspen Pharmacare, NSW Australia) contained 0.84 g sodium bicarbonate (NaHCO₃)

per tablet, with subject's consuming a total of 0.3 g·kg⁻¹ body weight (24). Placebo (P) contained lactose, which was consumed in a matched dosage to supplement. Each lot of NaHCO₃ or P tablets were taken with 200-250 ml of water. For each test session, subjects consumed the designated dosage of NaHCO₃ or placebo in 5 aliquots administered in 15 min intervals with the final aliquot administered 75 min prior to testing (2, 25). Capillary ear lobe blood samples were collected 10 min prior to each simulated race and 2 min post completion of each athlete's seventh lap; each sample was immediately analyzed using a Lactate Pro Analyzer to assess blood lactate concentration (Bla) (KDK Corporation, Kyoto, Japan). Due to a simple limitation due to equipment of the elite training environment, direct measures of NaHCO₃ blood concentrations were not recorded.

Exercise Test. The testing protocol was identical for both experimental sessions, as a simulated short track speed skating relay race. Air temperature was consistent at 12° - 13° C between experimental sessions. Race protocol consisted of 1 skater from each team simultaneously racing at maximal effort for 1 lap before tagging in a teammate via "double push technique", commencing from a flying start. Transition between relay skaters occurred over a distance of 0.5 laps but was not included in analysis. The pattern of 1 race lap per skater followed by a transition to a teammate continued until all 4 members of the team had completed a race lap. The skating order was maintained between subjects, and the skating pattern continued for 7 cycles. In total, each subject completed 7 maximal sprints of approximately 9 - 10s in duration (113-120m distance per) and approximately 37million s rest between efforts.

Split times, registered in half lap increments, were recorded via panning camera (Sony HDR-FX1E, Tokyo, Japan) positioned off-ice at the centre line opposite the timing official. Footage was subsequently analysed by Swinger Motion Analysis Software (WebbSoft Technologies, VIC Australia); half and full lap splits were determined for each skater. Times were interpolated to 0.01s from fields of video footage captured every 0.02s.

Statistical Analyses. To verify an appropriate level of exercise induced stress, paired sample t-tests between NaHCO₃ and P conditions were conducted for initial plasma blood lactate concentration (Bla), peak Bla, and percent change

of Bla from pre- to post- as well as between pre- and post- time points for both conditions. Performance data were analyzed using paired sample t-tests between NaHCO₃ and P conditions for 7 lap total time, 7 lap mean lap time, and fastest individual lap. Raw data are expressed as mean ± SD.

To consider whether supplementation had an effect on fatigue over the course of exercise, percent change between total time of first 3 laps and final 3 laps was calculated per individual and compared between NaHCO₃ and P conditions by paired sample t-test. Data were log-transformed to reduce bias due to non-uniformity of error, back-transformed and expressed as a percentage (coefficient of variation [CV]). Uncertainty of the estimates is reported as confidence limits (CL) at the 90% level.

Effect sizes (ES) were calculated and interpreted qualitatively as trivial; < 0.2, small; 0.2 – <0.6, moderate; 0.6 – <1.2, large; 1.2 - <2.0, very large; >2.0 (26). Where the 90% CL for the ES extend beyond the boundaries of -0.2 to 0.2, effects are deemed unclear. Individual responses in performance time subsequent to NaHCO₃ supplementation are calculated using a publicly available spreadsheet (27) the SD representing individual responses is the typical variation in the response to the treatment from individual to individual.

Results

Changes in Blood Lactate Concentration. Prior to simulated relay racing Bla concentrations for each condition were 3.3 ± 0.6 mmol (P) and 3.6 ± 0.6 mmol (NaHCO₃).

Following simulated relay racing, Bla concentrations were 13.0 ± 2.1 mmol (P) and 13.5 ± 2.6 mmol (NaHCO₃) demonstrating a mean increase of 296.6% (CL: 225.7 to 383.0) (P) and 276.1% (CL: 222.0 to 339.2) (NaHCO₃). While the overall increase in both conditions was very large (ES: 6.43, CL:

5.51 to 7.34, and ES: 6.03, CL: 5.32 to 6.74 for P and NaHCO₃ respectively; Figure 1), the difference between conditions was unclear (ES: 0.10; CL: -0.74 to 0.94).

