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The effect of sodium bicarbonate ingestion on 1500-m racing time

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Twelve athletes, all of whom regularly participated in middle- or long-distance running races at club to national standard, competed in simulated 1500-m races under three conditions: following ingestion of 300 mg sodium bicarbonate per kg of body mass (B); following ingestion of a placebo (100 mg sodium chloride per kg of body mass and 200 mg calcium carbonate per kg of body mass) (P); and following ingestion of neither (C). A double-blind protocol was used between the B and P trials. Each condition was replicated so that the athletes competed in six races. Ten of the athletes completed all the races. The athletes' average times for trials B, P and C were 253.9, 256.8 and 258.0 s, respectively. The data were analysed using a two-way ANOVA with replicates and Tukey tests. This revealed a difference between trial B and trials P and C ($P < 0.05$), but no difference between trials P and C. These findings, therefore, indicate that sodium bicarbonate can have an ergogenic effect upon 1500-m running.

Keywords: Ergogenic aid, running, sodium bicarbonate.

Introduction

During sustained high-intensity exercise such as 1500-m running, the onset of fatigue has been attributed largely to the accumulation of protons which cause a decrease in both the intramuscular and extracellular pH. This increase in acidity is believed to contribute to the onset of fatigue by: (1) inhibition of key enzymes, in particular the rate-limiting enzyme phosphofructokinase (Sutton *et al.*, 1981); (2) inhibited release of calcium ions from the sarcoplasmic reticulum and their binding to the troponin complex (Donaldson and Hermansen, 1978; Fabiato and Fabiato, 1978); and (3) reduced contractility of the muscle fibres (Chase and Kushmerick, 1988; Mainwood and Cechetto, 1980).

The rationale behind the use of sodium bicarbonate as an ergogenic aid is the belief that it can augment an individual's reserve of alkaline buffer, a factor which should provide the athlete with potential to buffer more effectively the protons produced from anaerobic glycolysis during high-intensity exercise. This should enable the athlete to generate more adenosine triphosphate (ATP) from anaerobic glycolysis before an equivalent level of fatigue is reached. In support of this belief, the capacity to increase the alkaline reserve through the ingestion of sodium bicarbonate has been demonstrated by a number of authors (Costill *et al.*, 1984; Goldfinch *et al.*, 1988; Katz *et al.*, 1984; McNaughton, 1992a; Wilkes *et al.*, 1983). Furthermore, an ergogenic effect has been demonstrated in a number of studies, even if these findings are not always consistent. For example, Goldfinch *et al.* (1988) and Wilkes *et al.* (1983) demonstrated significant improvements in running times following the ingestion of bicarbonate, for the 400 m and 800 m respectively, while Kindermann *et al.* (1977) found it to have no significant improvement in the 400 m.

Research by Hood *et al.* (1988), Mainwood and Worsley-Brown (1975) and Roth and Brooks (1990a,b) indicates that the physiological basis for sodium bicarbonate's ergogenic effect is an enhanced efflux of protons and lactate from the muscle, and a greater capacity to buffer the protons in the extracellular fluid. In his review of the topic, McNaughton (1992b) stated that to produce such an ergogenic effect, the dosage of bicarbonate used should be at least 300 mg per kg of body mass (BM), since research using lower dosages

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produced less consistent results. He also considered 300 mg kg BM^{-1} to be the optimal dose, since higher dosages were associated with an increased incidence of gastrointestinal disorders.

For sodium bicarbonate to have an ergogenic effect upon an activity, anaerobic glycolysis must make a substantial contribution to the energy requirements of that activity. Therefore, maximal exercise of between 40 and 420 s is generally recommended (Linderman and Fahey, 1991; McNaughton, 1992c; Serresse *et al.*, 1988). To date, much of the research investigating the potential ergogenic effects of sodium bicarbonate in running has centred on the 400 and 800 m, with few studies conducted over 1500 m, which also requires a substantial anaerobic contribution. Indeed, the research of Osnes and Hermansen (1972), which compared a number of post-exercise variables in subjects who ran distances from 100 to 5000 m, found the highest levels of lactate, the lowest recordings of blood pH and the lowest levels of bicarbonate following the completion of 1500 m. This suggests that, if bicarbonate ingestion is effective in enhancing performance over 400 and 800 m, it should also have an ergogenic effect over 1500 m. Therefore, this study was undertaken to investigate the effects of bicarbonate ingestion on 1500-m running.

