

Ergogenic Aid Evaluation of Sodium Bicarbonate 1

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A. Introduction

The sodium bicarbonate (NaHCO_3), or baking soda, has undergone a long history of scientific study as an ergogenic aid since it was first experimentally studied in the 1930s. It has a physiological explanation that lies in acid-base biochemistry. Hydrogen ions (H^+) are generated by glycolysis during spurts of vigorous exercise at a rate that exceeds the inherent buffering ability of the muscle tissue, causing intracellular acidosis. This gradual decrease in intracellular pH interferes with the activity of the enzymes and interferes with the calcium-dependent cross-bridge cycling that takes place in muscle contraction and leads to the rapid development of fatigue (Akritas et al., 2024). When consumed before exercise, sodium bicarbonate increases extracellular bicarbonate concentration and blood pH, which increases the electrochemical gradient that causes H^+ to be pumped out of working muscle into the bloodstream (Durkalec-Michalski et al., 2023), allowing it to be easily buffered.

This extracellular buffering process is best applicable to exercise that lasts between about one and seven minutes, where the glycolytic energy system prevails, and lactate buildup is the main physiological performance constraint (Miller et al., 2025). Sporting events that fall within this range, such as middle-distance running, rowing, cycling time trials, and repeated-sprint sports, are thus believed to be the main circumstances under which NaHCO_3 supplementation can provide a significant competitive edge. Gurton et al. (2024) note that the breadth of such applicability is what has been a point of significant research motivation, with meta-analytic results indicating a consistent moderate performance improvement of about 1 to 2%.

The current research tested the acute influence of NaHCO_3 supplements on two exercise performance variables, including post-exercise blood lactate concentration (BLA, mmol/L) and heart rate (HR, bpm). Blood lactate was chosen as a measure of glycolytic metabolic stress,

which provides a direct measure of the acid-base stress of the body during exercise and a way to determine whether supplementation changed physiological reactions (Zhou et al. 2022). Heart rate was taken as a secondary cardiovascular indicator. Collectively, these steps enable a feasible assessment of whether the ingestion of acute NaHCO_3 created a measurable physiological response in a small, mixed-ability group of five male subjects.

B. Methodology Summary

Trial Design

A within-subjects crossover design was used, whereby two experimental conditions were carried out on different occasions by the same participants. Condition B consisted of the administration of 0.3 g/kg body mass of NaHCO_3 dissolved in water, which was ingested 60 to 90 minutes before the exercise, which was in accordance with the dosing regimens determined in the literature (Grgic et al., 2021). Condition A was used as the control, in which the same amount of sodium chloride solution was used, but in the same manner to reduce expectancy effects. Condition order allocation was counterbalanced when feasible to minimise the effects of order and carry-over, but the rigour with which this was done was limited by the small size of the convenience sample.

Participants

The study included 5 men who volunteered (mean age 29.8 years, range 21 to 51 years; mean height 178.8 cm; mean body mass 87.7 kg, range 79 to 100 kg). The sample was a heterogeneous set of undergraduate sport and exercise science students, with one older participant, which makes the sample heterogeneous in terms of age and training background. No known cardiovascular or metabolic contraindication to exercise was found in any of the

participants. The participants were requested to normalise their diets, eliminate caffeine, and not engage in vigorous physical exercise 24 hours before each trial.

Protocol and Measurement Tools

The subjects had undergone a standard warm-up before a high-intensity exercise session that was meant to generate a significant glycolytic workload and resultant lactate build-up. Post-exercise blood lactate was determined using a fingertip capillary blood sample (Okano et al., 2025), which was analysed using a portable lactate analyser. Chest-strap monitors were used to record the heart rate during every session and extract the means to analyse it. The tests were done at the same time of the day in both conditions to eliminate circadian differences in physiological responses.

