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Effects of Sodium Bicarbonate Ingestion during an Intermittent Exercise on Blood Lactate, Stroke Parameters, and Performance of Swimmers

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ABSTRACT

Campos EZ, Sangali EB, Gerosa Neto J, Gobbi RB, Freitas Junior IF, Papoti M. Effects of Sodium Bicarbonate Ingestion during an Intermittent Exercise on Blood Lactate, Stroke Parameters, and Performance of Swimmers. **JEPonline** 2012;15(6):84-92. The purpose of this study was to investigate the effects of sodium bicarbonate ($NaHCO_3$) ingestion in high intensity intermittent exercise on blood lactate ($[La^-]$), stroke parameters, and performance of swimmers. Ten swimmers completed six maximal front crawl efforts of 100 m interspaced by 6 min of rest in both situations: $NaHCO_3$ (SB) and dextrose (placebo). The SB (0.3 $g \cdot kg^{-1}$ of body mass) or the placebo was ingested 60 min before the training in gelatin capsules. After each effort, the rating of perceived exertion (RPE) was assessed and blood sample was collected. Stroke length (SL), stroke rate (SR), and stroke index (SI) were measured. All parameters were compared using two-way repeated measures ANOVA, followed by Tukey post-hoc test. The significance was set at 5%. The $[La^-]$ in the sixth effort after SB (17.93 ± 3.8 $mmol \cdot l^{-1}$) supplementation was significantly higher than placebo $[La^-]$ (15.67 ± 3.29 $mmol \cdot l^{-1}$) ($P<0.05$). No difference was found between SB and placebo for the time·100 m^{-1} of any of the six swims. Neither stroke parameters (SL, SF, and SI) nor RPE were significantly different in all swim efforts. In conclusion, $NaHCO_3$ did not improve performance in swimming training, but did enhance the glycolytic source without alteration of RPE.

Key Words: Swimming, Sodium Bicarbonate Supplementation, Rating of Perceived Exertion, Exercise

INTRODUCTION

The success of intermittent training is dependent on intensity and effort recovery relationship that consists of increases both aerobic and anaerobic components (5,10,23,30). When compared to continuous training of the same energy expenditure, intermittent exercise promotes an improvement in carbohydrate and lactate metabolism (18). Elevated glycolytic metabolism increases the production of lactic acid and the dissociation into hydrogen ions (H^+) and lactate, simultaneously decreasing the pH of the blood (11,16,30). Among the effects of reduced pH (increased H^+) are the inhibitions of calcium ions released from the sarcoplasmic reticulum, of the interaction of actin and myosin, and of the activity of phosphofructokinase. All three effects lead to decreased force production (20).

The use of sodium bicarbonate ($NaHCO_3$) is suggested to delay fatigue during maximal efforts with duration between 1 to 10 min (2,14,20) by mitigating the decline of pH (6,12). Thus, despite some contradictory findings (3,14,21,24,25,27,28) about the ergogenic effects of $NaHCO_3$, it has been used to enhance performance in several sports (6,18,22). Lindh et al. (14) found that supplementation of 300 $mg \cdot kg^{-1}$ of $NaHCO_3$ improved the performance of 200 m in elite swimmers due to the increase in buffering capacity. The benefits of $NaHCO_3$ on high intensity intermittent exercise were recently demonstrated. Findings by Siegler and Gleadall-Siddall (21) suggest a potential use of $NaHCO_3$ in training sessions for swimmers who want to improve the quality of their high-intensity training.

In swimming, the quality of the training sessions is extremely dependent on the stroke parameters (21). If $NaHCO_3$ promotes the maintenance or even alleviates the deterioration in stroke parameters during the sessions of intermittent high-intensity training, it would be reasonable to conclude that the swimmers would benefit from this nutritional strategy. However, to our knowledge, no study assessed the effects of $NaHCO_3$ on the changes in the parameters of swimming together with the performance of the swimmers. Thus, the aim of the present study was to evaluate the effect of supplementation of $NaHCO_3$ on the mechanical parameters of swimming, physiological responses, rating of perceived exertion, and performance of high-level swimmers.

METHODS

Subjects

Ten swimmers (3 female and 7 male) (mean ± SD: age 18.33 ± 3.33 yr), volunteered to participate in the present study. The subjects had a minimum of 2 yr in competitive swimming, training a volume of approximately 7000 $m \cdot d^{-1}$ with a frequency of 6 $d \cdot wk^{-1}$. Personal best times were at 85% of the world record of the specific style. The subjects were informed about experimental procedures and risks, and signed an informed consent before their participation in the study. The experimental protocol was approved by the Research Ethics Committee of the associated institution and was performed in accordance with ethical standards.