Methods

Twelve male distance runners volunteered to participate in the study, of whom 10 completed all six trials. Of the two who failed to complete all six trials, one withdrew for personal reasons and the other was unable to attend all races because of other commitments. In view of the findings of McNaughton (1992b), it is important to emphasize that neither of these runners withdrew due to gastrointestinal problems. All runners were non-smokers, aged 18–24 years, and had a body mass of 56–69 kg. All subjects competed regularly in middle- or long-distance running races at club to national standard. At the commencement of the study, the athletes' fastest times for the 1500-m during the current and previous seasons were between 231.5 and 279.0 s ($\bar{x} \pm$ S.D. = 247.7 ± 12.5 s). The runners were recruited from three clubs in two different geographical regions of the country and thus formed two distinct groups, which were designated groups 1 and 2. All testing took place on two synthetic tracks (one in each region). Prior to the assessment races, each runner completed a series of preliminary 1500-m runs, which were a mixture of competitive races and organized time-trials. The athletes were therefore considered to be 'race fit' and familiar with competing over the designated distance.

The investigation consisted of a series of 1500-m races over 4 weeks (group 1) and 7 weeks (group 2) with the athletes racing only against members of their own group. Each athlete competed in six races; two following the ingestion of bicarbonate (B), two following the ingestion of the placebo (P) and two following the ingestion of neither (C). For each athlete the trials were completed in a random order, so that within each race athletes were competing under a mixture of conditions. A double-blind protocol was employed for the B and P conditions, with the solutions being administered by an independent investigator. Additionally, the researchers present at the trials were not aware of which athletes were racing under the control (C) condition. In group 2, the 'random order' was semi-structured into two blocks of three races so that each athlete completed one race under each of the conditions within his first three races, and one race under each of the conditions within his second three races. This design was employed due to the extended test period of 7 weeks.

The protocol attempted to simulate competitive races. This was a feature of the research of Goldfinch *et al.* (1988) and Wilkes *et al.* (1983), who found that ingestion of sodium bicarbonate improved running times for the 400 and 800 m.

Each 1500-m race was preceded by a 3-h fast, during which time the bicarbonate or placebo solutions were administered to the subjects as described above by an independent investigator to produce a double-blind design between the athletes' B and P trials. The experimental solution of sodium bicarbonate (B) was administered in a dosage of 300 mg kg BM^{-1}, the same as in a number of previous studies which found it to produce significant ergogenic effects in runners (Goldfinch *et al.*, 1988; Wilkes *et al.*, 1983) and as recommended by McNaughton (1992b).

The placebo (P) was made up of sodium chloride (100 mg kg BM^{-1}) and calcium carbonate (200 mg kg BM^{-1}). Each solution was mixed with 200 ml of pure orange juice diluted with 200 ml of water. Half the solution was consumed 2 h prior to the trial and the other half 1 h before the trial. Following the ingestion of each half of the solution, the subjects were encouraged to drink a cup of water immediately, preferably without pausing for breath, in order to wash the taste of the solution from their mouths. In accordance with the recommendations of Linderman and Fahey (1991), the subjects were also advised to drink water *ad libitum* after consuming the solutions and throughout the 3-h fast. The purpose of this was to aid the absorption of the large quantities of sodium and minimize the likelihood of gastrointestinal disorders. Each athlete's control runs (C) were also preceded by a 3-h fast, during which they consumed water *ad libitum*.

While participating in the investigation, the subjects were asked to maintain their normal diet and they undertook only light training on the day preceding any trial. This was the normal practice for the athletes before participating in competitive races and helped to ensure that they were fully rested before each race.

Prior to each race, the subjects completed a self-selected warm-up, which generally consisted of 10–20 min jogging, 5 min of static stretching and loosening exercises, and then a series of 60–90 m 'strides' at close to sprinting speed. The exact content of the warm-up was determined by each individual, the aim being to prepare themselves physically and psychologically in a similar manner to competitive races. All races were completed during the early evening (18:00–20:00 h) to prevent the possible influences of circadian rhythms (Winget *et al.*, 1985).

