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Effect of induced alkalosis on performance during a field-simulated BMX cycling competition

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ABSTRACT

Objectives: The aim of the present study was to test the effect of sodium bicarbonate ($NaHCO_3^-$) ingestion on performance during a simulated competition on a Bicycle Motocross (BMX) track.
Design: Double-blind cross-over study.
Methods: Twelve elite male BMX cyclists (age: 19.2 ± 3.4 years; height: 174.2 ± 5.3 cm; body mass: 72.4 ± 8.4 kg) ingested either NaHCO3- (0.3 $g.kg^{-1}$ body weight) or placebo 90 min prior to exercise. The cyclists completed three races in a BMX Olympic track interspersed with 15 min of recovery. Blood samples were collected to assess the blood acid-base status. Performance, cardiorespiratory, heart rate variability (HRV) as well as subjective variables were assessed.
Results: The main effect of condition ($NaHCO_3^-$ vs. placebo) was observed in pH, bicarbonate concentration and base excess ($p < 0.05$), with a significant blood alkalosis. No changes were found in time, peak velocity and time to peak velocity for condition ($p > 0.05$). The HRV analysis showed a significant effect of $NaHCO_3^-$ ingestion, expressed by the rMSSD30 (root mean square of the successive differences) ($p < 0.001$). There was no effect of condition on oxygen uptake, carbon dioxide production, or pulmonary ventilation ($p > 0.05$). Finally, there was no effect of condition for any subjective scale ($p > 0.05$).
Conclusions: We present here the first field condition study to investigate the effect of bicarbonate ingestion over performance in BMX discipline. The results showed that $NaHCO_3^-$-induced alkalosis did not improve performance in a simulated BMX competition in elite BMX cyclists, although future studies should consider the effects of NaHCO3- on autonomic function as a component of recovery.

1. Introduction

Numerous studies have demonstrated that increasing the extracellular buffer concentration via the oral ingestion of an alkaline solution such as sodium bicarbonate ($NaHCO_3^-$) may enhance human exercise performance.[1–3] These findings have maintained the practice of inducing alkalosis within the field of Sport Science for decades, although the physiological mechanism directly responsible for performance augmentation in humans is unknown. In the present study we focus on $NaHCO_3^-$ as a potential ergogenic aid to increase bicycle motocross (BMX) cycling performance via its effect on blood alkalosis, since $NaHCO_3^-$ is believed to mitigate fatigue through the attenuation of intramuscular acidity.[1,4]

Literature focusing on the effect of $NaHCO_3^-$ supplementation has shown contradictory findings. Some studies showed no effect on intermittent and all-out exercise,[5–7] despite significant blood alkalosis, while others have reported performance improvements.[8–10] Recent studies combining sodium bicarbonate ingestion with other substances, such as glucose or β-alanine, did not find significant benefits in exercise.[11,12] In general, during continuous dynamic exercises the performance has been usually improved whilst all-out exercise of shorter duration presents con-

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flicting results.[13] Thus, whether bicarbonate ingestion increases performance remains unclear.

Bicarbonate ingestion could be beneficial in a discipline such as BMX, where repeated efforts at high intensity with short recoveries between bouts are required. The physiological demands and technical factors of a simulated BMX competition have been previously reported,[14,15] showing that elite cyclists reach oxygen uptake (VO_2) values higher than 90% of maximal oxygen uptake, while there is a high contribution from the anaerobic metabolism and a significant impairment of the acid-base balance.[14]

Previous studies on the effect of $NaHCO_3^-$ administration on BMX performance have been conducted on laboratory simulating a competition.[5,16,17] Some of these studies have shown no effect,[5,16] while others have reported performance improvements during short high intensity exercise.[17] However, to the best of our knowledge, there is no study investigating the effect of $NaHCO_3$ on BMX performance in a real competition scenario. In sum, the purpose of our study was to investigate the impact of $NaHCO_3^-$ administration on BMX performance in a real competition context. We first tested whether $NaHCO_3^-$ induced the expected blood alkalosis. Then, we analyzed both objective (e.g., peak velocity) and subjective (e.g., perceived effort) measures of BMX performance. Finally, we explore the impact of $NaHCO_3^-$ administration on post-exercise recovery, by means of the analysis of HRV data.

2. Methods

Twelve elite male BMX cyclists from the Spanish National Team volunteered to participate in this study. Their mean ± standard deviation (SD) age, height and body mass were 19.2 ± 3.4 years, 174.2 ± 5.3 cm and 72.4 ± 8.4 kg, respectively. None of the participants were involved in any kind of nutritional supplementation that would interfere with the administration of sodium bicarbonate. Written consent was obtained from each participant after explanation of the procedure, benefits and associated risks of the study protocol. The experiment was conducted according to Helsinki Declaration and was approved by the Technical University of Madrid Ethics Committee for Human Studies.

