Bicarbonate Loading to Enhance Training and Competitive Performance

Louise M. Burke and David B. Pyne

Bicarbonate loading is a popular ergogenic aid used primarily by athletes in short-duration, high-intensity sporting events and competitions. Controlled experimental trials have shown that small (worthwhile) benefits can obtained from acute doses of bicarbonate taken before exercise. Gastrointestinal problems encountered by some athletes limit the widespread use of this practice, however. The transfer of positive research findings to the competitive environment has proved problematic for some individuals. More recent applications involve serial ingestion of bicarbonate over several days before competition or during high-intensity training sessions over a few weeks. A number of research questions need to be addressed to enhance applications of bicarbonate loading in the elite sport environment. This commentary examines some of research and practical issues of bicarbonate loading used to enhance both training and competitive performance.

**Key Words:** athletic training, exercise performance, metabolism, nutrition, sport physiology

The potential benefits of bicarbonate ingestion on sports performance have been investigated since the 1980s. The interest in this question has stimulated many experimental investigations and some review articles in the exercise literature. Athletes and coaches are seeking small gains in performance, and many are amenable to the idea of ergogenic aids. The main body of research work in this field has focused on acute loading involving ingestion of bicarbonate in the hours before competition. This practice elevates both pH and bicarbonate concentrations in the blood before and during exercise. Requena and coworkers conclude that athletes competing in high-intensity sports involving fast motor-unit activity and large muscle-mass recruitment (athletics events, cycling, rowing, swimming, and many team sports) might benefit from bicarbonate loading. Although most studies (and athletes in the field) have used bicarbonate loading, there are a small number of studies that have examined the effectiveness of citrate supplementation. Other strategies have evolved in which bicarbonate is ingested over several days before the competition—the so-called serial loading—to ameliorate the gastrointestinal problems occasionally encountered with acute loading. More recently there has been interest in using bicarbonate in training, particularly before high-intensity training sets. Issues of which athletes in which sports or events might benefit, guidance of

Burke is with the Dept of Sports Nutrition, and Pyne, the Dept of Physiology, Australian Institute of Sport, Belconnen, ACT 2616 Australia.
dosage and timing of administration, and avoidance of gastrointestinal problems are key questions for researchers, practitioners, coaches, and athletes.

**Physiology of Bicarbonate Loading**

Bicarbonate is an extracellular buffer with an important role in maintaining a stable electrolyte gradient between intracellular and extracellular environments. The primary aim of exogenous bicarbonate loading is to increase (indirectly) the skeletal-muscle buffering capacity to dispose of excess hydrogen ions generated through anaerobic glycolysis. It is acknowledged that elevated lactate and hydrogen-ion concentration is not the sole explanation for fatigue and reduction in exercise performance. Several studies have shown that increases in extracellular pH and bicarbonate-ion concentration elevate the rate of hydrogen and lactate ions efflux from active muscles. Presumably these responses induce a shift in metabolism toward anaerobic-energy production important for high-intensity exercise in many different sports and events. Although the direct role of hydrogen-ion accumulation in muscle fatigue is under question, other physiological and metabolic processes including oxidative phosphorylation, enzyme activity, and iron regulation can also be affected by hydrogen-ion accumulation. In summary, it appears that bicarbonate ingestion exerts its ergogenic effects on exercise and sports performance by reducing both the degree of metabolic acidosis and the degree of impaired muscle oxidative capacity.

**Acute Loading for a Race**

Acute loading is the most extensively researched and practiced form of bicarbonate loading. Studies have generally examined the physiological and performance effects in laboratory settings or in individual sports such as middle-distance running, swimming, and rowing. Analysis of the relevant studies shows there is a worthwhile benefit from acute loading, particularly in events or sports in which high lactate and hydrogen-ion production and fatigue are issues. The traditional acute dose of bicarbonate is 0.3 g of sodium bicarbonate (NaHCO₃) per kilogram body mass taken 60 to 90 minutes before the exercise bout or competitive event. This dose equates to 24 g of NaHCO₃ for an 80-kg male athlete and 19.5 g of NaHCO₃ for a 65-kg female athlete. For citrate, doses of 0.3 to 0.5 g/kg body mass are ingested about 60 to 90 minutes preexercise. The buffers are usually taken in capsule or powder form with 500 to 2000 mL of water. Commercially available capsules typically consist of ~0.8 g of bicarbonate, which translates to a total of ~30 capsules for an 80-kg male athlete. The powder form of bicarbonate is mixed with water and consumed as a drink. These volumes of capsules, powder, and water are quite large, and many athletes experience discomfort taking in this amount of material. For this reason, the capsules and drink are often consumed in 3 or 4 smaller doses.

Although most studies have examined the effect of a single episode of bicarbonate loading, it should be remembered that the competition format undertaken by many athletes involves a series of events over several days (e.g., heats, semifinals, and finals). Therefore, a practical question is whether it is possible or valuable to repeat the acute bicarbonate-loading protocol over successive days. It would be
important to know whether performance effects are sustained in subsequent protocols and whether the risk of gastrointestinal side effects is increased or attenuated by repeated loading. Although these questions have not been specifically addressed, a newer protocol for bicarbonate loading that uses a serial approach to loading over the days before a race might provide the answer.