At the start of each race the athletes were informed that they should attempt to complete the distance as fast as possible, so that the races were not 'tactical' in the sense of consisting of a slow pace during the early stages and a 'sprint finish'. The subjects were given their split times at 400, 800 and 1200 m, thus simulating a race situation, but they were not informed of their final time until they had completed all the trials.

Group 1 completed all assessment trials within 4 weeks, with a minimum of 72 h recovery between trials or other races. In group 2, the races took place over 7 consecutive weeks, allowing a full week to recover between trials and a minimum of 48 h recovery following other races. The assessment time for group 2 was extended over 7 weeks due to holiday commitments and poor weather, which resulted in the cancellation of some assessment sessions.

The finishing times of the athletes were recorded to the nearest 0.1 s using a digital stopwatch and the data later analysed using a two-way ANOVA and Tukey tests (Cohen and Holliday, 1982).

Results

The results are summarized in Table 1. Of the 10 athletes who completed all six runs, 8 recorded their fastest two-race average times following the ingestion of bicarbonate. The group means (± S.D.) were: B, 253.9 ± 12.4 s; P, 256.8 ± 12.2 s; C, 258.0 ± 12.9 s. The athletes' finishing times were then analysed using a two-way ANOVA, with replicates and the differences between the means compared using a Tukey test (Table 2). This revealed a difference ($P < 0.05$) between the experimental conditions, with the athletes averaging faster times following the ingestion of the bicarbonate, but no significant difference between the P and C trials. The $T_{0.05}$ for the Tukey test was 2.6 s. Differences ($P < 0.001$) were also recorded among the athletes, which were to be expected due to differences in fitness.

Compared with group 1, a much greater intra-subject variation was noted for the finishing times of some of the athletes from group 2. There was also a trend for most athletes in group 2 to run a slower time

Table 1 Time taken to complete 1500 m (s) (range in brackets)[a]

Subject	Condition											
	Sodium bicarbonate				Placebo				Control			
	Trial 1	Trial 2	Mean	Diff. trial 1/ trial 2	Trial 1	Trial 2	Mean	Diff. trial 1/ trial 2	Trial 1	Trial 2	Mean	Diff. trial 1/ trial 2
1a	252.9	254.2	253.6	(1.3)	258.3	258.7	258.5	(0.4)	257.5	258.9	258.2	(1.4)
1b	249.6	248.2	248.9	(1.4)	251.9	252.1	252.0	(0.2)	253.4	251.3	252.3	(2.1)
1c	249.1	249.9	249.5	(0.8)	252.5	254.1	253.3	(1.6)	253.3	255.5	254.4	(2.2)
1d	254.3	254.7	254.5	(0.4)	256.7	257.6	257.1	(0.9)	258.2	259.4	258.8	(1.2)
1e	250.9	250.1	250.5	(0.8)	256.1	255.1	255.6	(1.0)	254.3	255.7	255.0	(1.4)
2a	238.1	238.9	238.5	(0.8)	241.1	243.9	242.5	(2.8)	240.7	241.7	241.2	(1.0)
2b	240.0	247.0	243.5	(7.0)	240.2	246.8	243.5	(6.6)	249.1	245.9	247.5	(3.2)
2c	246.9	254.9	250.9	(8.0)	253.1	254.9	254.0	(1.8)	253.1	253.8	253.5	(0.7)
2d	260.1	274.4	267.3	(14.3)	267.5	263.3	265.4	(4.2)	272.6	272.5	272.6	(0.1)
2e	274.7	289.4	282.1	(14.7)	287.1	284.0	285.6	(3.1)	286.7	286.7	286.7	(0.0)
Mean	251.7	256.2	253.9		256.5	257.1	256.8		257.9	258.1	258.0	
S.D.	10.3	14.8	12.4		13.4	11.0	12.2		12.9	13.0	12.9	

[a] Subjects from group 1 are prefixed with a 1 and subjects from group 2 are prefixed with a 2.