At the time of the experiment, participants were taking part in an official monitoring phase in-season with the Spanish national team, thusthe athletes were under supervision of the training staff for eating and training. Participants visited the track on three occasions. On the first day, cyclists were familiarized with the experimental procedure and with the Madrid BMX Olympic outdoor track, used in national and international competitions. The bouts started from an official BMX starting ramp and start gate that was triggered by an official acoustic signal (Bensink BMX gates, Voorst, Nederland). The track layout consisted of an exit descending ramp of 5 m and a 10% slope, then a flat distance of 3.3 m to the first obstacle (small double jump, with no high technical difficulty), and then another flat and straight line of 25 m. The rest of the track was composed of 3 corners each of approximately 180° which were connected by 4 straights, from higher to lower technical difficult, with a total length of 400 m. Experimental data were collected during the subsequent two days. The two treatment conditions, $NaHCO_3^-$ and placebo, were administered in a counterbalanced, crossover, randomly assigned, double blind manner, with each session separated by 4 days. Each subject was instructed to refrain from caffeine, alcohol, and exercise for 24 h before each session, and both sessions were performed at the same time of day.

The experimental protocol was designed to simulate a BMX competition. In each testing session, participants performed a self-selected warm-up of 10 min typical of pre-competition. After a 6 min rest period, they completed three races (R1, R2 and R3). The athletes raced in pairs and they were motivated to do their best in the competition simulation. Following each race, participants had 15 min of passive recovery. Every participant performed the whole session with his own race bike and cycling suit to reproduce as closely as possible the physiological demands of a BMX competition. Participants were given verbal encouragement throughout the session but they were blinded to performance variables until the experiment was completed. Each cyclist performed the races at the same time of day under similar outdoor environmental conditions (10.8 ± 0.6 °C and 61.4 ± 4.4% relative humidity).

Prior to each session, participants reported to the experimental setting in a 3-h post-absorptive state. Heart rate (HR) and heart rate variability (HRV) was recorded during 10 min in resting baseline condition before substance ingestion. The participants ingested an individualized number of gelatin capsules containing $NaHCO_3^-$ (0.3 g kg^{-1} body weight) or placebo (0.045 g kg^{-1} body weight of NaCl) and were allowed to consume water *ad libitum*. Both substances were ingested 90 min prior to exercise as recommended by previous research.[13,18] Gelatin capsules were matched by shape and taste and we assured the intake of equal number of pills during the two conditions. The researchers were blinded from the conditions. None of the participants reported serious gastrointestinal distractions.

An 18G catheter was inserted into a forearm vein for blood sampling. Blood samples were drawn prior to the substance ingestion at rest, immediately prior to and after each race, 3 min after completion of each race, and after 15 min of recovery. Blood samples were analyzed immediately using a blood gas analyzer (ABL 77, Radiometer, Copenhagen, Denmark) for pH, bicarbonate concentration ($[HCO_3^-]$) and base excess. Blood lactate concentration ($[La^-]$) was analyzed by enzymatic method (YSI 1500, Yellow Springs Instruments Co., Ohio, USA).

The indexes of cycling performance were: time to complete the race (time) measured by 2 photocell barrier cuts SportMetrics (sensitivity 0.001 s) connected to a ChronoMaster timer (SportMetrics, Picaña, Valencia, Spain), peak velocity during the race (peak velocity) and time to reach the peak velocity (time to peak velocity) measured by Garmin Edge 510 GPS device (Garmin International Inc., Olathe, Kansas City, USA).

Heart rate and HRV were recorded throughout the experimental sessions using a Polar RS800 monitor (Polar Electro, Kempele, Finland). Mean and peak HR were obtained for each race. Subsequently, each downloaded R-R interval file was analyzed by means of the Kubios HRV 2.2 analysis software for MAC OSX (The Biomedical Signal and Medical Imaging Analysis Group, University of Kuopio, Finland). The recordings were preprocessed to exclude artefacts by eliminating RR intervals which differed more than 25% from the previous and the subsequent RR intervals. Removed RR intervals were replaced by conventional spline interpolation so that the length of the data did not change. We used the smoothness prior method with a Lambda value of 500 to remove disturbing low frequency baseline trend components. All HRV data were transformed to their natural logarithms in order to ensure a normal distribution.

To assess parasympathetic reactivation in the first 3-min after the end of each race, a time domain HRV vagal index (i.e., the root mean square of successive differences [rMSSD]), was calculated sequentially at each 30-s segment of the recovery period (%$rMSSD_{30}$).[19,20] The rMSSD baseline measurement (i.e., before the ingestion of the substance) was taken into consideration to relativize the magnitude of the parasympathetic reactivation by subject and experimental condition.

