

## Research Article

### The Effect of Sodium Bicarbonate in Sports Drink on the Metabolism of Athletes

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**Abstract:** It is known that sodium bicarbonate ( $\text{NaHCO}_3$ ) is used by athletes before exercise to delay fatigue and improve performance based on the knowledge that it removes  $\text{H}^+$  ions from the body through the creation of a metabolic alkalosis state. In this study, the effects of 0.3 g/kg  $\text{NaHCO}_3$  given orally to athletes and non-athletes before a 600 m race were compared. After resting for 48 h, 0.3 g/kg  $\text{NaHCO}_3$  was given orally as a 500 mL fruit juice and the same determinations made under the same conditions 2 h later. In the study, the time taken to complete race after the administration of  $\text{NaHCO}_3$  fell compared to that before its administration in the athletes. The level of  $\text{HCO}_3^-$  before the administration of  $\text{NaHCO}_3$  in the athletes was observed to be higher than after the administration of  $\text{NaHCO}_3$ . A rise in the HLa levels was observed after exercising following the administration of  $\text{NaHCO}_3$  in the athletes. The differences in the other parameters apart from that in pH were not statistically significant ( $p < 0.01$ ), ( $p < 0.05$ ). In conclusion, it can be said that, use of  $\text{NaHCO}_3$  at doses low enough not to cause gastrointestinal disturbances is one of the factors that positively affect anaerobic performance in athletes, but this effect is lower than that observed in individuals leading sedentary lives.

**Keywords:** Administration, athletes, exercise performance, metabolism, sodium bicarbonate

## INTRODUCTION

Sodium bicarbonate, also known as baking soda, is a common baking ingredient you can buy in any grocery store. You can also find a version of it in every person working and shopping in those stores, because bicarbonate is a naturally occurring substance in the human body. Normally produced by the kidneys and in a lesser degree in the intestinal tract, bicarbonate works to eliminate hydrogen ions and reduce acidity in the blood (Ahrendt, 2001). Given how blood acidity builds up over the course of strenuous exercise, it should be no surprise that people have looked at sodium bicarbonate as a performance supplement. Sure enough, it's an ingredient in some pre-workout and fat-burner blends, but it may also be one of the longest-lived supplements (Requena *et al.*, 2005). Competitive endurance athletes in particular have been including baking soda for decades in their own home-brewed pre-workout blends.

Sodium bicarbonate (baking soda) is a supplement that provides dietary bicarbonate, which can increase serum levels of bicarbonate (normally produced by the kidneys) and subsequently buffer acid production in the body. The main mechanism of action of sodium bicarbonate is in negating the effects of acidosis (Maughn *et al.*, 2004a). It provides benefits both in situations of chronic mild acidosis, commonly seen in metabolic ailments or during aging as kidney function slowly declines and in exercise-induced acidosis.

In athletes, the standard doses of sodium bicarbonate supplementation (200-300 mg/kg) tend to

reliably benefit performance when failure on the exercise is associated with metabolic acidosis, aka "the burn." Sports where failure occurs due to the cardiorespiratory system or due to force production by the central nervous system (e.g., single sprints or elite rowers) do not appear to reliably benefit from supplemental bicarbonate. Benefits of sodium bicarbonate can be observed with a single dose taken 60-90 min before exercise, but supplementation should be approached cautiously as it can cause gastrointestinal side effects if too much is taken at once or, if it's consumed too rapidly (Stellingwerff *et al.*, 2007).

With developments in the field of sports, a direct result of the effects of increasing professionalism in sports, records have become unbreakable and in a field where seconds and milliseconds as well as grams have become important, studies aimed at improving performance have also gained intake of sodium bicarbonate ( $\text{NaHCO}_3$ ) a pharmacological ergogenic, before exercise, delays fatigue by removing  $\text{H}^+$  ions from the body through the creation of a metabolic alkalosis state, it has been used by athletes to enhance performance (Maughn *et al.*, 2004b) The bicarbonate ( $\text{HCO}_3^-$ ) system, one of the buffer systems responsible for the removal of lactic acid from the body is a natural buffer system that preserves the acid-base balance in the intra- and extracellular spaces as well as the blood and skeletal muscles.

