Pre-exercise optimisation of the alkalosis response to sodium bicarbonate ingestion: Have we been missing its peak ergogenic effect?

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Presentation Outline

- Personalised $NaHCO_3$ ingestion and individual variability
- Performance effects
- Practical Recommendations

Image: @cadence_images

- Work on acid-base manipulations showed performance improvements in high intensity short duration exercise with extracellular buffering agents:

- Sodium bicarbonate
- Sodium citrate
- Sodium lactate
- Calcium lactate

Journal of Sports Sciences, 1992, **10**, 415–423

Bicarbonate ingestion: Effects of dosage on 60 s cycle ergometry

LARS R. McNAUGHTON
Centre for Physical Education, University of Tasmania, P.O. Box 1214, Launceston, Tasmania 7250, Australia

Accepted 17 July 1991

Table 1. Mean (±S.D.) total accumulated work and peak power achieved by the subjects in the seven tests

	Total work ($kJ\ min^{-1}$)	Peak power (W)
Control	35.1 ± 2.7	1090 ± 124.3
Placebo	35.8 ± 2.9	1163 ± 139.8
100 $mg\ kg^{-1}$ body mass $NaHCO_3$	36.4 ± 3.6	1131 ± 127.1
200 $mg\ kg^{-1}$ body mass $NaHCO_3$	39.3 ± 1.8[a]	1178 ± 104.0
300 $mg\ kg^{-1}$ body mass $NaHCO_3$	41.9 ± 1.2[b]	1295 ± 72.8[a]
400 $mg\ kg^{-1}$ body mass $NaHCO_3$	41.7 ± 1.7[b]	1218 ± 68.9[a]
500 $mg\ kg^{-1}$ body mass $NaHCO_3$	41.3 ± 1.2[b]	1244 ± 81.5[a]

[a]Significantly different from control ($P < 0.05$).
[b]Significantly different from control ($P < 0.005$).

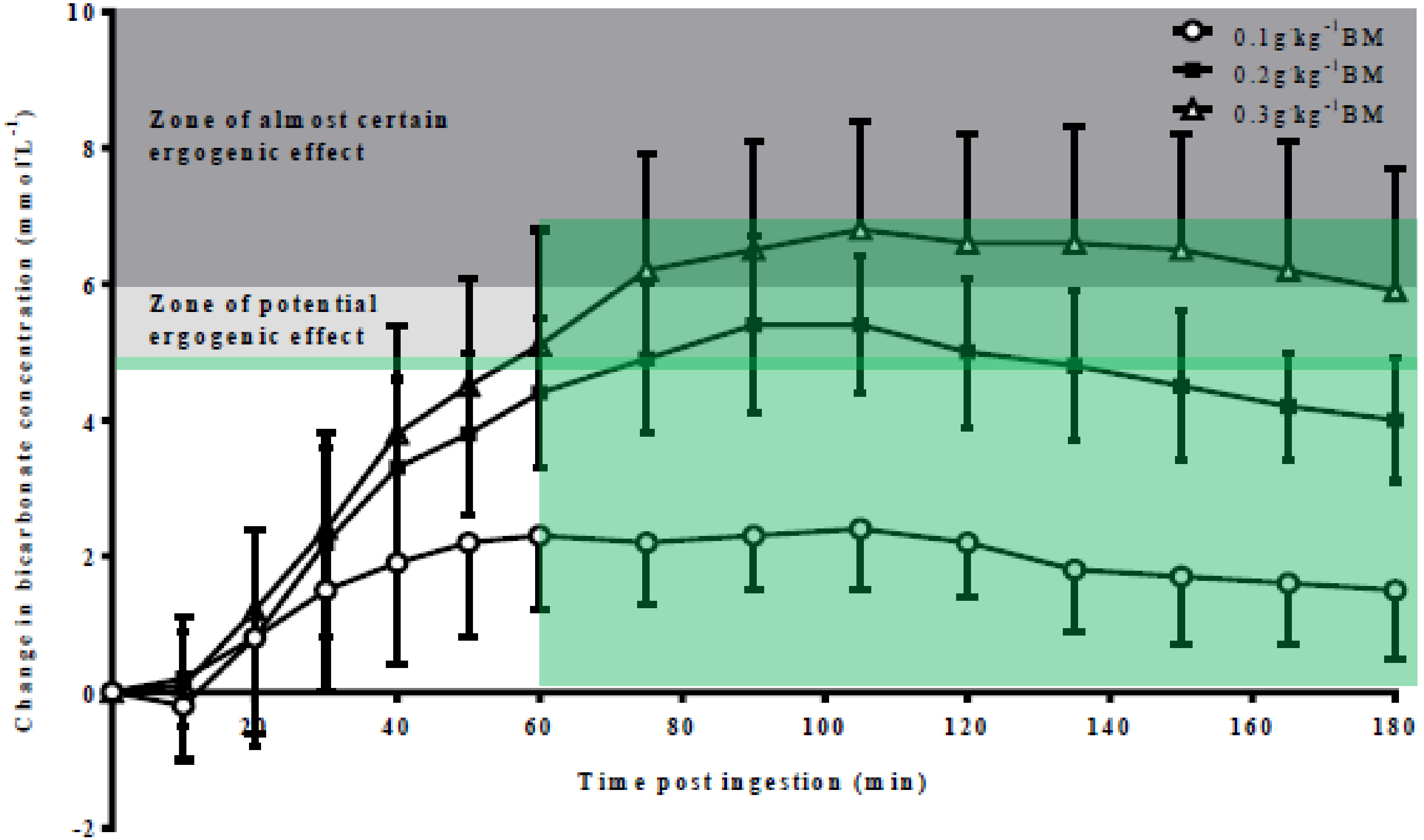

Figure 2: Mean absolute change in bicarbonate concentrations across 15 intervals (3 hr) following ingestion of 0.1 (open circles), 0.2 (solid square) and 0.3 g·kg^{-1}BM (open triangle) of $NaHCO_3$. Zone of ergogenic effect (+6 mmol·L^{-1}) is based on concentrations from Carr et al. (2011).

[Jones et al., 2016. *Int J Sport Nutr Exerc Metab*. 26(5):445-453]

Table 2: Individual blood bicarbonate responses following $NaHCO_3$ ingestion across supplemental condition. Absolute and percentage change in bicarbonate responses refer to the difference between baseline and peak concentrations; absolute changes of ≥5 mmol·L^{-1} are highlighted in bold. Position based on response ranks participants on absolute change in descending order, highest response equates to 1, whilst lowest absolute change equates to 16. Significant differences between supplementation conditions for absolute change and time-to-peak are denoted by * (0.1 and 0.3 g·kg^{-1}BM) ^{X} (0.1 and 0.2 g·kg^{-1}BM) and $^{\Delta}$ (0.2 and 0.3 g·kg^{-1}BM; P≤0.05).