Ethical Considerations

All participants signed informed written consent before they commenced. The subjects were informed about the main side effect of ingesting NaHCO_3 , which is GI discomfort, and were given the freedom to withdraw at any time without any penalty. Sodium bicarbonate is not prohibited in the World Anti-Doping Agency Prohibited List (WADA, 2024), which proves that it can be used in competitive sport legally. All the procedures were held according to the appropriate institutional ethical standards and were consistent with the postulates of the Declaration of Helsinki (Kurihara et al., 2024).

C. Results Summary

The results of the blood lactate of everyone in each condition are indicated in Table 1. There is also the reporting of individual percentage changes and group means.

Table 1

Individual and Mean Blood Lactate Concentrations (mmol/L) Across Placebo and Sodium Bicarbonate Conditions.

Participant	Age (yrs)	Mass (kg)	BLa – Cond. A (mmol/L)	BLa – Cond. B (mmol/L)	% Change	HR Dir (A→B)
Jay	24	81.3	13.5	12.0	-11.1%	↓
Kris	27	100.0	15.0	20.1	+34.0%	↑
Zac	26	96.0	17.6	18.4	+4.5%	↑
Josh	21	79.0	24.8	21.7	-12.5%	↓
Geraint	51	82.0	14.1	17.1	+21.3%	↑
Mean	29.8	87.7	17.00 ± 4.63	17.86 ± 3.71	+5.1%	Mix

Note. Condition A = Placebo; Condition B = Sodium Bicarbonate (0.3 g/kg body mass). Values are given as mean SD where applicable. HR direction reflects an increase (↑) or a decrease (↓) of the mean heart rate between Condition A and Condition B.

The mean blood lactate showed a slightly higher value in the NaHCO₃ (17.86 ± 3.71 mmol/L) than in the placebo (17.00 ± 4.63 mmol/L), which was an increase of 5.1%. Nevertheless, the difference is minimal and will not be statistically significant in this case since the sample size is rather large. The levels were quite different in individuals: Jay and Josh were found to have lower lactate in the state of NaHCO₃ (-11.1% and -12.5%, respectively), and Kris and Geraint had a significant and a moderate increase (+34.0% and +21.3%, respectively). The data on heart rate had an equally uneven trend, although there was no consistent directional trend that could be blamed on the supplement.

D. Discussion and Practical Implications

At a glance, the fact that there is no clear reduction in blood lactate under the NaHCO_3 condition may seem to be contrary to the existing literature. The published meta-analyses continuously show that acute supplementation with 0.3 g/kg body mass positively influences high-intensity exercise performance, and outcomes are usually in the range of 1.7 to 2.0% and decreases in perceived workload and lactic acid accumulation in the blood compared to exercise intensity (Miller et al., 2025; Gurton et al., 2024). The process is highly characterised in that the presence of high pre-exercise bicarbonate increases the concentration gradient across which H^+ is lost in contracting muscle and postpones the effect of acidosis that interferes with enzymatic activity and prolongs the production of sustained forces (Curran-Bowen et al., 2024). The current figures are, however, more subtle, and the seemingly absent effect is not only coincidental but also educational.

was slightly higher (+5.1) is directionally consistent with the hypothesis that some participants experienced more metabolic effort. This is a speculative interpretation that lacks a corresponding measure of work output but emphasises the need to use outcome variables that directly measure performance, not only metabolic by-products.

The most notable aspect of the current data is that the inter-individual variability of response is significant. Kris showed an increase of 34.0 per cent in blood lactate under the NaHCO_3 condition and 12.5 per cent in blood lactate in Josh, with the difference in heart rate responses being equally significant. This level of fluctuation does not lack precedence. Durkalec-Michalski et al. (2023) particularly assessed the high-intensity cycling capacity in the presence of a NaHCO_3 supplement and discovered that even the responses of individuals were

extremely varied, and thus, the magnitude and direction of the effect are mediated by differences in baseline buffering capacity, habitual dietary sodium, training status, and GI tolerance. The age interval of the current cohort, between 21 and 51 years, provides another confounding factor, since older persons could have impaired acid-base regulatory responsiveness, but the evidence base of the given interaction is still scarce.