Though the energy yield of anaerobic glycolysis is low, as a result of the formation of high glucose, the amount of lactic acid in muscles and blood rises as the

pH falls. The rise in lactic acid levels is the result of the increase in the hydrogen ion ( $H^+$ ) concentration in both the intracellular and extracellular spaces. The major cause of fatigue seen in exercise under anaerobic conditions has for many years been attributed to the increase in the  $H^+$  ion concentration.

The buffering power of a solution is directly related to its concentration. For this reason, if the concentration of the buffer is increased its capacity to neutralize metabolic acids will also increase proportionately (McNaughton *et al.*, 1999). During vigorous exercise 15-18% of the total buffering capacity is derived from the bicarbonate system. When the capacity of the extracellular buffers are increased the efflux of lactate and  $H^+$  ions from cells increases.

A fall in the  $H^+$  accumulation probably increases performance to some degree. For this reason, in an attempt to increase the buffering capacity of the body in order to compensate for the metabolic acidosis to prevent the fall in pH as well as prolong the onset of fatigue, sodium bicarbonate taken orally was given the preference in this study. The aim of this study was to investigate the effect of an oral intake of 0.3 g/kg  $NaHCO_3$  prior to a 600 m racing exercise in athletes and non-athletes.

## MATERIALS AND METHODS

**Materials:** In this study volunteer athletes actively involved in sprinting and who were with their teams in the current season and those non-athletes similarly matched for age were enrolled. The subjects were briefed on the aim of the study as well as the tests and blood analysis to be conducted during the study period.

**Research methods:** Before and after racing, the heart beats of the subjects were measured, a briefing about the contents of the study made and the maximal oxygen consumption values estimated by the Shuttle Run Test. On both testing days they were fed with diets of similar contents at the same times (3 h before the exercise). The subjects were given placebo orally, 2 h before exercising on the first day and after a 10 min warm-up made to run for 600 m and their times recorded. After resting for 48 h the subjects were offered 500 mL of fruit juice premixed with 0.3 g/kg  $NaHCO_3$ . After resting for 2 h they were again made to run a 600 m race and their times recorded.

For the determination of the blood pH,  $HCO_3^-$  and HLa levels, blood was drawn with a heparinized 2 mL syringe from a vein in the forearm of the subjects before and after the race. The blood samples taken from the subjects were analyzed in the Stat Profile Ultra C blood gas analyzer from Nova Medical. The pH,  $HCO_3^-$  and HLa values were printed from a printer attached to the analyzer within 90 sec. The SPSS (Statistical Package for the Social Sciences) v11.0 packet program was used

in the analysis of the data from the study. The one-way ANOVA and student t tests were used in the statistical analysis of the results obtained. P values of ( $p < 0.01$ ) and ( $p < 0.05$ ) were considered statistically significant.

## RESULTS AND DISCUSSION

**Results display:** In both groups, comparison of exercise performance after the administration of placebo and  $NaHCO_3$  revealed much higher levels in that for  $NaHCO_3$ . The difference was found to be statistically significant ( $p < 0.05$ ).

