



# AIS SPORTS SUPPLEMENT FRAMEWORK

## SODIUM BICARBONATE

### What is it?

- > Bicarbonate is an endogenously produced extracellular anion, and an integral component of the body's primary pH buffering system. During high rates of anaerobic glycolysis (inevitable during prolonged periods of intense exercise), the muscle can produce hydrogen ions ( $H^+$ ) in excess, which eventuates in metabolic disturbances and ultimately may contribute to fatigue. Extracellular bicarbonate facilitates the removal of these  $H^+$ , and to a point, supports the body's ability to match the high rates of energy demand required to maintain muscle contractile function during such activity.
- > Numerous studies have demonstrated that endogenous bicarbonate levels can be safely and acutely increased after the oral ingestion of between 200 and 300 mg/kg body mass (BM) of sodium bicarbonate.<sup>1,2</sup> The additional bicarbonate is believed to attenuate the inevitable increase in intramuscular  $H^+$ , synonymous with high-intensity exercise, although the physiologic mechanisms *directly* responsible for performance augmentation in humans are unclear.<sup>3</sup> It has been suggested that the reduction in extracellular  $H^+$  after sodium bicarbonate ingestion can reduce rating of perceived exertion (RPE);<sup>4,5</sup> which could be beneficial for athletes competing in one or more events on the same day.<sup>6</sup>
  - Meta-analyses have reported that supplementation at these levels can result in an approximate 2 to 3% improvement across a variety of performance measurements (e.g. power, speed, work capacity, time to failure) during both single and repeated bouts of high-intensity exercise typically lasting 1-10 minutes in duration.<sup>7,8,9,10</sup>
  - The 2018 International Olympic Committee Sports Nutrition Consensus Statement recommendations suggest that sodium bicarbonate is one of five dietary supplements that consistently improves performance in the elite athlete.<sup>11</sup>
  - It has been suggested that the change in blood bicarbonate concentration ( $HCO_3^-$ ) from baseline levels is more important for predicting effects on performance than absolute levels, after taking sodium bicarbonate. A recent meta-analysis reported that an increase of 4-6 mmol/L from an individual athlete's baseline values) is associated with a moderate improvement in performance, and an increase of 6 mmol/L or more is associated with a large improvement in performance.<sup>10</sup>
  - It is also important to recognise that ingesting sodium bicarbonate increases the amount of sodium ( $Na^+$ ) in the blood which may lead to improvements in hydration status, as indicated by increased plasma volume.<sup>12</sup>

### What does it look like?

- > The most commonly available and economical source of sodium bicarbonate is the household/baking product baking soda. However, most athletes find ingesting sodium bicarbonate mixed in water or even diluted with cordial to be unpalatably salty.
- > A more palatable delivery of sodium bicarbonate can be provided in tablet or capsule form (e.g. *Sodibic*<sup>TM</sup> at 840 mg per tablet. Enteric capsules can be purchased as an alternative, either as a ready-made product (e.g., Umara<sup>®</sup>) at 1g per product), or while less convenient, purchased and filled (e.g. Capsugel<sup>®</sup>) with either bicarbonate powder or aqueous solution may also be a viable option. This capsule casing is proposed to resist the acidity of the stomach, instead dissolving in the intestine, which may also reduce gastro-intestinal (GI) symptoms of bicarbonate ingestion.<sup>13,14</sup>
- > More recently, a gel form of sodium bicarbonate has been introduced (Maurten "Bicarb System"). This product has been reported to elicit a very low incidence of gastrointestinal symptoms, an earlier time to peak [ $HCO_3^-$ ], and higher peak buffering capacity compared with sodium bicarbonate capsules. Although only two studies have been conducted to quantify the effect of the Maurten Bicarb System on performance, improvements in 40 km cycling time trials and repeated 4 km cycling time trials have been reported to date.<sup>15,16,17</sup> Given the limited published research on this new product (which has only covered one exercise modality) trials with individual athletes are therefore important.
- > Transdermal delivery of sodium bicarbonate is commercially available (Amp Human<sup>®</sup>). One study reported improvements in repeated sprint running performance, but further research is needed on the efficacy of this delivery system, given the equivocal results across the small number of published studies.<sup>18,19,20</sup>