	0.1 g·kg^{-1}BM					0.2 g·kg^{-1}BM					0.3 g·kg^{-1}BM				
Participant number	Baseline (mmol·L^{-1})	Absolute Change (mmol·L^{-1})	Percentage change (%)	Time-to-peak (min)	Position based on response	Baseline (mmol·L^{-1})	Absolute Change (mmol·L^{-1})	Percentage change (%)	Time-to-peak (min)	Position based on response	Baseline (mmol·L^{-1})	Absolute Change (mmol·L^{-1})	Percentage change (%)	Time-to-peak (min)	Position based on response
1	23.7	3.9	16.5	90	5	23.2	**6.9**	29.7	90	3	23.7	**8.9**	37.6	165	2
2	25.1	4.4	17.5	50	3	25.7	**6.0**	23.3	90	8	24.8	**8.9**	35.9	90	3
3	25.9	2.7	10.4	120	14	25.5	**6.0**	23.5	120	9	25.5	**8.1**	31.8	105	10
4	24.6	2.0	8.1	90	16	23.9	**5.5**	23.0	105	12	25.4	**7.0**	27.6	90	12
5	25.3	3.8	15.0	120	6	24.7	**5.6**	22.7	105	10	25.1	**8.5**	33.9	150	7
6	25.9	3.1	12.0	90	12	25.2	**5.3**	21.0	120	13	25.2	**6.9**	27.4	150	14
7	25.1	3.8	15.1	50	7	24.9	**6.4**	25.7	90	6	27.1	**8.8**	32.5	120	4
8	26.6	4.9	18.4	105	2	25.7	**5.1**	19.8	105	15	28.5	**7.7**	27.0	120	11
9	26.6	2.6	9.8	75	15	25.3	**7.1**	28.1	120	2	26.7	**12.3**	46.1	150	1
10	24.9	4.3	17.3	150	4	24.9	**6.6**	26.5	135	5	23.1	**8.6**	37.2	180	6
11	25.0	3.1	12.4	90	13	24.9	**6.4**	25.7	90	7	24.2	**7.0**	28.9	180	13
12	26.4	3.3	12.5	50	10	24.5	**8.1**	33.1	90	1	25.9	**8.6**	33.2	105	5
13	24.9	**5.0**	20.1	30	1	26.7	**5.5**	20.6	40	11	26.7	**6.0**	22.5	90	16
14	27.6	3.7	13.4	50	8	26.6	**5.2**	19.5	165	14	26.1	**8.3**	31.8	120	9
15	26.8	3.2	11.9	40	11	25.1	**5.1**	20.3	60	16	24.9	**6.6**	26.5	75	15
16	26.2	3.4	13.0	50	9	25.2	**6.7**	26.6	50	4	25.4	**8.4**	33.1	75	8
Mean	25.7	3.6 ^{*X}	14.0	78 *		25.1	6.1 $^{\Delta}$	24.3	98 $^{\Delta}$		25.5	8.2	32.0	123	
SD	1.0	0.8	3.3	34		0.9	0.9	3.9	32		1.3	1.4	5.6	36	
Min	23.7	2.0	8.1	30		23.2	5.1	19.5	40		23.1	6.0	22.5	75	
Max	27.6	5.0	20.1	150		26.7	8.1	33.1	165		28.5	12.3	46.1	180	

[Jones et al., 2016. *Int J Sport Nutr Exerc Metab*. 26(5):445-453]

THE EFFECTS OF NOVEL INGESTION OF SODIUM BICARBONATE ON REPEATED SPRINT ABILITY

PETER MILLER,[1] AMY L. ROBINSON,[1] S. ANDY SPARKS,[1] CRAIG A. BRIDGE,[1] DAVID J. BENTLEY,[2] AND LARS R. MCNAUGHTON[1]

[1]Department of Sport and Physical Activity, Edge Hill University, Ormskirk, United Kingdom; and [2]School of Medical Sciences, University of Adelaide, Adelaide, Australia

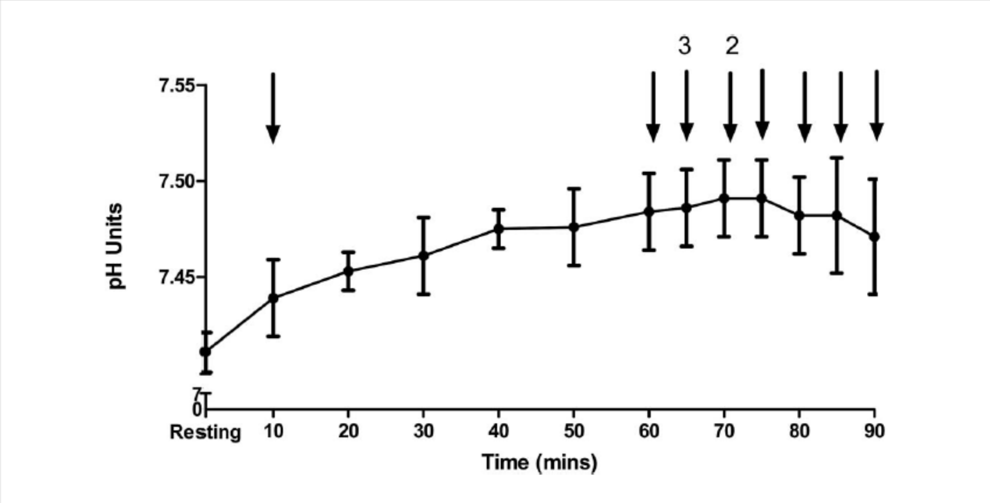

Figure 1. Mean ± *SD* pH measurements to determine the time-to-peak pH. Arrows indicate subjects' time-to-peak with numbers indicating the number of subjects peaking at that time.

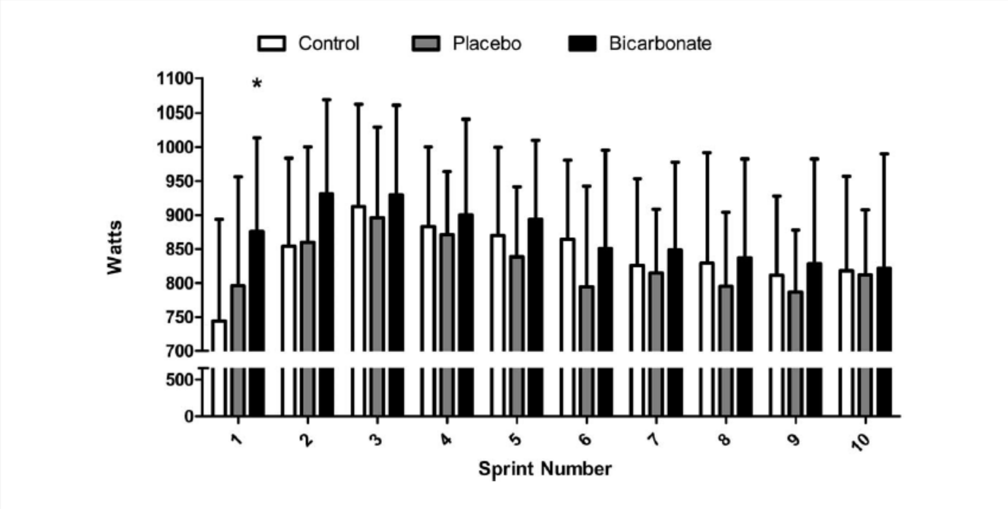

Figure 2. Mean ± *SD* peak power outputs across the 10 sprints in the 3 conditions. *Significantly different ($p \leq 0.05$) to both control and placebo conditions.

Edge Hill University

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Sodium bicarbonate ingestion and individual variability in time-to-peak pH

Andy Sparks, Emily Williams, Amy Robinson, Peter Miller, David J. Bentley, Craig Bridge & Lars R. Mc Naughton