In Table 1, the  $HCO_3^-$ , pH and HLa levels after the administration of placebo and  $NaHCO_3$  in the athletes are shown. Whereas the difference in pH levels before and after exercise was not found to be significant ( $p > 0.05$ ), while that of the  $HCO_3^-$  and HLa concentrations were observed to be statistically significant ( $p < 0.01$ ). In Table 2, comparison of the  $HCO_3^-$ , pH and HLa levels before and after exercise in athletes after the administration of placebo and  $NaHCO_3$  is presented. Whereas no significant difference was observed in the pH before and after exercise ( $p > 0.05$ ), the differences in the  $HCO_3^-$  and HLa concentrations were found to be statistically significant ( $p < 0.05$ ), ( $p < 0.01$ ). In Table 3, comparison of the  $HCO_3^-$ , pH and HLa levels before and after exercise after the

Table 1: Comparison of the  $HCO_3^-$ , pH and HLa levels after the administration of placebo and  $NaHCO_3$  before and after exercise (average  $\pm$  standard deviation)

n = 20		
$HCO_3^-$		
mMol/L	Placebo	24.29 $\pm$ 1.34
	$NaHCO_3$	26.13 $\pm$ 0.94
pH	Placebo	7.300 $\pm$ 0.05
	$NaHCO_3$	7.400 $\pm$ 0.07
HLa	Placebo	2.210 $\pm$ 0.73
mMol/L	$NaHCO_3$	2.480 $\pm$ 0.77

Table 2: Comparison of the  $HCO_3^-$ , pH and HLa levels in the non-athletes after the administration of placebo and  $NaHCO_3$  (average  $\pm$  standard deviation)

n = 20		
$HCO_3^-$		
mMol/L	Placebo	25.32 $\pm$ 1.28
	$NaHCO_3$	26.80 $\pm$ 0.97
pH	Placebo	7.340 $\pm$ 0.05
	$NaHCO_3$	7.470 $\pm$ 0.09
HLa	Placebo	3.440 $\pm$ 0.65
mMol/L	$NaHCO_3$	3.520 $\pm$ 0.88

Table 3: Comparison of the  $HCO_3^-$ , pH and HLa levels after the administration of placebo and  $NaHCO_3$  in athletes and non-athletes (average  $\pm$  standard deviation)

n = 20		
$HCO_3^-$		
mMol/L	Placebo	24.29 $\pm$ 1.34
	$NaHCO_3$	26.13 $\pm$ 0.94
pH	Placebo	7.300 $\pm$ 0.05
	$NaHCO_3$	7.400 $\pm$ 0.07
HLa	Placebo	2.210 $\pm$ 0.73
mMol/L	$NaHCO_3$	2.480 $\pm$ 0.77
		Non-athletes group
		25.32 $\pm$ 1.28
		26.80 $\pm$ 0.97
		7.340 $\pm$ 0.05
		7.470 $\pm$ 0.09
		3.440 $\pm$ 0.65
		3.520 $\pm$ 0.88

administration of placebo and NaHCO<sub>3</sub> in athletes and non-athletes is presented. The differences in the pre-exercise pH levels ( $p > 0.05$ ) and the HCO<sub>3</sub><sup>-</sup> and HLa concentrations were found to be statistically significant ( $p < 0.05$ ).

**The effect of NaHCO<sub>3</sub> on anaerobic performance:** In this study the effects of 0.3 g/kg of NaHCO<sub>3</sub> given in fruit juice to the subjects 2 h before exercising on the HCO<sub>3</sub><sup>-</sup>, pH, HLa concentrations and the performance during the 600 m race were investigated. With the aim of investigating the effect of NaHCO<sub>3</sub> use on anaerobic performance, the times taken for the subjects to complete a race of 600 m after placebo and NaHCO<sub>3</sub> was administered were compared. In the athlete group, after the administration of NaHCO<sub>3</sub> the racing time of  $1.42 \pm 0.44$  sec though still lower than that of the placebo racing time of  $1.51 \pm 0.18$  sec was below that expected. In subjects leading sedentary lives, the racing time after the administration of NaHCO<sub>3</sub> was  $2.07 \pm 1.02$  sec, while after administration of placebo fell to  $2.02 \pm 1.33$  sec. The fall in athlete time was 9 sec whereas that in the non-athletes group remained at 5 sec. In both groups the difference was found to be statistically significant.

