COMPARISON OF THE EFFECT OF SODIUM BICARBONATE USE ON THE PERFORMANCE OF ATHLETES AND NON-ATHLETES

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ABSTRACT
It is known that sodium bicarbonate (NaHCO₃) is used by athletes before exercise to delay fatigue and improve performance based on the knowledge that it removes H⁺ ions from the body through the creation of a metabolic alkalosis state. In this study, the effects of 0.3 g/kg NaHCO₃ given orally to athletes and non-athletes before a 600 m race were compared. The study included 20 sprinters involved in active sports and 20 non-athlete volunteers. The subjects were fed with the same diet on the study day, and three hours after their lunch meal they were made to warm up for 10 minutes after which their serum HCO₃⁻, pH and Hla levels before and after a 600 m race were determined. After resting for 48 hours 0.3 g/kg. NaHCO₃ was given orally as a 500 ml fruit juice and the same determinations made under the same conditions 2 hours later. The results obtained were evaluated by the one way ANOVA and the student t tests. Statistical significance was established as (p< 0.01) and (p < 0.05). In the study, the time taken to complete race after the administration of NaHCO₃ fell compared to that before its administration in the athletes. In the same way, the racing time in the non-athletes group showed a fall after the administration of NaHCO₃. However, the fall was below the fall recorded in the athletes group. The level of HCO₃⁻ before the administration of NaHCO₃ in the athletes was observed to be higher than after the administration of NaHCO₃. In a similar manner, the increase was observed in the non-athletes group. The pH after the administration of NaHCO₃ was found to be higher than that before its administration both before and after exercising. A rise in the HLa levels was observed after exercising following the administration of NaHCO₃ 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 NaHCO₃ at doses low enough not to cause gastrointestinal disturbances (like nausea, vomiting, abdominal cramps, diarrhea, bleeding, pain and unpleasant taste) 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.

Introduction
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 momentum. With the knowledge that the intake of sodium bicarbonate (NaHCO₃) a pharmacological ergogen, before exercise, delays fatigue by removing H⁺ ions from the body through the creation of a metabolic alkalosis state, it has been used by athletes to enhance performance.

The bicarbonate (HCO₃⁻) 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 both the intra- and extracellular spaces as well as the blood and skeletal muscles (1, 3).

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 (3, 5, 7, 9, 21). 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 (1, 3, 4, 7, 9, 15).

The buffering power of a solution is directly related to its concentration (10). For this reason, if the concentration of the buffer is increased its capacity to neutralize metabolic acids will also increase proportionately. 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 (3, 5, 10, 18).

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 (3, 5, 7, 9, 15). The aim of this study was to investigate the effect of an oral intake of 0.3 g/kg NaHCO3 prior to a 600 m racing exercise in athletes and non-athletes.

Materials and Methods
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.

Before and after racing, the heart beats of the subjects were measured, a briefing about the contents of the study made, and the max. VO2 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 hours before the exercise). The subjects were given placebo orally, 2 hours before exercising on the first day and after a 10 minute warm-up made to run for 600 m and their times recorded. After resting for 48 hours the subjects were offered 500 ml of fruit juice premixed with 0.3g/kg NaHCO3. After resting for 2 hours they were again made to run a 600 m race (3, 13, 19, 23) and their times recorded.

For the determination of the blood pH, HCO3- 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, HCO3- and HLa values were printed from a printer attached to the analyzer within 90 seconds.

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 the statistical analysis of the results obtained. P values of (p < 0.01) and (p < 0.05) were considered statistically significant.

Results and Discussion
The physical characteristics of the subjects are presented in Table 1.

In both groups, comparison of exercise performance after the administration of placebo and NaHCO3 revealed much higher levels in that for NaHCO3. The difference was found to be statistically significant (p < 0.05).
TABLE 1

The Physical and Physiological Characteristics of the Subjects (average ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Athletes</th>
<th>Non-Athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.90 ± 2.23</td>
<td>21.27 ± 3.16</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>1.76 ± 3.46</td>
<td>1.70 ± 2.79</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.30 ± 3.46</td>
<td>74.30 ± 4.35</td>
</tr>
<tr>
<td>Duration of sporting activity (years)</td>
<td>7.10 ± 3.21</td>
<td>-</td>
</tr>
<tr>
<td>Resting Heart rate</td>
<td>55.78 ± 3.27</td>
<td>72.78 ± 4.81</td>
</tr>
<tr>
<td>Max VO2 (ml/kg/min)</td>
<td>42.85 ± 4.55</td>
<td>31.16 ± 3.25</td>
</tr>
</tbody>
</table>