### How and when should I use it?

- > Current ingestion recommendations are to consume between 200 to 400 mg/kg BM with a small, carbohydrate dense meal (~1.5 g/kg BM CHO) approximately 120 to 150 min prior to exercise.<sup>11,21</sup> This ingestion protocol has been demonstrated to be effective when using sodium bicarbonate capsules. Although not included in published recommendations, the existing research on the new Maurten 'Bicarb System' indicates that the sodium bicarbonate gel should be taken 120 min after a small, carbohydrate dense meal, and that training or competition would commence 120 min after ingesting the Bicarb System.<sup>15,16,17</sup>
  - Broad ingestion recommendations should only serve as a starting point, as several practical issues associated with sodium bicarbonate may influence the efficacy of this supplement such as ingestion timing, individual tolerability and/or susceptibility to GI distress, and the potential co-ingestion of other supplements.<sup>11</sup> Where practicable, monitoring of blood bicarbonate concentrations and pH in response to sodium bicarbonate ingestion, warm-up and event are also strongly encouraged. Valuable information can also be obtained by using a validated questionnaire to quantify participants' experiences of gastrointestinal symptoms.<sup>22</sup> Experience at the AIS has shown that this frequently uncovers issues that can be manipulated to enhance outcomes for the individual athlete.
  - Monitoring  $HCO_3^-$  and pH in response to sodium bicarbonate ingestion introduces an additional substantial cost, associated with blood collection and analysis consumables, and imposes logistical challenges (e.g., laboratory access is required if the sport science team do not have access to a

portable blood-gas analyser). Our experience has demonstrated that there can also be limited benefits if using the Maurten bicarbonate system, particularly if athletes have a long warm-up duration (e.g., 60 min), because testing before the warm-up means there has been only 60 min since ingestion.

- There is some evidence that timing an individual's ingestion protocol to commence competition at their individualized peak blood buffering capacity may improve performance. However, this requires periodically measuring blood bicarbonate changes over multiple testing sequences.<sup>23,24,25</sup>
- If individualizing the ingestion strategy is not feasible, when using sodium bicarbonate capsules, ingestion at the higher end of the recommended doses (e.g. 300 to 400 mg/kg BM) 2 to 3 hours pre-competition should significantly elevate blood buffering capacity to levels presumed to be ergogenic (~ 5 – 6 mmol/L increase) with effects lasting for 3 to 4 hours. Co-ingestion with a small high carbohydrate meal supports blood alkalosis while reducing the occurrence of GI symptoms. This method of delivery would allow more time for those athletes susceptible to GI distress (which typically peaks 90 min post-ingestion) to resolve any potential issues before competition. If using the Maurten "Bicarb System" and it is not feasible to individualise the ingestion strategy, the existing evidence suggests a small, carbohydrate-rich meal 4 hours pre-competition and ingestion of the 'Bicarb System' gel 120 min pre-competition, at a dose of ~200 to 300 mg/kg BM (Table 1).<sup>15,16,17</sup>
- There is currently very limited research on buffering agents conducted in females, and an audit of sodium bicarbonate studies conducted in 2022 reported that only 4% were conducted in female participants<sup>27</sup>, even though supplement use in athletes across different sports is similar.<sup>28</sup> The existing evidence does suggest however that sodium bicarbonate ingestion at standard doses of 200-300 mg/kg increases buffering capacity and has a positive effect on performance in females.<sup>29</sup>
- > There is good evidence for the use of bicarbonate by athletes competing in high-intensity activity lasting from 30 s to 10 minutes – for example, swimming, rowing and middle-distance running events.<sup>9</sup> Over the past decade, there have been a few studies reporting benefits in physical performance improvements in skill-based sports requiring prolonged, repeated high-intensity efforts (e.g. team, racquet and combat sports).<sup>10,30</sup>
  - It should be recognised that in many events of this type, competition may require the athlete to undertake several events within a relatively short timeframe, or to compete later the same day. This competition schedule may require an adjustment of sodium bicarbonate loading protocols to account for repeated events. In this example, "split" strategies of loading may be incorporated around time constraints, or alternatively using a "top-up" approach with smaller amounts (e.g. 100 mg/kg BM) consumed once or twice over the remainder of the competition timeframe.<sup>11</sup> As there is no published data on the efficacy of split- or top-up approaches, this would need to be trialed in training. A recently published framework suggests that athletes performing multiple competitive events separated by shorter recover periods (e.g., ~60–90 min between track cycling heats and final) could benefit from using sodium bicarbonate as a recovery aid. Whilst specific studies have not confirmed the benefit to performance in high-performance athletes in real-world competition contexts, based on the available evidence, athletes may incorporate into their trials during training:<sup>6</sup>
    - 200-300 mg/kg BM prior to or after the initial bout of repeated efforts (e.g., track cycling, swimming, sprint skiing).
    - 200-300 mg/kg BM combined with a "top up" dose of ~100 mg/kg BM immediately at the start of recovery.
    - The top-up dose could alternatively be consumed during longer events (e.g., road cycling) when ~75 min recovery is available. In this context, sodium bicarbonate might be an effective strategy for improving subsequent exercise performance.<sup>6,31</sup>
  - Alternatively, a bicarbonate supplementation protocol involving multiple divided doses over several days before competition may be appropriate. This involves a higher daily bicarbonate dose (500mg/kg BM) in several even doses (e.g., 100mg/ kg BM with 3 main meals and 2 snacks) up to 5 days before competition, as well as the day of competition.<sup>11</sup>
- > Given this evidence, high-intensity events of ~1 hour or more which are conducted at work rates just below an individual's anaerobic/lactate threshold may also be relevant for sodium bicarbonate supplementation. In this instance, the additional buffering capacity may support the athlete's ability to increase their pace/work output for strategic periods (e.g. surges, sprint finishes).<sup>31</sup>
- > There is a growing body of evidence that suggests increases in aerobic adaptability (e.g. increased oxidative and mitochondrial function) are augmented with sodium bicarbonate supplementation during blocks of interval training sessions.<sup>32,33</sup>
  - There is also evidence supporting fatigue attenuation after acute sodium bicarbonate supplementation in measures of explosive power (e.g. rate of force development).<sup>34,35</sup>
- > There have been studies investigating the efficacy of co-ingestion with other supplements (e.g. caffeine, creatine, beta-alanine, ketone bodies). The existing evidence suggests that combined beta-alanine and sodium bicarbonate supplementation is the combination that may elicit performance benefits.<sup>36,37</sup>