Considering the fact that NaHCO<sub>3</sub> taken before exercise leads to removal of hydrogen ions from the exercising muscles the result of which is increase in performance due to the delay in the onset of fatigue, the result obtained from this study demonstrates its agreement with other studies. In some studies, the use of NaHCO<sub>3</sub> has not been demonstrated to affect exercise performance. In several studies there is a general consensus that after the administration of an alkali substance there is an increase in the pH and HCO<sub>3</sub><sup>-</sup> levels before exercise as well as in the HLa value after exercise. The results of this study are in line with this consensus. However, it does not seem to agree with the suggestion that it increases performance to any significant extent. An explanation for this controversy probably is the fact that the gastrointestinal disturbances associated with NaHCO<sub>3</sub> in our subjects who were exposed to NaHCO<sub>3</sub> for the first time could have negatively affected the performance. Inasmuch as the psychological effects of substance use was reduced through the administration of placebo, from field studies conducted, the fact that standardization of physical, mental and psychological factors known to affect performance has not been possible, coupled with factors such as the adverse effects of NaHCO<sub>3</sub> like nausea seen in our subjects that can also act as barriers to the increase in performance might have all contributed to the results.

The effect of the reactions from exercise that limits performance can only be offset by the buffering mechanisms that keep the internal milieu of the organism constant by maintaining the acid-base balance. Support is offered to the organism by delaying the onset

of fatigue in this way. The bicarbonate buffer system, one of the buffering systems that provide this support, accounts for 15-18% of the total buffering capacity under vigorous exercise. The aim in the administration of sodium bicarbonate was to enhance the removal of the HLa and H<sup>+</sup> ions from muscle tissues through the establishment of an alkalosis condition during vigorous exercise. This fall in the HLa and H<sup>+</sup> concentrations delays the onset of fatigue and so leads to improved performance. In this study, the pre-exercise HCO<sub>3</sub><sup>-</sup> level was higher after the administration of NaHCO<sub>3</sub> than after placebo in both the athlete and non-athlete groups. At the end of the study, with the aim of improving anaerobic performance and to determine whether differences exist between that of athletes and those leading sedentary lives or not, an increase in the HCO<sub>3</sub><sup>-</sup> concentration, the buffering component, was observed after the administration of bicarbonate in both groups. The increase was higher in the athletes than in those in the non-athletes. Comparison of the max VO<sub>2</sub> values of the subjects in the study revealed values of  $31.16 \pm 3.25$  mL/kg/sec for the non-athletes group and  $42.85 \pm 4.55$  mL/kg/sec for the athletes group with the difference between the two groups statistically significant. The increase in the HCO<sub>3</sub><sup>-</sup> levels in the athletes can be explained by their increased oxygen consumption reflected in their higher max VO<sub>2</sub> values.

Whereas the contraction mechanism is negatively affected by a falling pH, at the same time the efflux of calcium ions (Ca<sup>++</sup>) from the sarcoplasmic reticulum and its binding to troponin is also impeded by the low pH. In this state the pH is considered a critical limiting factor. Even minimal changes in the intracellular pH are known to cause changes in the rates of chemical reactions in cells. In this study, whereas the pre-exercise ( $7.30 \pm 0.05$ ) and post-exercise ( $7.02 \pm 0.10$ ) pH values in the athletes were found to be different, an increase in pH values was found both before ( $7.40 \pm 0.07$ ) and after ( $7.16 \pm 0.09$ ) exercise after the administration of NaHCO<sub>3</sub> compared to that after placebo. In the non-athlete group also, similar increases were observed with both the placebo and the NaHCO<sub>3</sub> studies. This increase in pH can thus be considered the positive effect of bicarbonate intake on the pH. Assuming that the extracellular pH is the most important determinant of the efflux rate of H<sup>+</sup> ions and HLa from muscle tissues, the importance of this change in pH during anaerobic exercise is increased another fold. In a similar manner, this change leads to improvement in muscle functions and contributes to performance.