TABLE 2

Comparison of the exercise performance (min) of the subjects after administration of placebo and NaHCO3 (average ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Placebo</th>
<th>NaHCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes</td>
<td>1.49 ± 0.18</td>
<td>1.40 ± 0.44 *</td>
</tr>
<tr>
<td>Non-Athletes</td>
<td>2.07 ± 1.02</td>
<td>2.02 ± 1.33 *</td>
</tr>
</tbody>
</table>

* p<0.05

In Table 3 the HCO3, pH and HLa levels after the administration of placebo and NaHCO3 in the athletes are shown. Whereas the difference in pH levels before and after exercise was not found to be significant (p>0.05), that of the HCO3 and HLa concentrations were observed to be statistically significant (p<0.01).

In Table 4 comparison of the HCO3, pH and HLa levels before and after exercise in athletes after the administration of placebo and NaHCO3 is presented. Whereas no significant difference was observed in the pH before and after exercise (p>0.05), the differences in the HCO3 and HLa concentrations were found to be statistically significant (p<0.01).

In Table 5 comparison of the HCO3, pH and HLa levels before and after exercise after the administration of placebo and NaHCO3 in athletes and non-athletes is presented. The differences in the pre-exercise pH levels (p>0.05), and the HCO3 and HLa concentrations were found to be statistically significant (p<0.05).

In Table 6, comparison of the HCO3, pH and HLa levels before exercise after the administration of placebo and NaHCO3 in the athletes and non-athletes is presented. The differences in pH levels (p>0.05), and the HCO3 and HLa concentrations (p<0.05), (p<0.01) before exercise were found to be statistically significant.

In this study the effects of 0.3 g/kg of NaHCO3 given in fruit juice to the subjects 2 hours before exercising on the HCO3, pH, HLa concentrations and the performance during the 600 m race were investigated.

With the aim of investigating the effect of NaHCO3 use on anaerobic performance, the times taken for the subjects to complete a race of 600 m after placebo and NaHCO3 was administered were compared. In the athlete group, after the administration of NaHCO3 the racing time of 1.42 ± 0.44 sec though still lower than that of the placebo racing time of 1.51 ± 0.18 sec was below that expected. In subjects leading sedentary lives, while the racing time after the administration of NaHCO3 was 2.07 ± 1.02 seconds that after administration of placebo fell to 2.02 ± 1.33 seconds. The fall in athlete time was 9 seconds whereas that in the non-athletes group remained at 5 seconds. In both groups the difference was found to be statistically significant. Considering the fact that NaHCO3 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 (17, 19, 20, 22, 25, 26). Along side this, though in some studies (3, 15, 22, 25) the use of NaHCO₃ has not been demonstrated to affect 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 HCO₃⁻ levels before exercise as well as in the HLa value after exercise (2, 6, 8, 13). The results of this study is 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 NaHCO₃ in our subjects who were exposed to NaHCO₃ 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 NaHCO₃ 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
TABLE 5
Comparison of the HCO₃, pH and HLa levels after the administration of placebo and NaHCO₃ in athletes and non-athletes (average ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Athletes Group</th>
<th>Non-athletes Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCO₃⁻ mMol / L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placebo</td>
<td>24.29±1.34</td>
<td>25.32±1.28 *</td>
</tr>
<tr>
<td>NaHCO₃</td>
<td>26.13±0.94</td>
<td>26.80±0.97</td>
</tr>
<tr>
<td>pH</td>
<td>7.30 ± 0.05</td>
<td>7.34 ± 0.05</td>
</tr>
<tr>
<td>Placebo</td>
<td>7.40 ± 0.07</td>
<td>7.47 ± 0.09</td>
</tr>
<tr>
<td>NaHCO₃</td>
<td>2.21 ± 0.73</td>
<td>3.44 ± 0.65 *</td>
</tr>
<tr>
<td>mMol / L</td>
<td>2.48 ± 0.77</td>
<td>3.52 ± 0.88 *</td>
</tr>
</tbody>
</table>