## Prescription

>When introducing sodium bicarbonate for an athlete, we recommend a four-phase approach to developing an individual supplementation protocol<sup>36</sup> (Figure 1), in collaboration with their coach and performance support practitioners (e.g., sports physiologist, sports dietitian). These steps can be used once an athlete and their performance support practitioners decide on the type of sodium bicarbonate to be introduced (e.g., *Sodibic*<sup>TM</sup> or “Maurten Bicarb System”), and can inform a systematic approach even if the athlete has some previous experience with sodium bicarbonate use.

- **Phase 1: Preparation** This phase is dedicated to working with coaches to identify athletes with established training and nutritional practices, and ensuring there is adequate time available in an athlete’s training schedule for multiple trials. During this phase, we also recommend an audit of an athlete’s current supplementation practices and removing any combinations of supplements for which there is limited evidence. We recommend documenting when competitions will be held in hot and/or hypoxic conditions, because performance can be impaired in extreme environments. There is some evidence that sodium bicarbonate can benefit performance in these environments. Information on female athletes’ menstrual cycle or hormonal contraceptive use can also be collected during this phase. There is current interest in the potential impact of menstrual cycle phase and the use of hormonal contraceptives on exercise performance in females, although there is very limited research focused specifically on high-performance female athletes. Trials with individual athletes when using sodium bicarbonate will therefore provide information about specific athletes’ responses in the context of their menstrual cycle phase or hormonal contraceptive use.
- **Phase 2: Isolated Buffering Trials:** The focus of this phase is quantifying gastrointestinal symptoms and buffering capacity (ideally measured every 30 min, depending on the available equipment and budget) in isolation (while the athlete is at rest, rather than during a training session). These trials can serve to identify the timing of any gastrointestinal side effects and quantify buffering capacity responses after sodium bicarbonate ingestion. Results from these sessions will provide information for the athlete’s performance support practitioners when deciding to change factors including the dose, timing of ingestion prior to training or competition, and co-ingested foods and fluids.
- **Phase 3: Buffering Trials During Training:** During this phase, athletes and coaches select high-intensity sessions to trial responses to sodium bicarbonate. The training sessions (e.g., one session without sodium bicarbonate and one session with sodium bicarbonate) can serve as a basis to quantify gastrointestinal symptoms and buffering capacity (e.g., prior to and after the warm-up and after the completion of the session). Training session performance is also quantified during this phase.
- **Phase 4: Buffering During Competition:** During this phase, gastrointestinal symptoms, buffering capacity and competition performance are quantified, with the measures taken depending on the feasibility of accessing the athlete in the competition environment. Some athletes may select a lower priority event for this phase.