**The effect of NaHCO<sub>3</sub> on the blood and muscle pH levels:** Similar results were obtained in this study with the aim of determining the blood and muscle pH levels under maximal exercise.

As lactic acid production increases during maximal vigorous exercise the H<sup>+</sup> ions concentration at the

intracellular and extracellular compartments also increases. This in turn leads to metabolic acidosis. Accumulation of lactic acid is the direct result of increase in the intracellular and extracellular  $H^+$  concentrations. Increase in the  $H^+$  ions has for years been advocated to be the major cause of fatigue in exercise under anaerobic conditions. It is known that  $H^+$  ions have inhibitory effects on the glycolytic enzymes, especially on the secretion of phosphofructokinase. In our study, post-exercise HLa levels in the athletes after the administration of  $NaHCO_3$  was found to be higher than that before exercise ( $2.48 \pm 0.77$ - $15.04 \pm 1.92$  mMol/L), with the difference being statistically significant ( $p < 0.05$ ). After the administration of  $NaHCO_3$  in the non-athlete group, the post exercise HLa levels were found to have increased relative to that before exercise ( $3.52 \pm 0.88$ - $15.10 \pm 2.07$ ). The increase was higher than that observed in the athletes group. The  $NaHCO_3$ , taken before anaerobic exercise, by raising the alkalosis condition enhanced the removal of  $H^+$  and HLa thereby delaying fatigue. By delaying fatigue performance is positively affected. In our investigation, the increase in the blood HLa concentration due to the ingestion of  $NaHCO_3$  showed similarity with those from some other studies. However, relative to the blood HLa increase, in the bicarbonate study a higher fall in pH would have been expected. The lack of a proportionate fall in pH with the increasing HLa in this study can be explained by the fact that the gastrointestinal adverse effects could have affected them since it was the first time subjects from both the athlete and non-athlete groups were exposed to  $NaHCO_3$  use.

During exercise the energy used by the muscle tissues is obtained from the metabolic processes that food substances ingested by the organism are subjected, resulting in their breakdown into sources of energy. The work done here is limited by the amount of energy stored, the rate of breakdown, liberation of by-products and the neurological activation of the muscles. During short duration maximal intensity exercise accumulation of HLa occurs as a result of anaerobic glycolysis which in turn leads to increase in the concentration of  $H^+$  ions in both blood and muscles.

Secretion of  $H^+$  ions and its resultant fall in the intracellular pH levels lead to inhibition of the glycolytic pathway and the contracting ability of the muscles. The probable result of this is fatigue and the negative effect on performance.

**Role of sodium bicarbonate during high-intensity exercises:** During high-intensity exercise, muscles keep up with the demand for energy by converting some carbohydrate to lactic acid. A build-up of acid inside the muscle cells is one of the factors responsible for fatigue. This system's total capacity is limited by the progressive increase in acidity within the muscles caused by the accumulation of lactate and  $H^+$  ions. Increased acidity

ultimately inhibits energy transfer and the ability of the muscles to contract, leading to a decrease in exercise performance. Reducing the build-up of acid should reduce fatigue and allow the athlete to go faster or further. The body's defenses against an increase in acidity are the bicarbonate "buffers", which help to neutralize the acid produced by intense exercise. The natural bicarbonate supply, part of the body's buffering system, provides a rapid first line of defense against this increased acidity.

Sodium bicarbonate is an alkalizing agent and therefore reduces the acidity of the blood (known as a buffering action). By buffering acidity in the blood, bicarbonate may be able to draw more of the acid produced within the muscle cells out into the blood and thus reduce the level of acidity within the muscle cells themselves. This in turn could delay the onset of fatigue. Studies have confirmed that increased extra cellular pH and higher bicarbonate raise the  $H^+$  and lactic acid efflux from active muscles. This is due to an increase in the activity of the Lactic acid/  $H^+$  co-transporter, which becomes more active as the intracellular/extracellular  $H^+$  gradient increases, during contraction as well as during recovery. It has been suggested that this mechanism causes a decrease in muscular fatigue, delaying the decrease in pH level and leading to a greater contractile capacity of the muscular tissue involved by means of enhanced muscle glycolytic ATP production. It has been proven that all of these metabolic perturbations imply a shift in muscle metabolism toward anaerobic energy production, which is especially advantageous during high-intensity exercise.