Procedures

The tests were performed in a 25 m outdoor pool with a water temperature of 24-25ºC. At the end of the specified preparatory period, the tests took place in 3 days with an interval up to 7 days. During the first day, body composition was estimated by a Dual-Energy X-ray Absorptiometry (DEXA,Lunar DPX-NT; General Electric Healthcare, Little Chalfont, Buckinghamshire, with software version 4.7). During the 2nd and 3rd days, the swimmers performed, randomly, six maximal efforts of 100 m after ingestion of $NaHCO_3$ (SB) or dextrose (placebo). A double-blind protocol was used. In order to keep the testing as close as possible to the practice sessions, the training load for each subject (i.e., athlete) was kept as usual.

Supplementation of Sodium Bicarbonate and Placebo

The SB supplementation involved a dose of 0.3 mg·kg^{-1} of body mass, while the placebo was the same dose of dextrose. The supplements were consumed 60 min before the start of efforts (13) with water consumption *ad libitum*. To reduce gastro intestinal discomfort the $NaHCO_3$ was ingested with individualized number of gelatin capsules (27).

Mechanical Stroke Parameters and Rating of Perceived Exertion (RPE)

The subjects indicated their rating of perceived exertion (RPE) at the end of each effort, using a table of 15 points (6-20) (4). Mechanical stroke parameters, the stroke frequency (SF), stroke length (SL), and stroke index (SI) were determined. The SF was determined by the ratio between the number of strokes (NS) and time·100 m^{-1}. The SL parameter was determined by dividing the NS for 100 m. The SI was assumed as the product between SL and swimming speed (7).

Blood Analysis and Lactate Accumulation Index (LAI)

Resting blood samples were collected prior to the warm-up of the subjects. After each effort, 25 µl of blood were collected and immediately deposited in eppendorfs tubes containing anticoagulant solution of sodium fluoride (1%). Later, the blood was analyzed using a lactimeter YSI Yellow Spring (Sport Model -1500®) to determine the lactate concentration ([La$^-$]). The subjects were verbally encouraged throughout the tests to ensure the attainment of maximal effort (8). The LAI was calculated in each sprint as the ratio of the [La$^-$] and the time·100 m^{-1} (s) (LAI = [La$^-$]/(time·100 m^{-1}).

Statistical Analyses

The normality and homogeneity of the data were confirmed with the Shapiro-Wilk's test and Levene's test, respectively. The physiological values ([La$^-$] and LAI), the mechanical parameters, and the time·100 m^{-1} (T1^o, T2^o, T3^o, T4^o, T5^o, T6^o) obtained in the placebo and SB conditions were compared by two-way ANOVA test for repeated measures, the post-hoc Tukey's test was used to evaluate the difference between the efforts and the placebo and SB conditions. The significance was set at 5%.

RESULTS

Significant differences were found between the times in the six 100 m effort both in the placebo and the SB conditions, while between placebo and SB no significant differences were found (Figure 1).

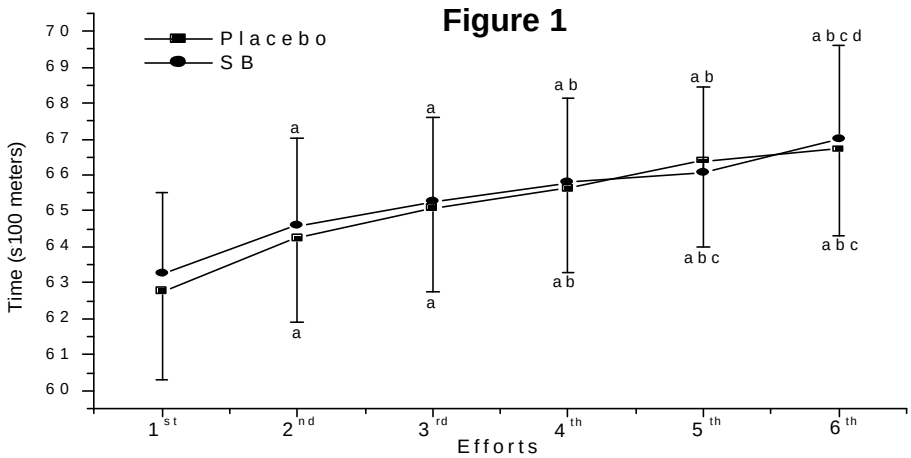

Figure 1. Performance (s·100 m^{-1}) Alterations During the 100 meters Efforts. ¦ , time (s·100 $^{-1}$) during the placebo condition; ?, time (s·100 m^{-1}) during SB. a, significantly difference of the 1st effort; b, significantly difference of the 2nd effort; c, significantly difference of the 3rd effort; d, significantly difference of the 4th effort.

