The BASES Expert Statement on Extracellular Buffering Agents

Introduction

Research investigating nutritional ergogenic aid strategies that delay the occurrence of metabolic acidosis during high intensity exercise have been widely investigated for many decades. The exogenous enhancement of the bicarbonate (HCO_3^-) buffering system is believed to have an important role in offsetting fatigue, by dampening hydrogen cation (H^+) elevations. Ingestion of sodium bicarbonate ($NaHCO_3$) and other buffers such as sodium citrate ($Na_3C_6H_5O_7$), sodium lactate ($C_3H_5NaO_3$) and sodium phosphate (Na_3PO_4) can be ergogenic through increasing blood bicarbonate concentration [HCO_3^-] within the extracellular fluid, increasing pH above the normal values of 7.35-7.37. Research suggests that ingestion leads to more high intensity work completed, and improved exercise capacity or performance. Current ingestion of buffering agents, by athletes for competition and training is typically based on ingesting $NaHCO_3$. Whilst other buffering agents ($Na_3C_6H_5O_7$, $C_3H_5NaO_3$ and Na_3PO_4) have been used, the ease of purchase of sodium bicarbonate continues to ensure this is the most common buffering agent. The scientific literature regarding acute buffering supplements demonstrates a high degree of individual variability. Many factors such as training status, individual variation in acid-base kinetics, intensity/duration of exercise, and gastrointestinal disturbances, have been identified as possible causes.

Therefore, the aim of this expert statement is to provide up-to-date information and guidance for athletes, coaches and exercise scientists who might be considering or currently using exogenous buffers as ergogenic aids.

Sodium Bicarbonate, Citrate, and Lactate

Recent developments in buffering have focussed on attempts to make supplement ingestion more effective, by examining the ingested dose, timing, and delivery method. A novel methodological change was employed by Miller et al. (2016) who developed the individual time to peak (pH or HCO_3^-) alkalosis ingestion method to align peak alkalosis with performance onset. Times ranging between 10 - 180 min were observed despite ingestion of the same dose (Miller et al. 2016), suggesting that a generic pre-exercise ingestion period is not appropriate (e.g. 60 or 90 min for all athletes).

Traditionally doses of 0.3 g·kg^{-1} BM were the accepted standard (McNaughton 1992). High doses such as this may however cause gastrointestinal (GI) upset in some athletes. Recent investigations using individualised time to peak (TTP) have suggested that 0.2 g·kg^{-1} BM of $NaHCO_3$ may cause similar ergogenic responses whilst reducing GI symptoms (Gough et al. 2018). Gough et al. (2018) reported that 4 km time trial cycling was improved to a similar extent by 8.3 and 8.6 s following 0.2 g·kg^{-1} BM and 0.3 g·kg^{-1} BM compared to a placebo. Current findings suggest that a dose of 0.2 g·kg^{-1} ingested at individual peak alkalosis can achieve an absolute change in HCO_3^- from baseline of ~5 mmol·l^{-1}, which is the level suggested to be required to elicit an ergogenic effect (Heibel et al., 2018), but also ensures athletes begin an event at their optimal buffering capacity.

Given that the severity of GI upset following supplementation is subject to individual variation, supplementing with smaller doses has been recommended. Recent contemporary work has shown the use of delayed-release or enterically coated capsule ingestion of $NaHCO_3$ can also reduce GI discomfort compared to fluid ingestion due to their gastro-resistant properties (Hilton et al., 2019). However, individuals are recommended to undertake out of competition testing to understand their personal TTP and GI responses to 0.2 g·kg^{-1} BM and 0.3 g·kg^{-1} BM supplementation.

An alternative exogenous buffer is sodium citrate, but its use is less prevalent than $NaHCO_3$ due to the difficulties of obtaining it. Research investigating sodium citrate has arguably adopted a sub-optimal timing of ingestion, with most opting for a 90 min ingestion period. Indeed, Urwin et al. (2016) showed that time to peak alkalosis could take between 180-210 minutes following 0.5g.kg^{-1} BM, although data were restricted to mean group responses only. Nonetheless, this may explain why minimal effects of sodium citrate supplementation have been reported on exercise performance. Given the larger molecular weight of sodium citrate (258.06 g·mol^{-1}) compared to $NaHCO_3$ (84.007 g·mol^{-1}) it is likely that TTP will be longer.