Taking a sufficient quantity of sodium bicarbonate (baking soda) before high-intensity event makes the muscles and blood less acidic during the event and can enhance physical performance. Athletes have been practicing "soda loading" or "bicarbonate loading" for over 70 years in an attempt to delay the onset of muscular fatigue during prolonged anaerobic exercise. The specific athletes who might stand to benefit from soda supplementation are those who typically compete in events that last between 1 and 7 minutes, i.e., 400-1500 m running, 100-400 m swimming, sprint cycling, kayaking, rowing and canoeing events at intensities that fall between 80 and 125% of peak maximal oxygen uptake and many team sports with their repeated nature of high intensity exercise. All these events stress the anaerobic glycolysis system significantly and produce a lot of acidity. Sports that are dependent on repeated anaerobic bursts may also benefit from bicarbonate loading.

**The effect of  $NaHCO_3$  on exercise performance:** Sodium bicarbonate or sodium hydrogen carbonate is the chemical compound with the formula  $NaHCO_3$ . Sodium bicarbonate is a white solid that is crystalline but often appears as a fine powder. It has a slight

alkaline taste resembling that of washing soda (sodium carbonate). It is a component of the mineral natron and is found dissolved in many mineral springs. The natural mineral form is known as nahcolite. It is also produced artificially. Since it has long been known and is widely used, the salt has many related names such as baking soda, bread soda, cooking soda, bicarbonate of soda. Colloquially, its name is shortened to sodium bicarbonate.

A study done by McNaughton *et al.* (1999), among moderately trained female athletes, showed the significant improvement in both work and power output, during a high-intensity exercise of 60 sec duration. The ingestion of sodium bicarbonate in the experimental trial had the desired effect of raising blood bicarbonate levels by 60% above the resting bicarbonate value.

According to Stellingwerff *et al.* (2007), a meta-analysis of 29 studies on the performance effects of sodium bicarbonate, featuring predominately untrained individuals, found that bicarbonate supplementation resulted in a performance effect that was 0.44 standard deviations better than in the control trial. An improvement of 0.44 of the standard deviation would bring the 2006 average men's 800 m Golden League time of 1:46.36 down to 1:45.52, which is a worthwhile improvement. In summary, most data suggest that the ingestion of 0.3 g/kg body weight of sodium bicarbonate administered in solution approximately 1-2 h before exercise offers a small, but significant, effect on middle-distance race performance.

In one study designed to simulate athletic competition, trained non-elite middle-distance runners performed a simulated 800 m race. In the alkalotic condition, they ran almost 3 s faster than in the placebo or control trials. Another report by Maughn *et al.* (2004a) indicated similar improvements (3-4 s) over a distance of 1500 m in runners who completed simulated races in about 4 min 15s. Although these effects on performance might appear small, they are of considerable significance to the athlete, for whom an improvement of even a fraction of a second in these events is considered to be a major achievement. In a study by VanMontfoort *et al.* (2004), ingestion of sodium bicarbonate was found to increase the sprint performance in elite male athletes compared to citrate, lactate and chloride ingestion.

Studies by McNaughton *et al.* (1999) have also found that sodium bicarbonate can be used as an ergogenic aid to offset the fatigue process in the high-intensity, competitive cycle ergometry of 1 h duration. However, even though many of the studies have shown that sodium bicarbonate administration modifies the blood acid-base balance, its effects on performance are not always positive. For instance, no improvements have been registered following 90 seconds of maximal cycle exercise by untrained men. No differences were found between the experimental or placebo trials in female

cyclists pedaling at 95% VO<sub>2</sub> max. This suggested that bicarbonate buffering does not improve performance in female athletes during repeated bouts of high intensity exercise.