The [La$^-$] in the 6º effort was significant higher in SB (17.93 ± 3.8 mmol·l^{-1}) compared with placebo (15.67 ± 3.29 mmol·ll^{-1}). In both conditions the [La$^-$] in the first effort was significantly lower than in the subsequent five, and the last effort was higher than the 2º, 3º and 4º sets (Figure 2).

Figure 2

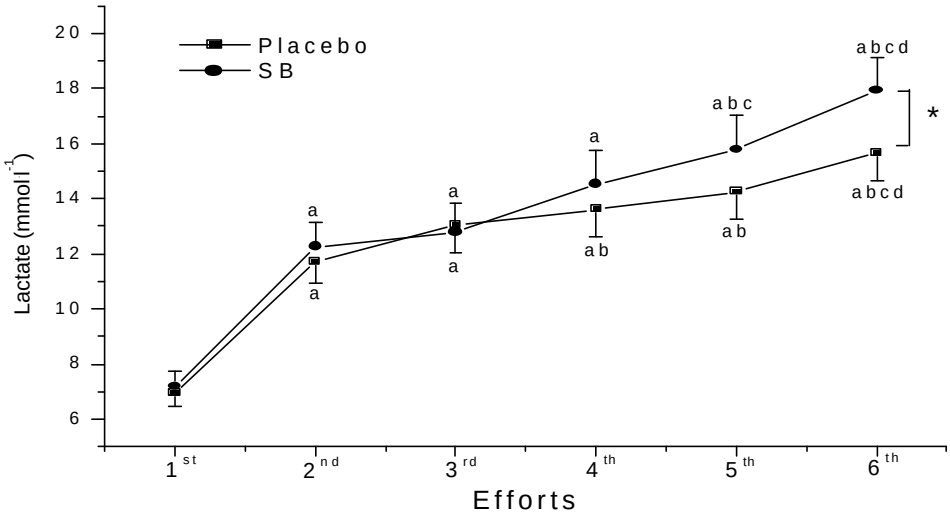

Figure 2. Lactate Concentration (mmol·l^{-1}) After Each 100 meters Effort. ¦ , [La$^-$] (mmol·l^{-1}) during the placebo condition; ?, [La$^-$] (mmol·l^{-1}) during SB. a, significantly difference of the 1st effort; b, significantly difference of the 2nd effort; c, significantly difference of the 3rd effort; d, significantly difference of the 4th effort. * P<0.05.

No difference was found in RPE between the placebo and SB. However, significant differences were found between RPE in the same condition (Figure 3).