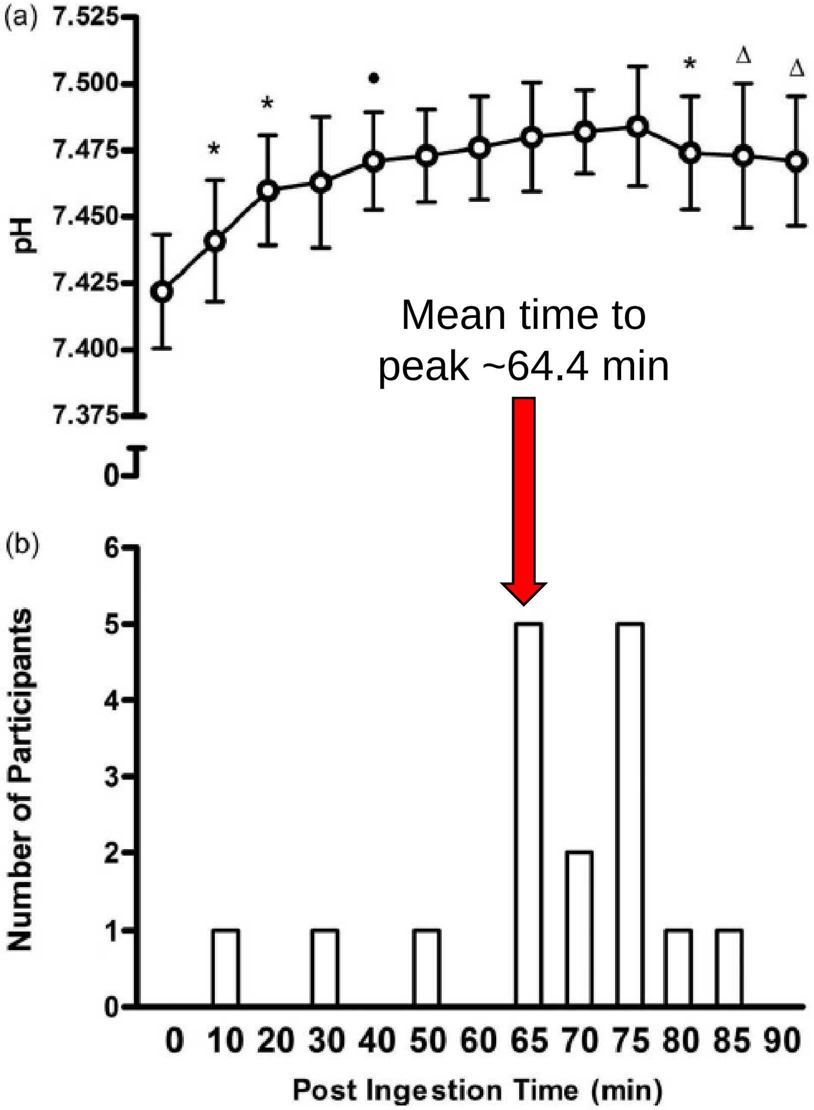
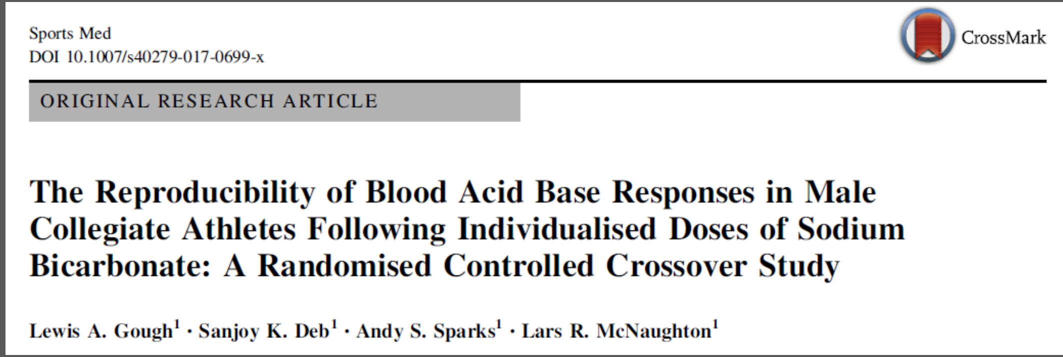


Figure 1. Mean (±SD) changes in pH following sodium bicarbonate ingestion (a) and individual participant time to peak pH Frequency (b).

Timing is Key

The vast majority of studies may have missed some, but more likely, most of their participant’s optimal alkalosis time

Okay, so it's inter-individually variable, but what about the intra-individual responses?


Sports Med
DOI 10.1007/s40279-017-0699-x
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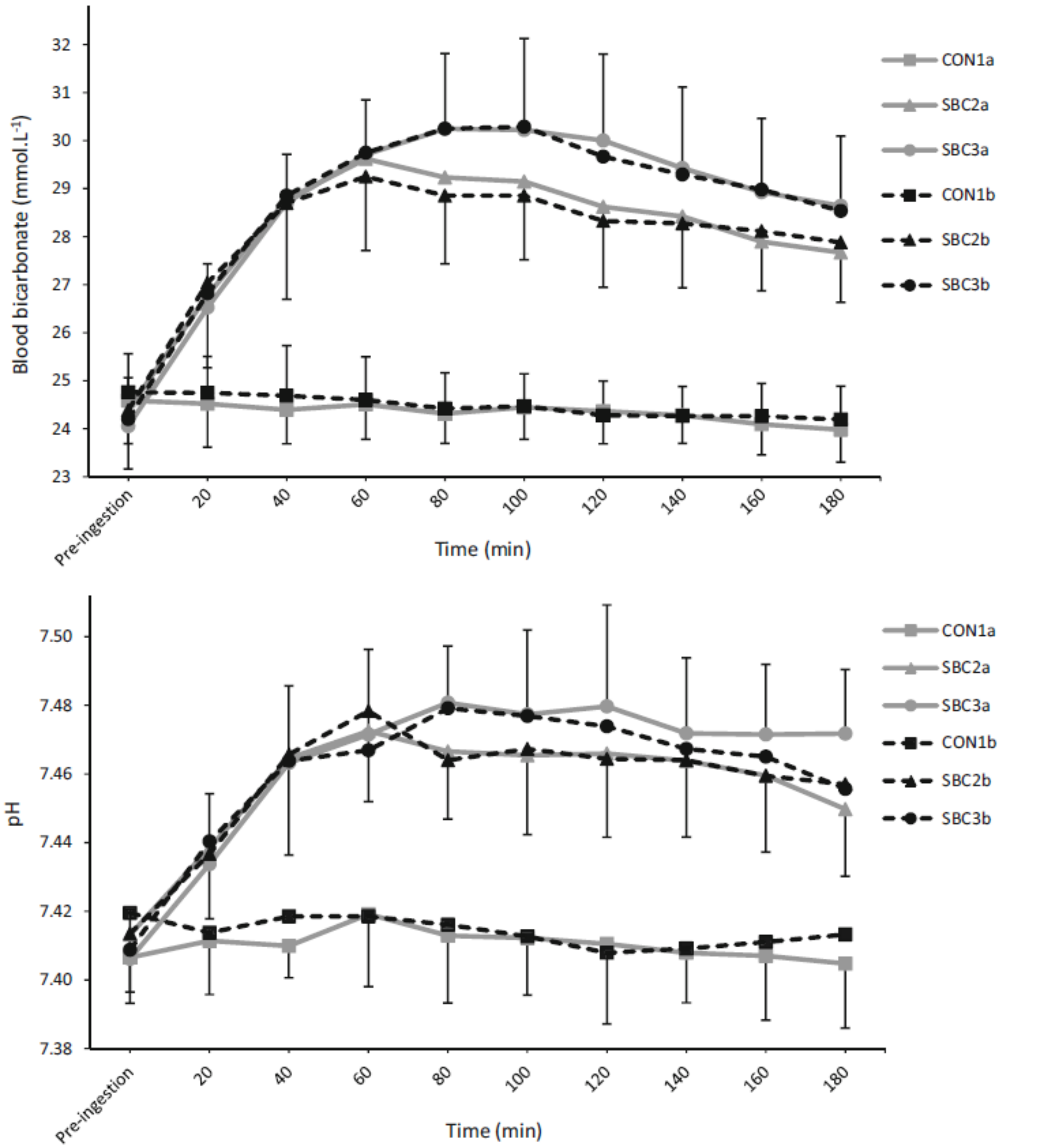
ORIGINAL RESEARCH ARTICLE

The Reproducibility of Blood Acid Base Responses in Male Collegiate Athletes Following Individualised Doses of Sodium Bicarbonate: A Randomised Controlled Crossover Study