The reasons for the conflicting effects are not altogether clear, but are at least in part due to variations in the intensity and duration of the exercise tests used, the nature of the exercise task, the dosage of bicarbonate administered and the time delay between bicarbonate administration and the beginning of the exercise test (i.e., the amount of metabolic alkalosis induced). Performance has been monitored over exercise durations ranging from a few seconds to more than 1 h and during continuous, incremental and intermittent dynamic exercise as well as during sustained isometric contractions.

There is no clear pattern of exercise duration between those studies where a positive effect was observed and those where no effect was seen. In most studies, a dose of 0.3 g of sodium bicarbonate/kg of body weight has been used to induce alkalosis and this has usually been administered orally in solution or in capsule form. Such a dose has usually resulted in an increase of 4-5 mMol/L in the plasma buffer base 2-3 h after administration, although the time-course of changes in acid-base status was not carefully followed in most of these studies. Those studies in which high-intensity and short-term exercises (less than 2 minutes) were used and in which the doses of sodium bicarbonate given were lower than 0.3 g/kg body weight, did not generally produce an enhancement of performance, which might be due to the use of an insufficient dose or due to the short duration of the effort. Therefore, it has been suggested that exercises lasting less than 1 minute may not be of sufficient duration for the glycolytic metabolism to activate completely, in that the capacity of the intracellular buffer is exceeded and a positive gradient between the intracellular and extracellular medium is established. The main reason for the lack in performance improvement may consequently be due more to the exercise duration than to the doses used.

Many studies indicate an effective dose of 300mg of sodium bicarbonate per kg body weight taken 1-2 h prior to short-term maximal, high intensity performance lasting 60 sec shows 30% improvement in performance. Sodium bicarbonate appears to be safe when taken in the recommended dose of 140 mg/pound of body weight. For a 150 pound athlete this translates to a dose of 5 teaspoons of baking soda that provides 21,000 mg or 21 g of bicarbonate. Safety should not be confused with side effects. Baking soda should be consumed with plenty of water, (e.g., a liter or more), when taken 1 or 2 h prior to exercise.

There are of course potential problems of severe alkalosis associated with the use of increased doses of bicarbonate. Additionally side effects like vomiting, gastrointestinal discomfort, bloating and diarrhea may

occur particularly if sufficient water is not taken with sodium bicarbonate. Vomiting and diarrhea are frequently reported as a result of ingestion of even relatively small doses of bicarbonate and this may limit any attempt to improve athletic performance by this method, certainly among those individuals susceptible to gastrointestinal problems. There have been reports of athletes using this intervention, which is not prohibited by the rules of the sport, being unable to compete because of the severity of these symptoms. Although unpleasant and to some extent debilitating, these effects are not serious and there are no long term adverse consequences.

### CONCLUSION

The important lessons from the analysis of the data in the study are: ingestion of NaHCO<sub>3</sub> at a dose of 0.3 g/kg of body weight 2 h prior to and after anaerobic exercise leads to an increase in the levels of HCO<sub>3</sub><sup>-</sup> pH and HLa. In contrast, it leads to a significantly greater fall in the HCO<sub>3</sub><sup>-</sup> and HLa levels after exercise than before exercise with that in athletes being more apparent. In the pH levels, however, a little rise was obtained after exercise. Though not significant, an improvement in performance under anaerobic condition was observed after administration of NaHCO<sub>3</sub>.

In conclusion, it can be said that ingestion of alkali in sufficient amounts not to cause gastrointestinal disturbances (nausea, constipation, abdominal cramps, diarrhea, bleeding, pain and unpleasant taste) is one of the factors that positively affect anaerobic performance, with this effect more apparent among athletes than in non-athletes.

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