Practically, the usefulness of NaHCO_3 as an ergogenic aid is best defined in relation to trained athletes who have to take part in 1-7 minutes of events during which glycolytic energy production is the most active and the buffering effect of the supplement is the most applicable (Grgic et al., 2021). It is also useful in repeated-sprint and high-intensity interval settings, with accumulating acid-base imbalance across subsequent efforts potentially being significantly mitigated (Aktitiz et al., 2024). The current generation, however, consisted largely of leisure-active undergraduate students as opposed to professional athletes. Probably, the exercise regimen did not elicit adequate levels of acidosis in all the subjects to allow the bicarbonate load to have its full effect. According to Niazi (2024), in case the placebo condition resulted in the relatively small lactate response, then there is inherently limited room to supplement that to a physiologically significant effect.

Whereas NaHCO_3 is a peripheral agent that broadens the H^+ concentration gradient at the muscle membrane, the other nutritional interventions are central to action. Along these lines, Beaven et al. (2013) showed that mouth rinses of carbohydrate and caffeine quickly increased the peak and mean power output in repeated sprint cycling, which the authors attribute to the effects of oral receptor activation and central nervous system receptor modulation, but not to the supply of metabolic substrates. This comparison makes clear that ergogenic approaches to different

physiological pathways cannot be directly compared, as they should be assessed in the framework of their individual mechanistic and contextual domains.

The conclusions of this study are also qualified by a number of methodological limitations. The number of participants (5) is not high enough to be able to find moderate effect sizes with statistical power. The lack of complete participant blinding opens the potential for expectantly induced behavioural dissimilarities between conditions. There was no $\text{VO}_{2\text{max}}$ data that was obtained, and therefore, it was not possible to standardise the exercise intensity to the individual aerobic capacity, which was a serious limitation considering that there was a great variation in body mass (79 to 100 kg) and training background of the group. More conclusive evidence of ergogenic effect would have been given by a direct measure of exercise performance output (e.g., power, time to exhaustion) than by post-exercise blood lactate alone. Although these limitations are present, the results do not conflict with the rest of the literature; they are not conclusive enough to prove it. Based on Couce et al.'s (2026) scientific evidence, NaHCO_3 supplementation can be a viable option for the right kind of athletes in anaerobic sports. Atakan et al. (2021) recommend that, however, individual tolerance testing should be conducted at the time of training, dosing, and timing should be observed, and the variability in response that defines its use should be communicated clearly.

E. Ethical and Safety Considerations

Sodium bicarbonate has been widely considered safe in healthy adults as part of established supplementation regimens, and its side-effect profile is well-characterised. Zhou et al. (2022) note that the most frequently reported adverse effect is gastrointestinal discomfort, and it could be in the form of bloating, nausea, abdominal cramping, and diarrhoea. These are dose-related symptoms and are mostly manifested in case NaHCO_3 is consumed as a single fast

bolus. The present study was guided by the clear communication of this risk to all the participants in the consent process. The most accepted methods of reducing GI discomfort are taking smaller, divided doses within a 30 to 60 minute interval; co-administration with food with carbohydrates; taking the supplement in an encapsulated form; or replacing it with sodium citrate (Grgic et al., 2021; Durkalec-Michalski et al., 2023), which produces a similar alkalotic effect.

As has been mentioned above, NaHCO_3 is not listed in the WADA Prohibited List (WADA, 2024) and is, therefore, not prohibited in all competitive sports worldwide. It is, however, recommended that practitioners use professional judgement when suggesting the supplement to particular groups. Patients with hypertension, kidney problems, or heart disease might be at a high risk due to the sudden intake of sodium as per the routine dosage regimens. In the same vein, simultaneous administration of drugs that affect acid-base control, like other diuretics or antacids, can also react unpredictably with the exogenous intake of bicarbonate.

Ethically applied use of NaHCO_3 means that the supplement should be trialled during training before being used in competition so that the GI experience of the individual has been determined. Ethical use means that the potential benefit and associated risk should be clearly explained while the athlete maintains free choice in regard to whether they use it.

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