* p<0.05

TABLE 6
Comparison of the HCO₃, pH and HLa levels after exercise in the athletes and non-athletes after the administration of placebo and NaHCO₃ (average ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Athletes</th>
<th>Non-athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCO₃⁻ mMol / L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placebo</td>
<td>21.84±1.90</td>
<td>23.68±1.83 *</td>
</tr>
<tr>
<td>NaHCO₃</td>
<td>20.33±3.00</td>
<td>25.33±3.00 **</td>
</tr>
<tr>
<td>pH</td>
<td>7.02 ± 0.10</td>
<td>7.13 ± 0.10</td>
</tr>
<tr>
<td>Placebo</td>
<td>7.16 ± 0.09</td>
<td>7.29 ± 0.09</td>
</tr>
<tr>
<td>NaHCO₃</td>
<td>12.17 ± 1.20</td>
<td>14.65 ± 1.18 *</td>
</tr>
<tr>
<td>mMol / L</td>
<td>15.04 ± 1.92</td>
<td>15.10 ± 2.07 **</td>
</tr>
</tbody>
</table>

** p<0.01, * p<0.05

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 (3, 5). The aim in the administration of sodium bicarbonate was to enhance the removal of the HLa and H⁺ ions from muscle tissues through the establishment of an alkalosis condition during vigorous exercise. This fall in the HLa and H⁺ concentrations delays the onset of fatigue and so leads to improved performance (3). In this study, the pre-exercise HCO₃⁻ levels was higher after the administration of NaHCO₃ 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 HCO₃⁻ 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 VO₂ values of the subjects in the study revealed...
values of 31.16 ± 3.25 ml/kg/sec for the non-athletes group and 42.85 ± 4.55 ml/kg/sec for the athletes group with the difference between the two groups statistically significant. The increase in the HCO₃⁻ levels in the athletes can be explained by their increased oxygen consumption reflected in their higher max VO₂ values.

Whereas the contraction mechanism is negatively affected by a falling pH, at the same time the efflux of calcium ions (Ca++) from the sarcoplasmic reticulum and its binding to tropinone 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 (22). In this study, whereas the pre-exercise (7.30 ± 0.05) and post-exercise (7.02 ± 0.10) pH values in the athletes were found to be different, an increase in pH values was found both before (7.40 ± 0.07) and after (7.16 ± 0.09) exercise after the administration of NaHCO₃ compared to the that after placebo. In the non-athlete group also, similar increases were observed with both the placebo and the NaHCO₃ 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⁺ ions and HLa from muscle tissues (27), 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.

Similar results were obtained in this study with the aim of determining the blood and muscle pH levels under maximal exercise (5, 6, 8, 11).

As lactic acid production increases during maximal vigorous exercise the H⁺ 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 (3, 5, 15). Increase in the H⁺ ions has for years been advocated to be the major cause of fatigue in exercise under anaerobic conditions (16). It is known that H⁺ ions have inhibitory effects on the glycolytic enzymes, especially on the secretion of phosphofructokinase (13). In our study, post-exercise HLa levels in the athletes after the administration of NaHCO₃ was found to be higher than that before exercise (2.48 ± 0.77 - 15.04 ± 1.92 mMol/L), with the difference being statistically significant (p< 0.05). After the administration of NaHCO₃ in the non-athlete group, the post exercise HLa levels were found to have increased relative to that before exercise (3.52 ± 0.88 - 15.10 ± 2.07). The increase was higher than that observed in the athletes group. The NaHCO₃, taken before anaerobic exercise, by raising the alkolosis condition enhanced the removal of H⁺ and HLa thereby delaying fatigue (5, 14). By delaying fatigue performance is positively affected. In our investigation, the increase in the blood HLa concentration due to the ingestion of NaHCO₃ showed similarity with those from some other studies (19, 26). 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 NaHCO₃ use.

During exercise the energy used by the muscle tissues is obtained from the meta-
bolistic 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 (18). 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 (12, 24).

The important lessons from the analysis of the data in the study are: ingestion of NaHCO3 at a dose of 0.3 g/kg of body weight 2 hours prior to and after anaerobic exercise leads to an increase in the levels of HCO3− pH and HLa. In contrast, it leads to a significantly greater fall in the HCO3− 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 NaHCO3.

In conclusion, it can be said that ingestion of alkali in sufficient amounts not to cause gastrointestinal disturbances (nausea, vomiting, 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.

REFERENCES