Figure 3

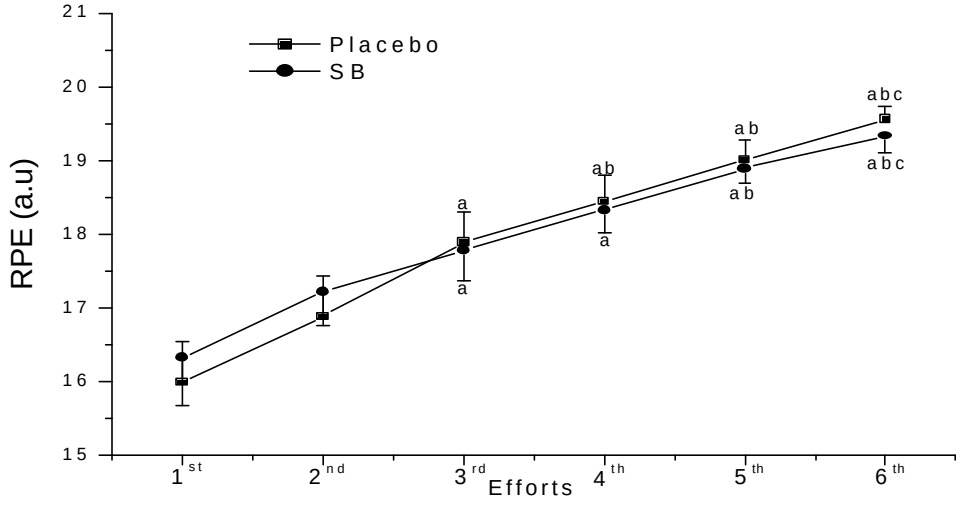

Figure 3. Rating Perceived Exertion (a.u) of Each 100 meters Effort. ¦ , RPE (a.u) during the placebo condition; ?, RPE (a.u) during SB. a, significantly difference of the 1st effort; b, significantly difference of the 2nd effort; c, significantly difference of the 3rd effort

In Table 1 are arranged the stroke parameters (SL, SF, and SI) of the six trials in two conditions (placebo and SB). No significant difference was found between SB and placebo in the stroke parameters. During the efforts, alterations were founds in SL, SF, and SI of placebo and SB (Table 1). A significant difference was found between placebo and SB in LAI of the 6th sprint (0.23 ± 0.06 mM·seg^{-1} vs. 0.27 ± 0.07 mM·seg^{-1}, respectively). No difference was observed between placebo and SB in other efforts.

Table 1. Stroke Parameters (mean ± SD) for SB and Placebo Condition at All the Six Effort.

	SF (Hz)		SL (m)		SI (a.u)	
	SB	Placebo	SB	Placebo	SB	Placebo
1st	1.19 ± 0.1	1.18 ±0.12	1.41 ± 0.16	1.42 ± 0.18	2.18 ± 0.42	2.26 ± 0.45
2nd	1.16 ± 0.1	1.15 ± 0.10	1.38 ± 0.15	1.40 ± 0.17	2.15 ± 0.41	2.19 ± 0.46[a]
3rd	1.14 ± 0.1	1.12 ± 0.11[a]	1.37 ± 0.14	1.40 ± 0.18	2.11 ± 0.40[a]	2.17 ± 0.45[a]
4th	1.12 ± 0.1[a]	1.11 ± 0.10[ab]	1.35 ± 0.13[a]	1.38 ± 0.18[a]	2.08 ± 0.40[ab]	2.15 ± 0.45[a]
5th	1.11 ± 0.1[abc]	1.10 ± 0.10[ab]	1.33 ± 0.13[ab]	1.36 ± 0.16[abc]	2.06 ± 0.38[ab]	2.12 ± 0.45[ab]
6th	1.07 ± 0.1[abc]	1.09 ± 0.11[abc]	1.31 ± 0.13[abc]	1.35 ± 0.16[abc]	2.03 ± 0.38[abc]	2.09 ± 0.44[abcd]
Mean	1.13 ± 0.1	1.13 ± 0.11	1.38 ± 0.14	1.39 ± 0.17	2.15 ± 0.40	2.17 ± 0.45

Abbreviations: SF; stroke frequency, SL; stroke length, SI; stroke index, SB; sodium bicarbonate trial, Placebo; placebo trial. [a], significantly different of the 1st effort; [b], significantly different of the 2nd effort; [c], significantly different of the 3rd effort; [d], significantly different of the 4th effort.

DISCUSSION

The primary finding was that $NaHCO_3$ supplementation had no ergogenic effect on the subjects' performance of 6 consecutive 100 m efforts with 6 min interval. But, $NaHCO_3$ supplementation did result in an increase [La$^-$] in the last effort without a change in RPE.

Although $NaHCO_3$ promotes an ergogenic effect on efforts lasting 1 to 10 min (14,19), the present study showed no improvement in the performance of any 100 m effort in the SB condition. The decrease in performance during the 6 efforts was similar in placebo and SB conditions (Figure 1). These findings are in disagreement with Lindh and colleagues (14) reported a single effort of 200 m performance improvement in elite athletes. Despite the different methodology, the first 100 m effort of the present study was not different between placebo and SB. It seems that elite athletes are able to swim faster. They also seem to present greater anaerobic capacity that allows for a higher level of acidosis and, therefore, benefit from $NaHCO_3$ more than non-elite athletes.