Simulated race performance. The total simulated race time for each condition was 65.74 ± 0.58 s (P) and 66.79 ± 1.28 s (NaHCO₃). P was faster compared with the NaHCO₃ condition (ES: moderate; Table I). Similarly, the mean lap time and fastest lap time was faster for P than for NaHCO₃ condition (mean lap time: 9.39 ± 0.08 s and 9.54 ± 0.18 s, respectively; ES: large, and fastest lap time: 9.22 ± 0.10 s and 9.36 ± 0.26 s; ES: large; Table I). The percentage difference in the mean Δ final v first 3 laps total time (i.e., pacing effect) between NaHCO₃ and P was -42.9% (CL: -73.3 to 22.1), indicating a trend towards improved performance in the latter stages of simulated race performance following NaHCO₃ supplementation, despite the effect being deemed unclear (Table I) due to large variation in individual performances (Table II).

Individual responses to simulated race performance. The magnitude of individual responses in simulated race performance times between conditions are presented in Table II. Greater magnitude of variation in performance times was observed between individuals in the NaHCO₃ compared with P condition for total time (ES: moderate; Figure 2a), mean lap time (ES: very large; Figure 2b), and fastest lap time (ES: large; Figure 2b). Large individual responses were also evident when comparing the percentage difference in the Δ final 3 lap v first 3 lap time (i.e., pattern of fatigue over race simulation) between conditions (Table II). Interestingly, when considering the individual responses for the percentage difference in the Δ final 3 lap v first 3 lap time in each treatment (i.e., NaHCO₃ or P), the magnitude of individual responses in the NaHCO₃ (ES: 0.50; CL: 0.17 to 0.69; small) condition was less than that observed for P (ES: 1.11; CL: 0.39 to 1.53; moderate).

Table I. Magnitude of difference in simulated race time performance between NaHCO₃ and placebo conditions

	% Δ (90% CL)	ES (90% CL)	Magnitude
Total Time	1.6 (0.2 to 3.0)	0.98 (0.13 to 1.82)	Moderate
Mean Lap Time	1.6 (0.2 to 3.0)	1.59 (0.22 to 2.95)	Large
Fastest Lap Time	1.6 (0.0 to 3.2)	1.26 (0.02 to 2.50)	Large
Δ Final 3 Lap v First 3 Lap Time	-42.9 (-73.3 to 22.1)	-0.68 (-1.60 to 0.24)	Unclear

% Δ: Percentage difference; CL: 90% confidence limits; ES: effect size statistic;
Magnitude: qualitative descriptor of magnitude of change in performance

Table II. Magnitude of individual responses in simulated race performance times between NaHCO₃ and placebo conditions

	% CV (90% CL)	ES (90% CL)	Magnitude
Total Time	1.7 (-0.4 to 1.5)	1.05 (-0.40 to 1.54)	Moderate
Mean Lap Time	2.0 (-0.4 to 1.5)	2.04 (0.71 to 2.79)	Very Large
Fastest Lap Time	2.3 (-0.4 to 1.5)	1.85 (0.64 to 2.54)	Large
Δ Final 3 Lap v First 3 Lap Time	163.2 (-12.6 to 295.6)	1.17 (-0.16 to 1.68)	Large

% CV: individual responses expressed as a coefficient of variation; CL: 90% confidence limits; ES: individual responses expressed as an effect size statistic; Magnitude: qualitative descriptor of magnitude of individual responses in performance.

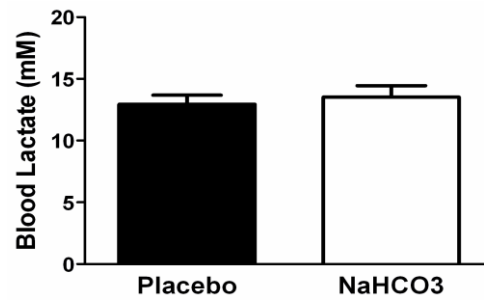


Figure 1. Mean (\pm SD) plasma peak Bla (mmol) for NaHCO₃ supplementation and Placebo conditions following Short track speed skating simulated relay race (n = 8)