**Serial Loading for a Race**

A variation of the acute-loading regime is to load bicarbonate in small doses over consecutive days before a competitive event or race. A number of research studies have examined this question, in parallel with anecdotal reports of uncontrolled experimentation in the field by athletes. The advantage of this method is that the muscle extracellular buffering capacity is enhanced with a reduced risk of gastrointestinal distress. Typically, a slightly larger dose than the acute dose is used: 0.3 to 0.5 g NaHCO₃, split into 3 or 4 smaller doses spread over the day or for 3 to 5 days before the exercise bout or competitive event. Studies show that several days of split doses of bicarbonate build up blood buffer levels that persist for at least 24 hours after the last dose. Therefore, this protocol could be used to achieve a loading preparation for multiple events over the same or successive days. Lower doses of bicarbonate are spread over the day and can be timed to avoid high-risk periods of exercise. It might also be possible to finish the loading a day or two before an important race. This approach would eliminate the need for any supplementation on race day, a strategy that would be welcomed by many athletes who would gladly avoid the distractions and possible adverse side effects.

**Chronic Loading for Training**

A more recent line of investigation is the chronic use of bicarbonate to support training activities rather than competition. Edge and coworkers at the University of Western Australia recently reported the effects of chronic bicarbonate loading (0.4 g/kg body mass per day for 3 d/wk for 8 weeks) in 16 moderately trained female athletes. The bicarbonate-supplemented group showed substantially greater improvements in both lactate threshold (26% vs 15%) and time to exhaustion (164% vs 123%) than a placebo group. The authors speculated that training intensity rather than accumulation of hydrogen ions is more important in increasing muscle buffering capacity. The chronic-loading approach also appears to have some efficacy for team-sport athletes preparing for weekly competition over a several-month season. Several questions remain open for investigation, however. Would the chronic effect be even greater if athletes supplemented with bicarbonate were able to train harder or more extensively? Similarly, does chronic bicarbonate loading during training allow an athlete to achieve higher levels of training adaptation (lactate threshold and endurance performance) or just allow them to achieve the same level of improvement in a shorter time or with less training? Another question is whether the same magnitude of effect is seen in highly trained and moderately trained athletes. In team sports, further information is required on whether supplementation should vary for players in different positions (e.g., forwards, midfielders, backs). Finally, dose-response studies are required to clarify the most effective
chronic-loading supplementation strategy (e.g., dosage and timing) and how this might vary from athlete to athlete.¹⁹

**Future Directions**

Although there is experimental evidence indicating target doses of 0.25 to 0.3 g NaHCO₃ per kilogram body mass, there is a need to develop a process for identifying the optimal dose for individuals (Table 1). Future studies should quantify the degree of individual response in addition to the mean effect of bicarbonate loading. Practical strategies to limit gastrointestinal stress need investigating rather than just commenting on. A couple of possibilities include the interaction between food, beverage (water or sports drink) consumption, and bicarbonate loading. Clearer guidelines on the issues of timing, split doses, and powder versus capsule loading would be welcomed by athletes and coaches. The interaction between bicarbonate loading and other ergogenic aids such as caffeine and creatine should be investigated. The issue of long-term adaptation to chronic bicarbonate supplementation also needs investigation.

Anecdotal reports in competitive sport indicate that there are athletes who use several ergogenic aids in combination without supervision and pay little or no attention to the possibility of interactive effects. Whether the combined effect of multiple ergogenic aids is the sum of the individual effects of each aid in isolation is unknown. The impact of multiple loading of ergogenic aids on the likelihood of gastrointestinal distress is also unknown. More work on the transfer of bicarbonate loading from the laboratory or routine training to the actual competitive environment is needed. In our experience some athletes tolerate bicarbonate loading

<table>
<thead>
<tr>
<th>Type of loading</th>
<th>Future directions</th>
</tr>
</thead>
</table>
| Acute loading for competition | • What are reasons for the variable transfer of results to field settings?  
• How can the optimal dose be established for individual athletes?  
• What are the effects of multiple loading of different ergogenic aids (e.g., bicarbonate + caffeine)? |
| Serial loading for competition | • What are the optimal dose-response and timing interaction over the days leading to competition?  
• Should athletes load on the day of competition?  
• How should extended loading be implemented for different events or stages held over several days? |
| Chronic loading for training | • Are the benefits the same for moderately and highly trained athletes?  
• What is the optimal dose and timing regime before high-intensity training sessions?  
• Can athletes train harder or adapt more quickly with chronic loading? |
in the laboratory or in time trials in training reasonably well but experience problems during the stress and anxiety of actual competition. One potential solution is to have athletes rehearse bicarbonate supplementation in minor local competitions before employing it in major national or international competitions. Resolution of some of these issues should lead to better management of bicarbonate use as an ergogenic aid in training and competition across a range of sports.

References