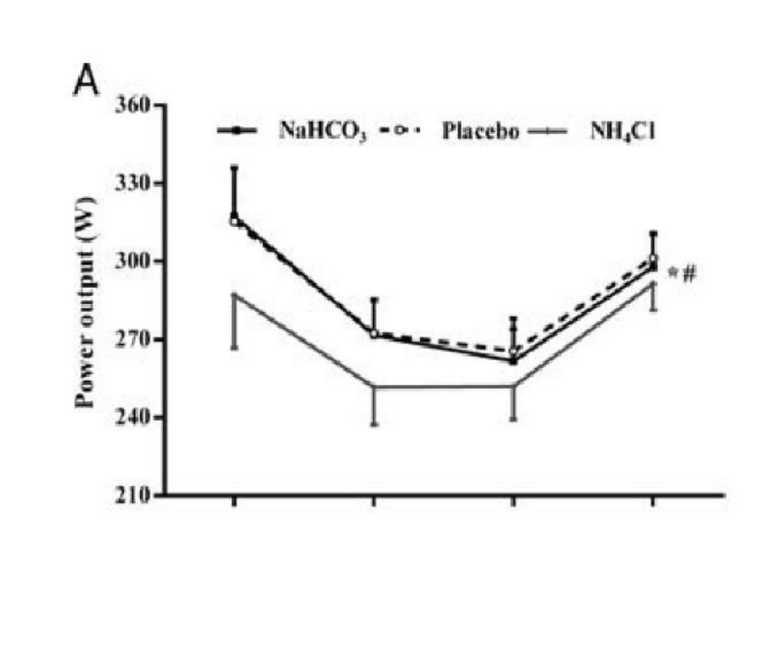
Lewis A. Gough[1] · Sanjoy K. Deb[1] · Andy S. Sparks[1] · Lars R. McNaughton[1]

For each individual, the acid-base response, is very repeatable

Fig. 1 Mean blood analyte responses for blood bicarbonate, pH and sodium following control treatments (*solid squares*), ingestion of sodium bicarbonate 0.2 g·kg^{-1} body mass (SBC2; *solid triangles*) and 0.3 g·kg^{-1} body mass (SBC3; *solid circles*). Some error bars and timepoints (5-min interval samples) are omitted for clarity



But there are some equivocal exercise performance data following $NaHCO_3$ ingestion!



Acidosis, but Not Alkalosis, Affects Anaerobic Metabolism and Performance in a 4-km Time Trial

CARLOS RAFAELL CORREIA-OLIVEIRA[1,2], JOÃO PAULO LOPES-SILVA[1], ROMULO BERTUZZI[2], GLENN K. MCCONELL[3], DAVID JOHN BISHOP[3,4], ADRIANO EDUARDO LIMA-SILVA[1,5], and MARIA AUGUSTA PEDUTI DAL'MOLIN KISS[2]

Med Sci Sports Exerc. 2017. 49(9):1899-1910.

TABLE 1. Performance time, mean PO, mean aerobic and anaerobic PO, and total, aerobic, and anaerobic energy expenditure during the 4-km TT in the alkalosis, placebo, and acidosis conditions.

	$NaHCO_3$	Placebo	NH_4Cl
Time (s)	385.8 ± 24.9	384.9 ± 19.1	395.7 ± 27.1*,**
PO (W)	287 ± 42	288 ± 35	269 ± 38*,**
P_{an} (W)	70 ± 20	69 ± 17	59 ± 19*,**
P_{aer} (W)	217 ± 26	219 ± 24	210 ± 24*
EE_{tot} (kJ)	109.8 ± 9.7	110.5 ± 8.2	105.7 ± 8.6*,**
EE_{an} (kJ)	26.7 ± 6.5	26.5 ± 5.9	23.2 ± 6.0*,**
EE_{aer} (kJ)	83.1 ± 5.5	84.0 ± 5.8	82.5 ± 5.1

Values are presented as mean ± SD. $NaHCO_3$, alkalosis condition; NH_4Cl, acidosis condition.
*Significantly different from placebo ($P < 0.05$).
**Significantly different from $NaHCO_3$ ($P < 0.05$).

However, with an individualised ingestion strategy, both 0.2 and 0.3 $g.kg^{-1}$ significantly improve 4 km TT performance

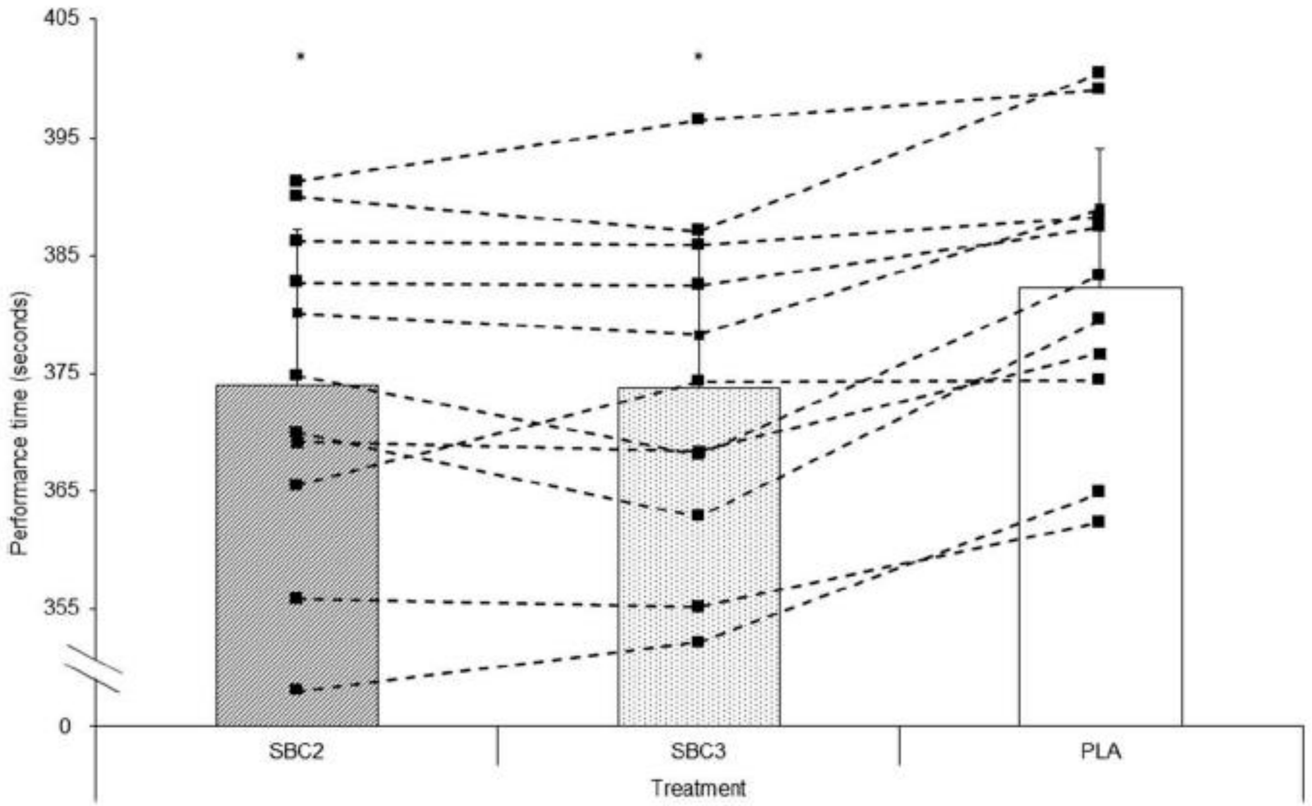
JOURNAL OF SPORTS SCIENCES, 2017
https://doi.org/10.1080/02640414.2017.1410875

Routledge Taylor & Francis Group

Sodium bicarbonate improves 4 km time trial cycling performance when individualised to time to peak blood bicarbonate in trained male cyclists

Lewis A. Gough[a], Sanjoy K. Deb[a], S. Andy Sparks[a] and Lars R. McNaughton[a,b]

[a]Sports Nutrition and Performance Group, Department of Sport and Physical Activity, Edge Hill University, Ormskirk, UK; [b]Department of Sport and Movement Studies, Faculty of Health Science, University of Johannesburg, Johannesburg, South Africa