Table 2 Summary of two-way ANOVA with replicates for time taken to complete 1500 m (n = 10)

Source of variation	SS	d.f.	MS	F	P
Subjects	8355.2	9	928.4	85.4	< 0.001
Treatments	176.3	2	88.2	8.1	< 0.01
Interaction	72.5	18	4.0	4.0	
Within-groups	326.1	30	10.9		
Total	8930.3	59			

$T_{0.05}$ for the Tukey test = 2.6 s.

in the second of their two replicate runs. It is possible that this could be attributed to the extended period of testing, with levels of fitness and motivation altering over the 7-week period. Therefore, to assess any improvements or deteriorations in performance, a two-way ANOVA was used. This indicated no differences ($P < 0.05$) between the trials, and while the average times were faster during the first two trials, no distinct trend was evident. The average times for runs 1–6 were 254.3, 254.4, 257.5, 257.3, 257.4 and 256.3 s, respectively.

Discussion

The simulated track races produced results which support the belief that sodium bicarbonate can have a significant ergogenic effect during sustained high-intensity exercise such as 1500-m running. This is in agreement with the findings of Goldfinch *et al.* (1988) and Wilkes *et al.* (1983), who studied the 400 and 800 m, respectively, using similar protocols. The mechanism for the observed ergogenic effect was not investigated in this study, but previous research indicated that a more rapid efflux of protons from the exercising muscle and a greater buffering capacity in the extracellular fluid are the most likely causes (Gledhill, 1984; Hood *et al.*, 1988; Linderman and Fahey, 1991; Mainwood and Worsley-Brown, 1975; Roth and Brooks, 1990a,b).

It is interesting to compare the magnitude of the improvement in performance with bicarbonate ingestion in the present study in the first run with those found by Goldfinch *et al.* (1988) and Wilkes *et al.* (1983), who also used only one run under each condition. The improvement in running time between trials B and P would appear to be roughly in proportion to the distance run, with 1.5 s for the 400 m (Goldfinch *et al.*, 1988), 2.9 s for the 800 m (Wilkes *et al.*, 1983) and 4.5 s for the 1500 m (this study). This observation is not unexpected given the results of Osnes and Hermansen (1972), who when comparing different distances, reported the highest levels of lactate, lowest recordings of blood pH and the lowest levels of bicarbonate following the completion of 1500 m. All of these indicate that sodium bicarbonate ingestion could produce the largest absolute improvements over this distance.

In many respects, the statistical significance observed between the different experimental conditions might be considered surprising, when taking into account the number of uncontrollable variables to which the protocol was vulnerable. These included such factors as the weather and the influence of other athletes during the trials, both of which might have produced variations in running time of similar magnitude to any ergogenic effect, and thus masking it. Another noteworthy feature of the results was that although the athletes attempted to produce their fastest time in each trial, some were consistently below the times they recorded in competitive races within the duration of the investigation. The time the athletes recorded for their best P and C trials ranged between 101.8 and 106.9% of the best time they had recorded in either the current or previous season. This difference was generally in the region of 5 s and would tend to indicate that, despite the endeavours of the investigators, the simulated races did not reproduce fully the same set of circumstances as a competitive race for some individuals. This must be a consideration in any piece of research which attempts to assess the implications of a variable upon performance. However, in contrast to this, one of the athletes recorded a personal best time during his first bicarbonate trial.

Two of the athletes (subjects 2b and 2d) reported gastrointestinal disturbances such as stomach ache and diarrhoea. Neither of them was the heaviest athlete, so the disturbances are not likely to have been caused by the absolute dosage of bicarbonate ingested. They were subject 2b, who averaged the same time in his B and P trials, and 2d, whose average was faster in his P trial. Both averaged faster performances in their B trials than their control runs (C). It is possible that the gastrointestinal disturbance in these two athletes could have interfered with the potential improvement in the B trials compared with the P trials, which was observed in the other participating athletes.

In conclusion, the results of the study indicate that the ingestion of sodium bicarbonate can have an ergogenic effect on 1500-m running, but that the effects could be prone to individual variations, in particular the athletes' susceptibility to gastrointestinal disturbances.

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