Calcium lactate and sodium lactate have both been suggested as extracellular buffers. In the only study to use sodium lactate, Van Montfoort et al. (2004) reported an increase in running performance

to exhaustion (1-2 min duration) following ingestion of 400 mg·kg^{-1} BM, within a group of trained distance runners. Morris et al. (2011) subsequently showed that total work done during repeated supramaximal exercise (2-3 min duration) can also be improved with calcium lactate ingestion using 120 mg·kg^{-1} BM. However, in recent studies, performance improvements have not been observed (see Oliveira et al., 2017). A mitigating factor may be the exercise protocols employed within these studies, such that they failed to sufficiently stress buffering systems in order to see an ergogenic effect. These studies were either Wingate tests or a 40 km cycling TT, which buffering agents have had minimal impact upon in previous investigations (McNaughton et al., 2016). Based on such limited evidence to date, further research is required to understand the best form of ingested lactate (i.e. sodium or calcium lactate), exercise type and duration, and dose that will produce consistent ergogenic effects.

Despite promising findings from an individualised ingestion strategy, understanding changes in acid base balance following $NaHCO_3$ supplementation represents a number of logistical challenges. Individuals who have access to laboratory facilities are recommended to identify the individual time to attain peak blood HCO_3; given emerging research has demonstrated an efficacious ergogenic response when exercising using this dosing regimen. Given the acting mechanism of exogenous buffering agents is via the action on the acid-base balance, the ergogenic effect is limited to exercise that induces fatigue through disturbances to acid-base balance. As such, sports/events that require athletes to perform above the lactate threshold for extended periods may benefit from supplementation. Current research suggests that this effect is most efficacious during high intensity exercise that lasts between 1- 10 min. It has been suggested that endurance-based sports involving intensity bursts throughout (e.g. hill climbs during road cycling competitions and team sports), may also benefit from $NaHCO_3$, although research is needed to confirm this hypothesis. In addition to their ergogenic properties, buffering supplements should also be considered as training aid, with a growing body of research demonstrating their potential to augment training adaptations.

Conclusion

Current and innovative work suggests that utilising an individualised approach to dosing to coincide with a peak [HCO_3^-] or pH and performance time is likely the most ergogenic strategy. The individualised strategy using both 0.2 and 0.3 g·kg^{-1} BM doses, produces repeatable blood and performance responses which we believe shows that [$NaHCO_3$] has a greater ergogenic effect than previously thought. Careful consideration should be afforded to the delivery method, given the effects on TTP and associated GI symptoms (Figure 1). Using the most contemporary research, athletes and practitioners should gain the most from these buffering substances and ingestions strategies.

Recommendations

Athletes who have used buffering substances as ergogenic aids as well as those that have not, should (re)consider their use given the recommendations below and in conjunction with the suggested protocols (Figure 1):

1) Current research suggests that buffering substances are most likely ergogenic for performances of 1-10 min and/or exercise intensities that are considerably higher than lactate threshold.
2) Athletes are recommended to undertake out of competition testing to understand their responses to supplementation.
3) Athletes should seek assistance in determining their TTP using blood samples at 10 min intervals with 0.3 g·kg^{-1} BM $NaHCO_3$.
4) Athletes should assess subjective measures of GI upset during TTP assessment.
5) Athletes with unacceptable levels of GI upset should experiment with a 0.2 g·kg^{-1} BM $NaHCO_3$.
6) The use of delayed release or enterically coated capsules may alleviate GI symptoms but should be sourced from suppliers that use batch testing or at the very least, from reputable sources.