Edge Hill University

Furthermore, the performance improvements are very reproducible

Gough *et al. Sports Medicine - Open* (2017) 3:34
DOI 10.1186/s40798-017-0101-4

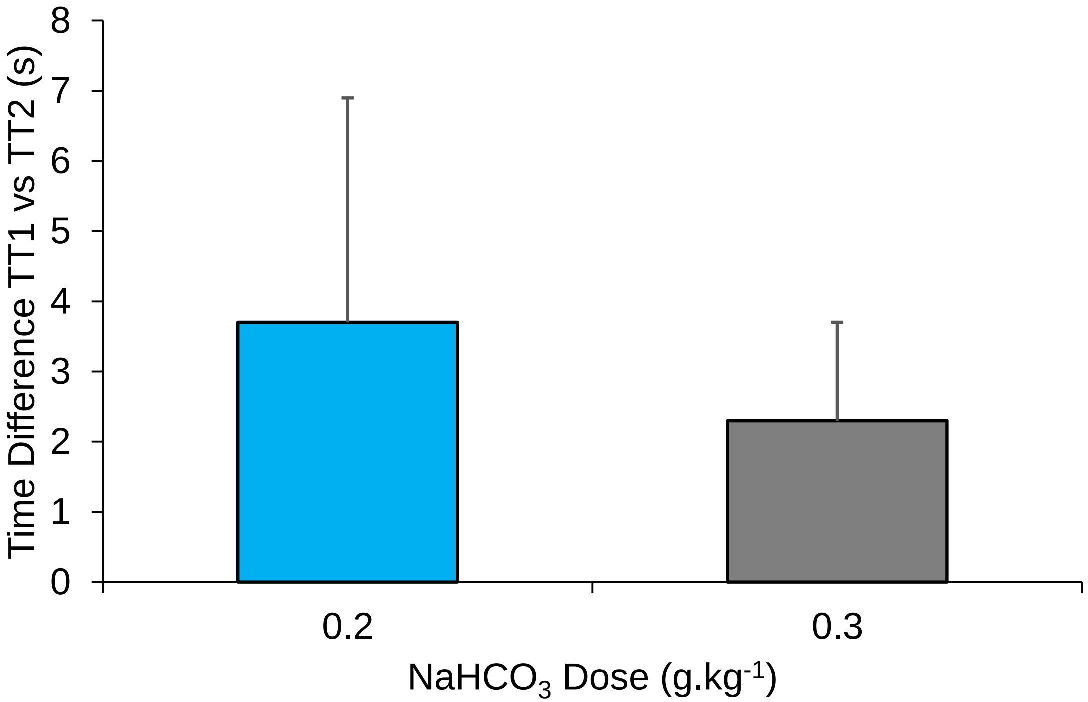
Sports Medicine - Open

ORIGINAL RESEARCH ARTICLE Open Access

CrossMark

The Reproducibility of 4-km Time Trial (TT) Performance Following Individualised Sodium Bicarbonate Supplementation: a Randomised Controlled Trial in Trained Cyclists

Lewis Anthony Gough*, Sanjoy Kumar Deb, Andy Sparks and Lars Robert McNaughton

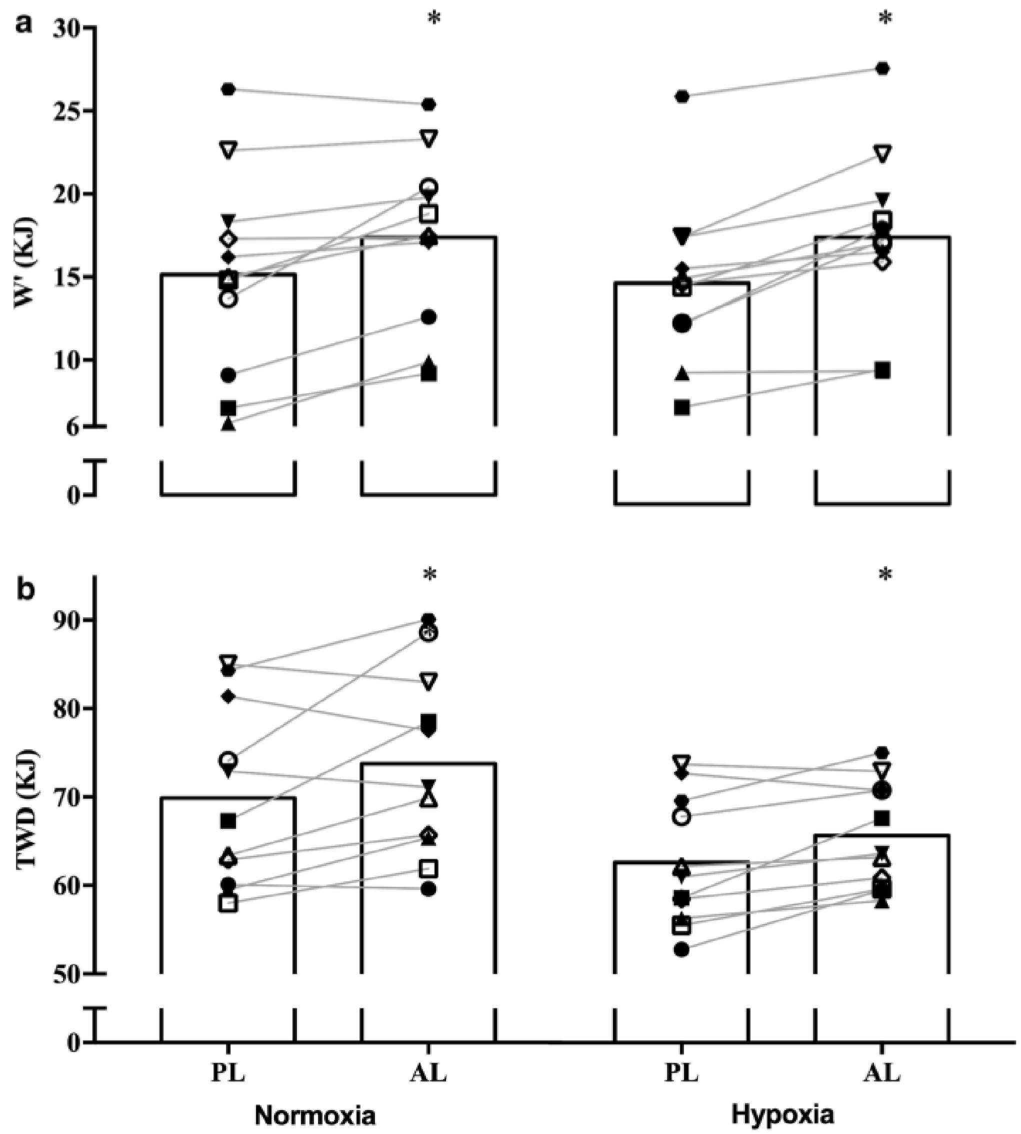


Okay, but what about other types of exercise?

TABLE 1. Group mean (± SD) physiological responses to the 3-min all-out test after PL and $NaHCO_3$ treatments.

	PL	$NaHCO_3$
CP (W)	248 ± 50	251 ± 51
W′ (kJ)	18.2 ± 6.4	17.5 ± 6.0
Total work done (kJ)	62.8 ± 10.1	62.7 ± 10.1
Peak power (W)	765 ± 160	792 ± 187
$\dot{V}O_{2peak}$ ($L{\cdot}min^{-1}$)	3.97 ± 0.66	3.99 ± 0.75
$\dot{V}CO_{2peak}$ ($L{\cdot}min^{-1}$)	5.54 ± 0.95	5.80 ± 1.00

[Vanhatalo et al., 2010. *Med. Sci. Sports Exerc*., 42(3): 563–570]



[Deb et al., 2017. *Eur. J. Appl. Physiol*., 117(5):901-912]

So why not recommend this to all riders competing for < 20 min in duration?

Image: @cadence_images

Gastrointestinal Symptoms (GIS)

- The use of sodium bicarbonate has become synonymous with GI problems

- Work by Carr et al., 2011 attempted to determine an optimal ingestion strategy but was unable to do so

- Whilst GIS are frequently observed, the underlying reasons for inter and intra-individual variability in responses is not understood.