Siegler and Gleadall-Siddall (21) reported on the effect of $NaHCO_3$ in trained swimmers following eight sets of 25 m with a 5-sec pause, and found a reduction in the total time of the sets (placebo: 163.2 ± 25.6 sec, SB: 159.4 ± 25.4 sec). Thus, the elimination of turn component could have influenced the subjects' improvement in swimming speed. In the present study, no difference in placebo and SB was found in any time·100 m^{-1}, and, as discussed by Siegler and Gleadall-Siddall

(21) and Lindh and colleagues (14), the technical and competitive level of the subjects may have influenced their performance and, therefore, the turn may have diluted the improvement in SB.

In addition, the interval between the sets may have influenced the response of the swimmers. Siegler and Gleadall-Siddall (21) used a shorter recovery time (5 sec) and found differences in performance. Although the present study did not analyze pH alterations, the dose of $NaHCO_3$ (0.3 $mg \cdot kg^{-1}$) was used in other studies (18,24,30) and showed to be effective in changing pH and the concentration of bicarbonate ion. The $[La^-]$ was significantly higher at the end of the last 100 m effort (placebo: 15.67 ± 3.29 $mmol \cdot l^{-1}$ and SB: 17.93 ± 3.80 $mmol \cdot l^{-1}$; $P<0.05$).

The increase in $[La^-]$ was reported by several studies (6,18,27). Some hypotheses may explain the higher values of $[La^-]$ on SB. The first one is related to the fact that the elimination of $[La^-]$ is increased when the extracellular pH increases, justifying the increased $[La^-]$ with the $NaHCO_3$ supplementation (12,15). The second relates to the higher glycolytic activity and anaerobic energy production due to a better internal environment, which would increase performance. However as to this hypothesis, in the present study, it was not confirmed since there was no significant difference between the $time \cdot 100m^{-1}$ in placebo and SB. Notwithstanding, the protocol used in the present study consisted of sets of specific training for improvement in the tolerance to acidosis, so SB, besides achieving the goal of training, allowed for a higher production of $[La^-]$ without a decrease in the performance of the subject.

The RPE was used to estimate physical stress during exercise. This approach is due to the close relationship between RPE and physiological markers related to intensity (such as heart rate and blood lactate) (9,17). The present study found no significant difference between the values of RPE in placebo or SB, but $[La^-]$ was higher in the last set of SB (17.93 ± 3.80 $mmol \cdot l^{-1}$ vs. 15.67 ± 3.29 $mmol \cdot l^{-1}$). Yamanaka et al. (26) did not find any difference in RPE when studying the legs, even with higher $[La^-]$ in SB after a set of intense exercise, which is in agreement with the present study. Numerous studies have shown elevated $[La^-]$ after $NaHCO_3$ supplementation (6,18,27). So, it seems that despite the no change in RPE, SB increased the production capacity and the lactate tolerance. Therefore, the ergogenic effect may be beneficial in training that is aimed at increasing tolerance and/or $[La^-]$ production.

As to the effect of SB on mechanical stroke parameters of swimming, no differences were found. The SF and SL did not change due to maintenance of the number of strokes in 100 m efforts. In the same way, such as no change in swimming speed ($time \cdot 100\ m^{-1}$) was verified (given that the SI was similar between the conditions. According to Siegler and Gleadall-Siddall (21), performance in swimming depends on mechanical factors such as the turn component (21) as well as the level of the athletes (elite, competitive, and non-elite) and protocol used (i.e., the time of stimulus and the recovery time).

The LAI in the last sprint was significantly higher with the ingestion of SB (0.23 ± 0.06 $mM \cdot seg^{-1}$ vs. 0.27 ± 0.07 $mM \cdot seg^{-1}$). The significant increase of $[La^-]$ in the last sprint in the SB condition is due to factors already mentioned, which influenced the higher LAI. According to Deminice et al. (8), LAI has positive association with swimming parameters, confirming the relationship between physiological and mechanical parameters. Despite the accumulation of lactic acid cause great discomfort, loss of efficiency and coordination of the swimmers (1), the present study did not observe changes of parameters with concomitant increase in $[La^-]$.

CONCLUSIONS

We conclude that the $NaHCO_3$ supplementation does not improve performance and stroke parameters after a session of high intensity intermittent training, with a mean duration of 65.2 sec and a 6-min interval. However, the [La^-] tolerance increases without changing the RPE and swimming parameters, being a good ergogenic to increase lactate tolerance. While this ergogenic might be useful in training sessions, it appears that it is not helpful in one single effort. This thinking may change with elite athletes where $NaHCO_3$ may help to improve performance due to better anaerobic performance and technical skills

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