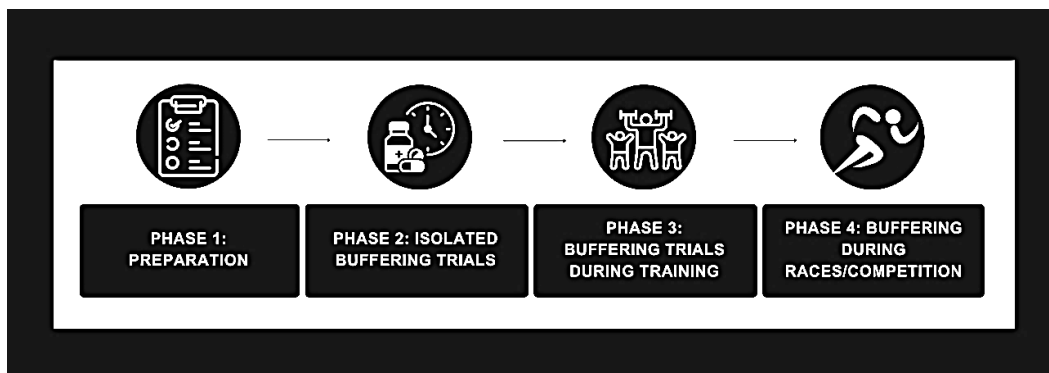


Figure 1: Recommended phases for developing sodium bicarbonate supplementation protocols for individual athletes.<sup>36</sup>

> A worked example is provided below for dose, timing and other considerations for *Sodibic*<sup>TM</sup> capsules, for a 70 kg athlete.

- **Dose:**  $70 \text{ kg} \times 0.3 \text{ g/kg} = 21\text{g}$  sodium bicarbonate.  $21 \text{ g} / 0.84 \text{ g}$  sodium bicarbonate per Sodibic capsules = 25 capsules
- **Timing:** -180 min: 9 capsules, and start to consume high-carbohydrate meal; -165 min: 8 capsules; -150 min: 8 capsules; 0 min: Event start:

- > Similarly, an example is provided below for dose, timing and other considerations for the Maurten Bicarb System (also for a 70 kg athlete):
  - The Maurten “Bicarb System” uses a different dosing strategy to capsules, in that athletes within a body mass range purchase a pre-prepared product (Table 1). The dosing system (where an absolute dose is purchased in a three-part packaged system that includes sodium bicarbonate mini-tablets and hydrogel, plus a bowl to which 200 mL water is to be added) requires a choice between a dose that is approximately 200 or 300mg/kg, rather than calculating an exact dose.
  - **Dose:** Maurten Bicarb System 19 (Table 1).
  - **Timing:** -240 min: Consume high-carbohydrate meal; -125 min: Prepare Maurten Bicarb System 19; -120 min: Maurten Bicarb System 19 (consume all gel); 0 min: Event start.

Body Mass Range (kg)	Maurten Bicarb Product	Dose (mg/kg)
44-51	Bicarb System 12	0.24-0.27
52-69	Bicarb System 15	0.22-0.27
70-84	Bicarb System 19	0.23-0.27
85-102	Bicarb System 22	0.22-0.26
103-142	Bicarb System 25	0.18-0.24

**Table 1: Body mass range and recommended dose of the Maurten Bicarb System, for novice sodium bicarbonate users.<sup>26</sup>**