Image: @cadence_images

There is huge variability in GIS responses both inter and intra-individually

Table 2 The most severe individual symptom of gastrointestinal upset experienced following ingestion of sodium bicarbonate 0.2 or 0.3 $g \cdot kg^{-1}$ body mass

Participant	SBC2a	SBC2b	SBC3a	SBC3b
1	None	None	None	None
2	Flatulence	None	None	None
3	Flatulence	None	Bowel urgency	Bowel urgency
4	Stomach cramp	Belching	Belching	Stomach ache
5	None	None	None	None
6	None	None	None	None
7	Stomach bloating	Stomach cramp	Bowel urgency	Stomach ache
8	Stomach ache	Nausea	Stomach cramp	Diarrhoea
9	Bowel urgency	Bowel urgency	None	Stomach bloating
10	Stomach bloating	Stomach bloating	Stomach ache	Stomach ache
11	Diarrhoea	Diarrhoea	Diarrhoea	Diarrhoea
12	None	None	Bowel urgency	None
13	Nausea	Nausea	Nausea	Nausea
14	None	None	None	None
15	None	None	None	None

SBC2 0.2 $g \cdot kg^{-1}$ body mass, *SBC3* 0.3 $g \cdot kg^{-1}$ body mass

[Gough et al., 2017. *Sports Medicine*, 47(10):2117-2127]

Perhaps the GIS can explain some of the equivocal performance findings?

Table 1 Total Work Done for All Participants, Those Who Did Not Experience Gastrointestinal (GI) Discomfort, Those Who Improved Exercise Capacity, and Those Who Did Not, Mean ± SD

	Total work done (kJ)
All participants (N = 21)	
placebo	45.6 ± 8.4
$NaHCO_3^-$	46.8 ± 9.1
No GI distress (n = 17)	
placebo	46.2 ± 9.2
$NaHCO_3^-$	48.4 ± 9.3*
Improved (n = 9)	
placebo	43.1 ± 7.3
$NaHCO_3^-$	47.5 ± 8.1*
Nonimproved (n = 12)	
placebo	47.5 ± 9.0
$NaHCO_3^-$	46.2 ± 10.1

*$P \le .01$ from placebo trial.

[Saunders et al., 2014. *IJSPP*, 9, 627-632]

Alternatively, could some of the equivocal findings be the result of insufficient increases in blood HCO_3?

frontiers in Nutrition

REVIEW
published: 08 May 2018
doi: 10.3389/fnut.2018.00035

Time to Optimize Supplementation: Modifying Factors Influencing the Individual Responses to Extracellular Buffering Agents

*André B. Heibel[1,2], Pedro H. L. Perim[1,3], Luana F. Oliveira[1,4], Lars R. McNaughton[5,6] and Bryan Saunders[1,7,8]**

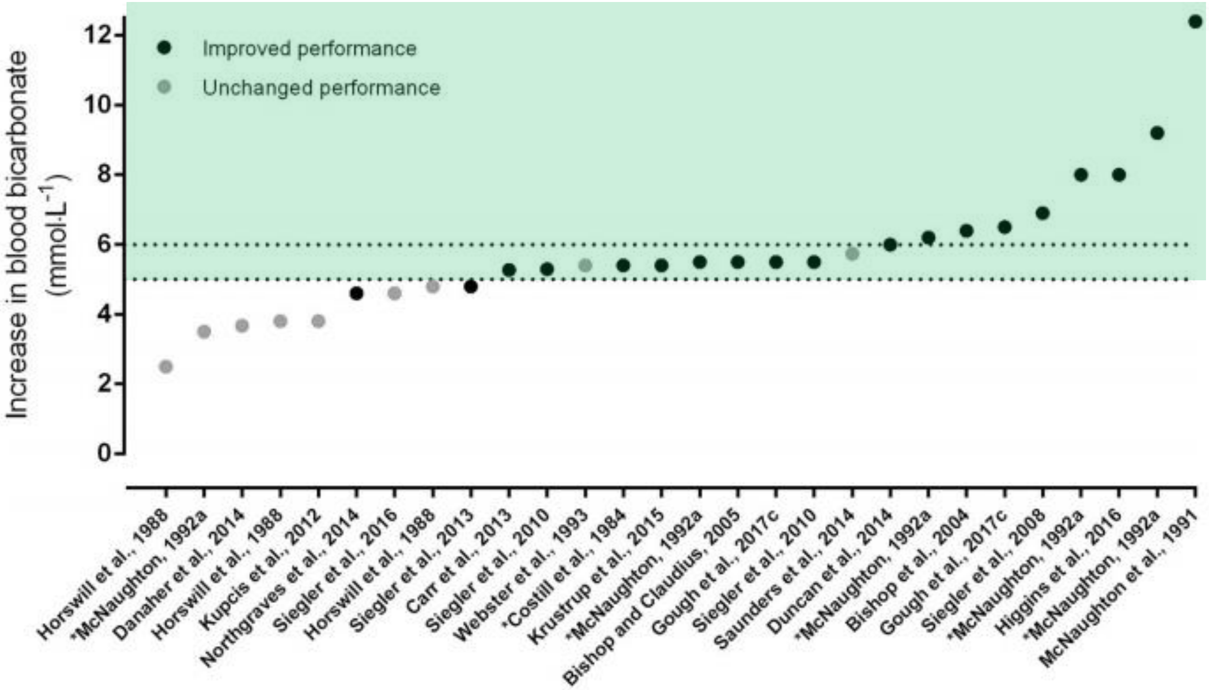
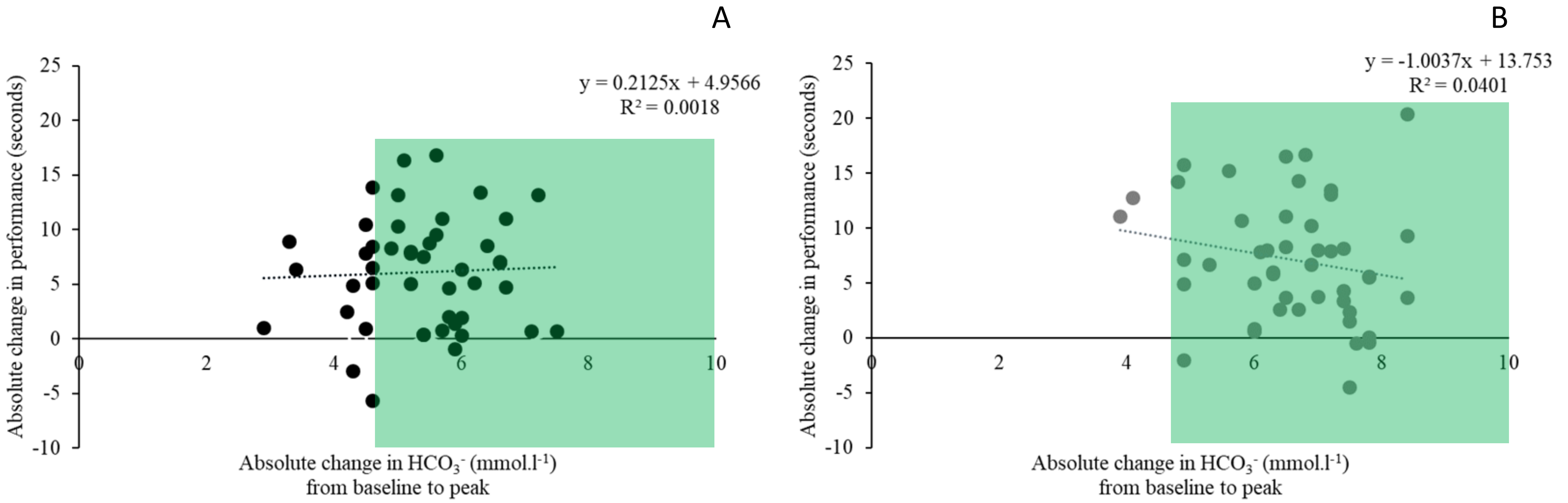


FIGURE 1 | Increases in blood bicarbonate from baseline following acute supplementation with sodium bicarbonate, in order of magnitude of change. Data points indicate whether exercise performance was improved with supplementation (dark circles) or not (light circles). The dotted lines indicate the thresholds for the zone of a potential ergogenic effect (+5 $mmol \cdot L^{-1}$) and the zone of an almost certain ergogenic effect (+6 $mmol \cdot L^{-1}$); taken from Carr et al. (2) and Jones et al. (19). *Denotes data estimated from graphs using specialized software (18, 20, 21, 23, 26, 29, 30, 33, 38, 42–53).