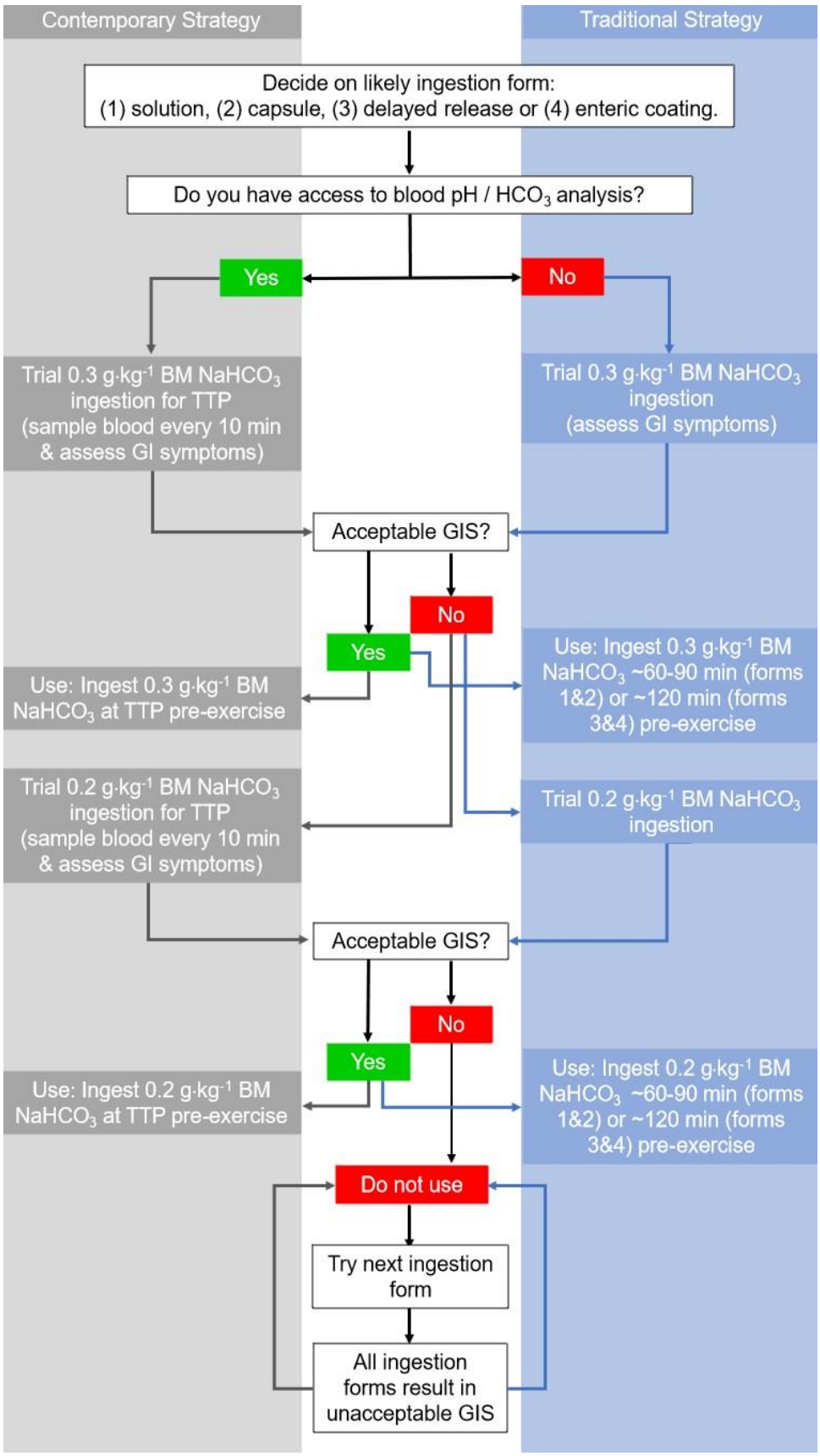

Figure 1. Recommended individualised and traditional sodium bicarbonate (NaHCO3) ingestion strategies. Body mass (BM), Bicarbonate (HCO_3), Gastrointestinal symptoms (GIS), individualised time to peak (TTP).

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