### Are there any concerns or considerations?

- > The major side effect associated with sodium bicarbonate supplementation is gastrointestinal distress, with symptoms including nausea, stomach pain, diarrhoea and vomiting. This is a serious practical consideration for athletes in a competition setting, and this may counteract the potential performance benefits from enhanced buffering.<sup>11</sup> Research undertaken at the AIS systematically studied a series of sodium bicarbonate supplementation protocols, varying the time taken to consume the load (spreading it over 30 to 60 mins), the form of the delivery (flavoured powder or capsules) and the consumption of various amounts of fluid or food with the sodium bicarbonate. Of the protocols tested, the best strategy to optimise blood bicarbonate levels and to reduce the occurrence of GI symptoms was to consume capsules in a spread-out protocol, commencing 120 to 150 min before the start of exercise and, if practical, at the same time as consuming a meal composed of carbohydrate-rich food choices and some fluid.<sup>21</sup>
- > The published research on the Maurten Bicarb system indicates that there is a low incidence and/or severity of any gastrointestinal symptoms. Our experience suggests that athletes could consider using this system if they have had previous experience of gastrointestinal symptoms after sodium bicarbonate use.<sup>17,18</sup>
- > It is generally advised to ingest sodium bicarbonate capsules or dissolvable powder with sufficient fluid to decrease the risk of hyperosmotic diarrhea (~ 10mL/kg BM).
- > Given the significant amount of fluid intake recommended to alleviate GI distress, consideration may be given toward the additional weight gain this might induce for weight-dependent sports.
- > Repeated use of acute loading protocols (e.g. heats and finals in a single or multi-day competition) may require individualised attention to exacerbate the risk of side-effects. This may be reduced if the athlete uses lower doses on subsequent occasions to compensate for bicarbonate remaining in the body. Recent evidence suggests that sodium bicarbonate could be used post-exercise, in gradual doses throughout competition days, or during training or competition. Whilst specific studies have yet to be performed, there may be beneficial applications to sports and events with repeated bouts, including BMX cycling, track cycling, soccer, American football, sprint skiing and Rugby 7s.<sup>6</sup> Changes in urinary pH are expected following bicarbonate supplementation. If an athlete is selected for a drug test, they may need to wait several hours before urinary pH returns to the levels that are acceptable to drug testing authorities. This may cause some disruption to the athlete’s routine.

### Where can I find more information?

Gatorade Sports Science Institute

[www.gssiweb.org/en/sports-science-exchange/Article/sse-124-buffers-and-their-role-in-the-nutritional-preparation-of-athletes](http://www.gssiweb.org/en/sports-science-exchange/Article/sse-124-buffers-and-their-role-in-the-nutritional-preparation-of-athletes)

[www.gssiweb.org/en/sports-science-exchange/Article/use-of-buffers-in-specific-contexts-highly-trained-female-athletes-extreme-environments-and-combined-buffering-agents](http://www.gssiweb.org/en/sports-science-exchange/Article/use-of-buffers-in-specific-contexts-highly-trained-female-athletes-extreme-environments-and-combined-buffering-agents)

Supplement safety information and batch tested product list

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The Australian Institute of Sport (AIS) Supplement Framework is an initiative of the Australian High Performance Sport System. The AIS acknowledges the support of members of the National Institute Network (NIN) and National Sporting Organisations (NSO) and their staff in delivering content expertise. This information is intended to help athletes, coaches and scientists make evidence-based decisions about the use of supplements and sports foods. Before engaging in supplement use, we recommend that each individual refer to the specific supplement policies of their sporting organisation, sports institute or parent body, and seek appropriate professional advice from an accredited sports dietitian ([www.sportsdietitians.com.au](http://www.sportsdietitians.com.au)).

Athletes should be aware that the use of supplements may have doping implications. Athletes are reminded that they are responsible for all substances that enter their body under the 'strict liability' rules of the World Anti-Doping Code. Some supplements are riskier than others. The Sport Integrity Australia (SIA) app is a useful resource to help mitigate the risk of inadvertent doping by helping to identify supplements that have been batch-tested. The SIA App provides a list of more than 11,000 batch-tested products. We recommend that all athletes consult the educational resources of SIA regarding the risks associated with supplements and sports foods. While batch-tested products have the lowest risk of a product containing prohibited substances, they cannot offer you a guarantee that they are not contaminated ([www.sportintegrity.gov.au/what-we-do/supplements-sport](http://www.sportintegrity.gov.au/what-we-do/supplements-sport)).

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