Possibly, but in our studies, change in HCO_3 is not correlated to a performance improvement



The relationship between the absolute change in HCO_3^- and the resulting 4 km TT performance improvement following $NaHCO_3$ ingestion. (A) 0.2 $g.kg^{-1}$ and (B) 0.3 $g.kg^{-1}$ compared to PLA (n = 46).

[Data from Gough et al., 2017. *Sports Medicine*, *Sports Med Open* and *JSS*, along with some unpublished observations]

So, can we use this approach with all our athletes?

No, not without "systematic trial and error"!

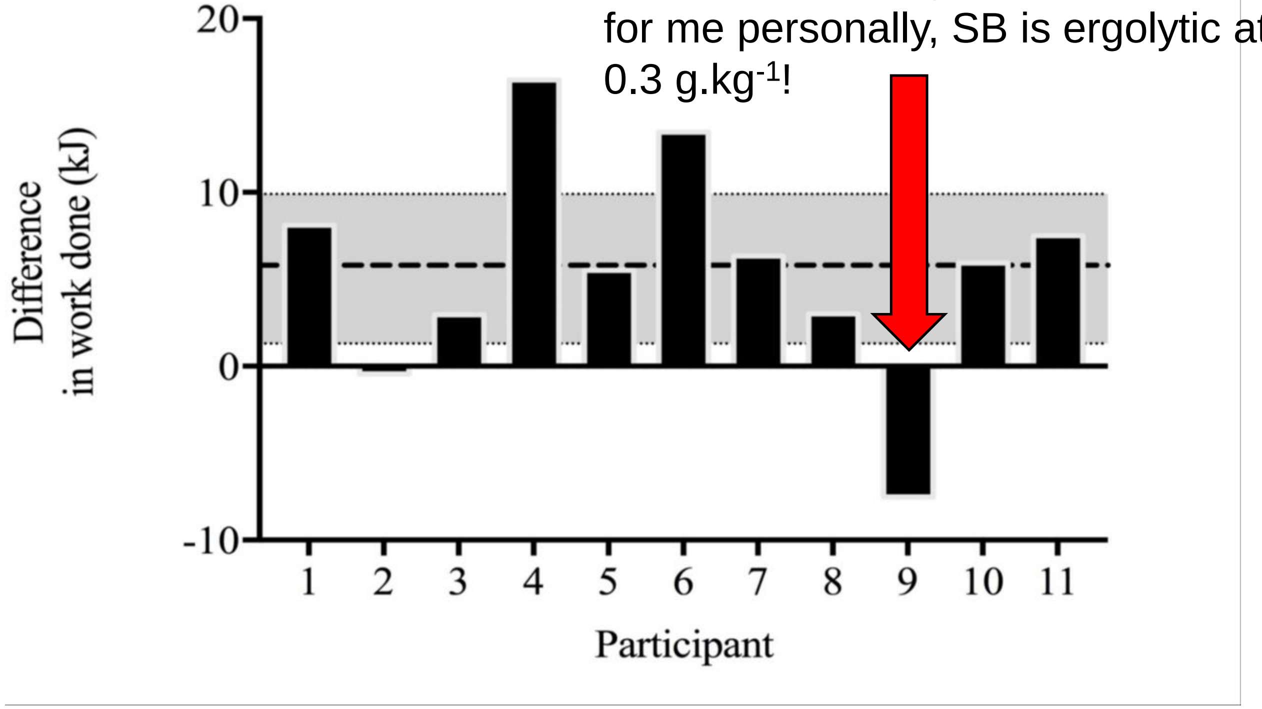
European Journal of Applied Physiology
https://doi.org/10.1007/s00421-018-3801-7

ORIGINAL ARTICLE

Sodium bicarbonate supplementation improves severe-intensity intermittent exercise under moderate acute hypoxic conditions

Sanjoy K. Deb[1] · Lewis A. Gough[1] · S. Andy Sparks[1] · Lars R. McNaughton[1,2]

One size definitely does not fit all – for me personally, SB is ergolytic at 0.3 $g.kg^{-1}$!



Difference in work complete between $NaHCO_3$ vs. placebo. Dashed line represents mean difference in work and the shaded band shows the ±95% CI of effect between treatments.

Practical Recommendations

- Athletes need to determine individual time to peak following $NaHCO_3$ ingestion to maximise ergogenic effects
- Ingestion should be 0.3 $g.kg^{-1}$ but if moderate-severe GIS occurs, 0.2 $g.kg^{-1}$ should be attempted
- Test this strategy extensively in training first.

Image: @cadence_images

Where next?

- Individualising ingestion times appears to increase the ergogenic benefit of $NaHCO_3$
- We need to explore low cost methods of determining peaks for athletes
- It's unknown why some athletes have worse GIS than others
- We need to establish if longer exercise bouts might actually benefit
- To get more athletes to use $NaHCO_3$, we need to reduce the GIS.

Image: @cadence_images

Thank you for your attention

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Edge Hill University, Ormskirk, UK

Thanks to:

Dr Sanjoy Deb
Dr Lewis Gough
Prof Lars McNaughton

@cadence Images

THE BICYCLE LOUNGE

Additional Slides

Edge Hill University

Optimising sodium bicarbonate supplementation: Are gastro-resistant capsules the answer?

Luana Farias de Oliveira[1,2], Bryan Saunders[1], Guilherme Yamaguchi[1,2], Bruno Gualano[1,2], Hamilton Roschel[1,2], Guilherme Giannini Artioli[1,2]

1 Applied Physiology & Nutrition Research Group, Rheumatology Division, Faculty of Medicine FMUSP, University of São Paulo, Brazil.
2 School of Physical Education and Sport, University of São Paulo, Brazil