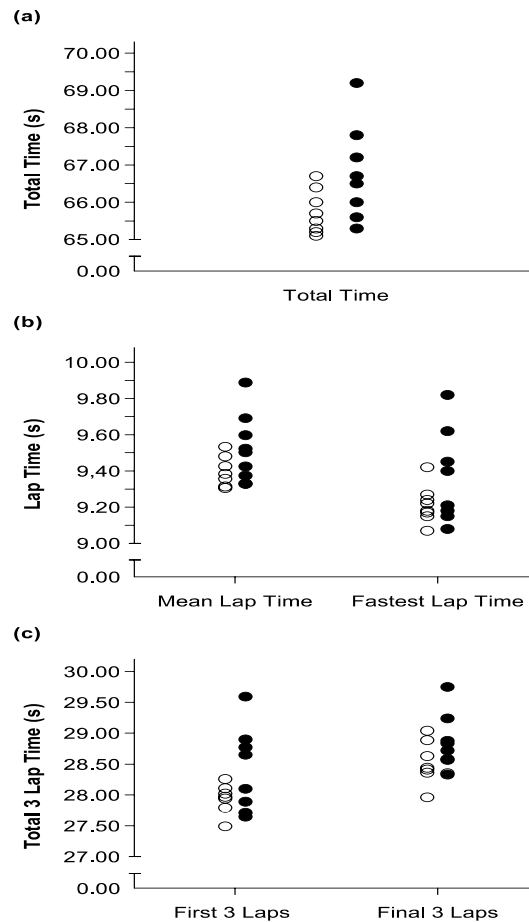


Figure 2. Individual performance times for NaHCO₃ (●) and P (○) conditions for (a) total time, (b) mean lap time and fastest lap time, (c) first 3 laps total time and final 3 laps total time.

Discussion

The findings reported provide support for understanding how acute NaHCO₃ supplementation influences athlete performance on an individual basis. This is supported by the moderate to very large magnitude of individual responses recorded in NaHCO₃ condition as compared with P for total (ES: moderate), mean lap (ES: very large), fastest lap (ES: large), (Table II). These observations provide strong evidence for the individual nature of response to acute NaHCO₃ supplementation. This alone is a novel and important finding as it provides plausible explanation for the marked dichotomy in the literature as several previous works have demonstrated NaHCO₃ supplementation as an ergogenic aid (10, 12, 28) while several others have found no benefit (15-17). A strong variation in the individual response to acute NaHCO₃ supplementation would result in the possibility that at least some of the studies reporting no benefit of supplementation actually contained individuals experiencing performance benefit and conversely other individuals experiencing performance decrement with a net result of a statistically non-significant finding due to the analysis techniques employed.

While the underlying causes of individual-based response is beyond the scope of this investigation, we propose gastrointestinal (GI) intolerance of acute NaHCO₃ supplementation as the likely cause. The issue of GI discomfort in response to supplementation has been documented previously (1, 2) and logically those athletes experiencing discomfort would display decreases in performance during maximal exercise, regardless of any underlying physiological benefit which supplementation may provide. Additionally, we feel it plausible a poor GI response would manifest itself primarily during the early stages of exercise as the athlete is forced to adapt to performance under discomfort. This contention is supported by the observation that the largest magnitude of individual response of all indices analysed occurs in the first 3-lap time when comparing NaHCO₃ with P (Table II).

While our findings support an individual-based performance response to NaHCO₃ supplementation it surprisingly provides no direct evidence of improvement in elite short track speed skating 3000m relay performance.

This lack of finding may be attributed to the limited sample size or single crossover design; unfortunate consequences of research utilizing elite athlete subject populations.

Regardless, we feel there is enough published scientific evidence to demonstrate NaHCO₃ as an ergogenic aid for at least some individuals (1, 2, 9, 12).

The findings of our investigation suggest the execution of further research or re-analysis of previous research evaluating the individual-based response to acute NaHCO₃ supplementation as methodology of statistical analysis may be the key to resolving the disconnect in the literature as it pertains to the performance benefit of NaHCO₃ supplementation. Relating to the recommendation of using NaHCO₃ as an ergogenic aid, the substantial rate of individual responses indicate that no encompassing recommendation can be made for all athletes; the response an athlete will have cannot be known until it is tried.

In summary, the novel statistical approach utilized in this investigation identified the effect of acute NaHCO₃ supplementation on repeat maximal effort exercise performance to be individual in nature.

As previous relevant literature has utilized a mean-based statistical approach, it follows logically the lack of scientific consensus on NaHCO₃ as an ergogenic aid may be explained by the statistical analysis employed as an effect, both positive and negative, may exist for some individuals, but be overlooked in mean-based statistical approaches as the net findings are statistically non-significant. While further research in the area is necessary, we propose the individual nature of response is caused by a negative GI response to supplementation in some individuals.

It is likely acute NaHCO₃ supplementation provides a mean physiological benefit to repeat maximal sprint effort performance, but this benefit is masked in some individuals due to GI discomfort. While our investigation demonstrates the individual nature of response, it provides no direct evidence for a benefit of acute supplementation on elite 3000m short track speed skating performance.

Nonetheless, we feel it likely NaHCO₃ supplementation benefits at least some individuals as reported in several previous works though

predicting which athletes will benefit can only be determined on a basis of trial-and-error well away from a competition period.

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