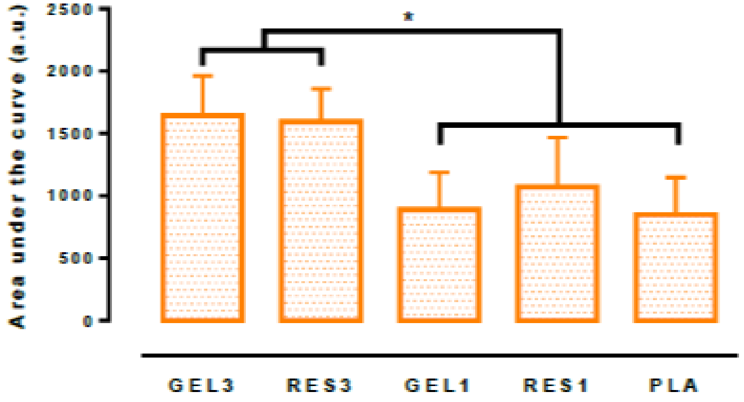


Figure 1: Area under the curve blood bicarbonate

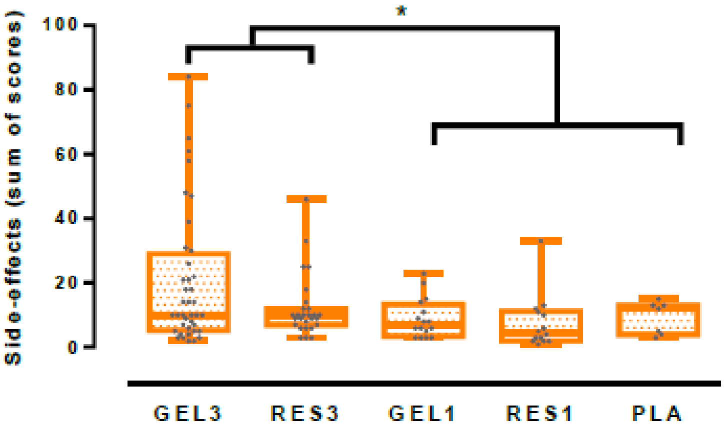
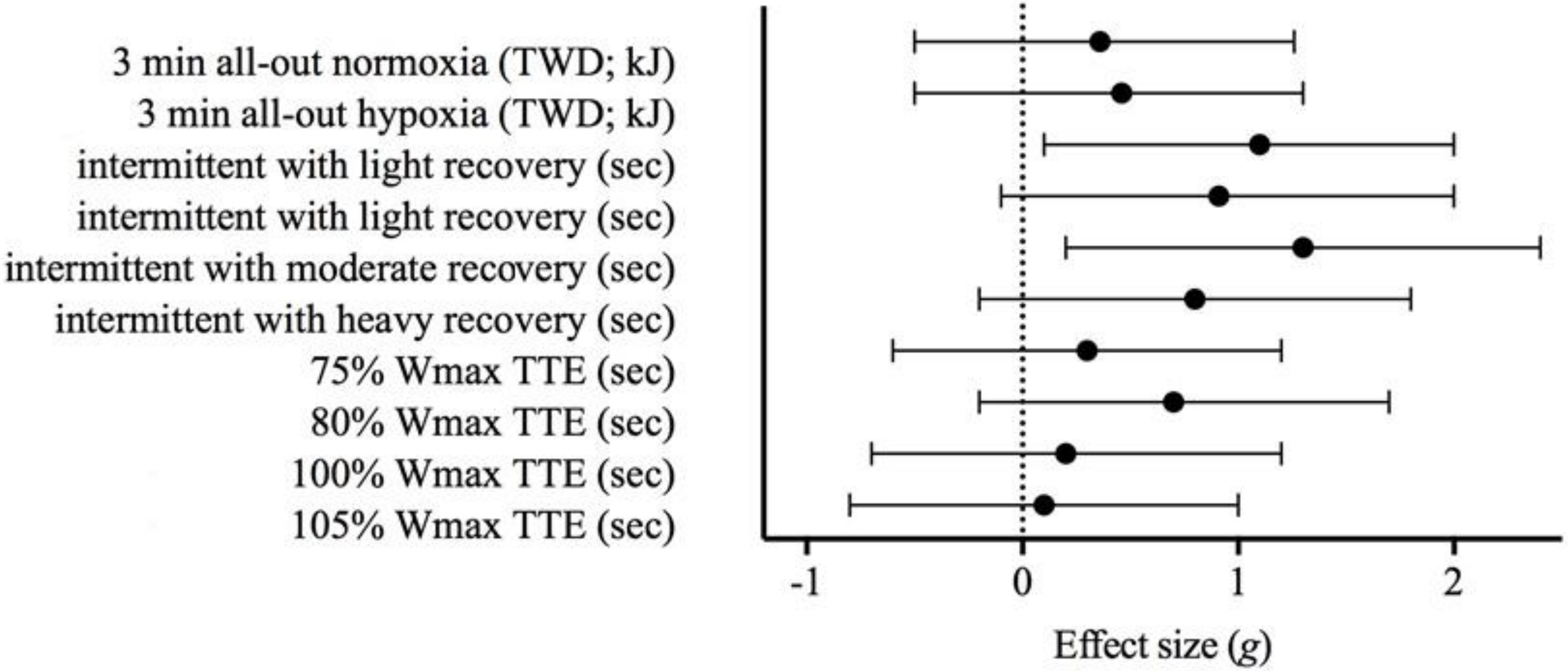


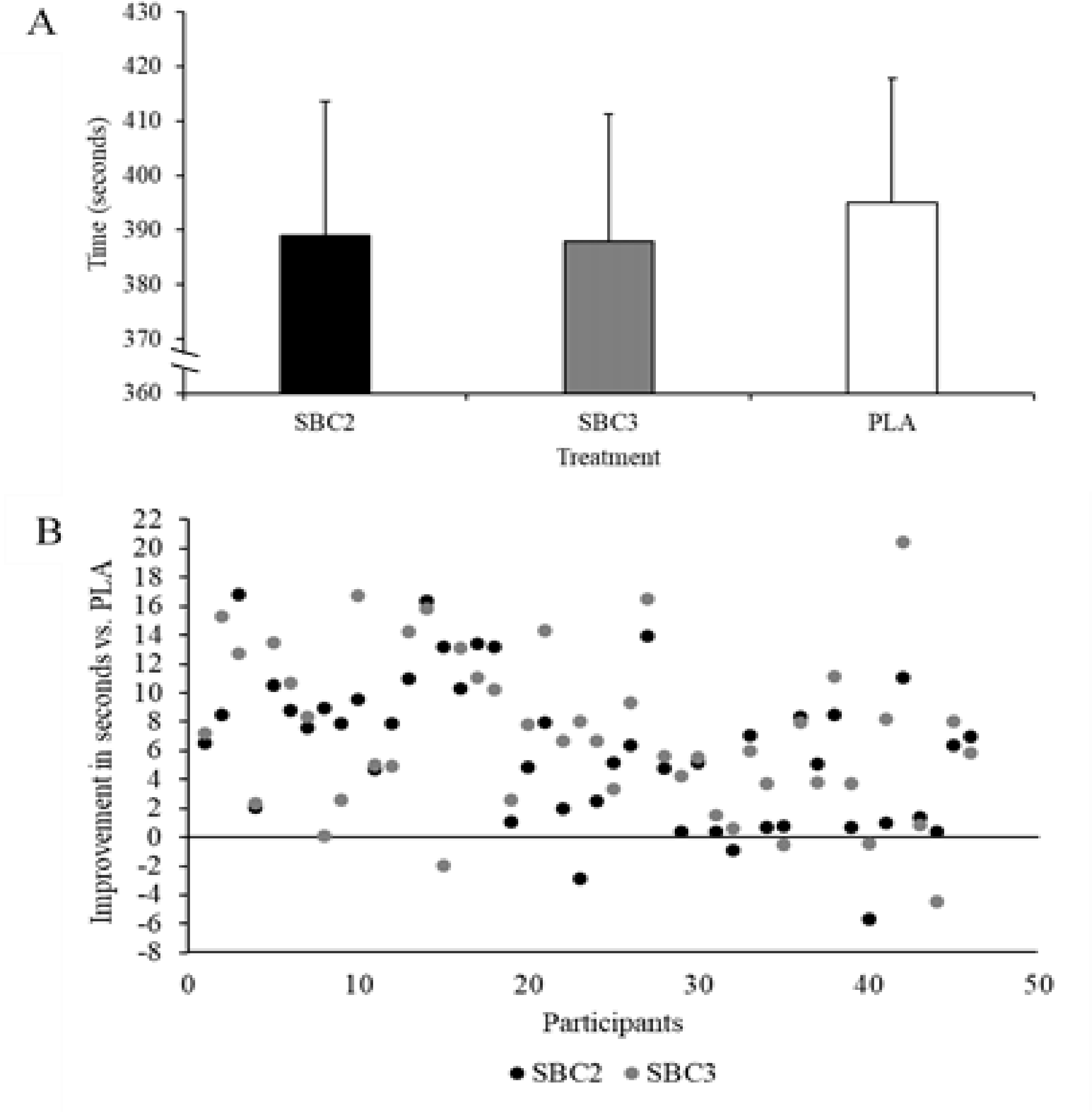
Figure 2: Side-effects

Applications to other exercise settings



Effect sizes (hedges *g*) and corresponding 95% CI showing the effect of $NaHCO_3$ compared to placebo in a variety of exercise tests.

[Data from Deb et al., 2017; 2018. *EJAP*, along with some unpublished observations]



Mean (± SD) time to complete the 4 km TT for all participants (n = 46) (A) and individual responses (B). * denotes significantly different to PLA ($p < 0.001$). No differences between SBC2 and SBC3 were evident ($p = 0.372$).