Expired gases were measured immediately before and after each race using the breath-by-breath portable gas analyzer Jaeger Oxycon Mobile (Erich Jaeger, Viasys Healthcare, Hoechberg, Germany). The mask was put on the face during the minute immediately before each race (within 10 s) and after the end of each race (within 10 s).

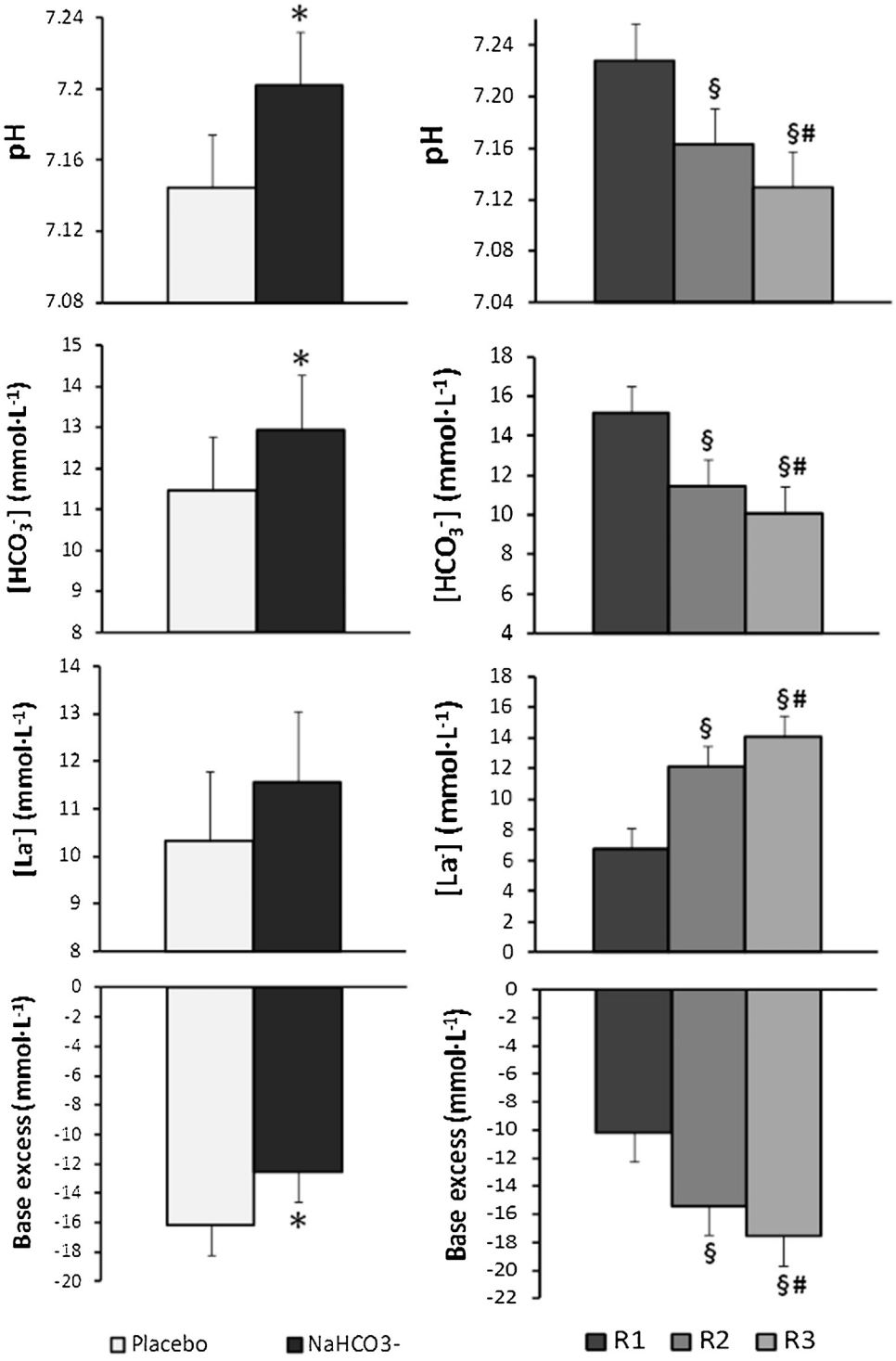

Fig. 1. Blood pH, Bicarbonate concentration [HCO_3^-], Blood lactate concentration [La^-] and Base excess. Values are means ± 95% CI. * Significant difference with placebo condition; § Significant difference with R1; # Significant difference with R2. R1: race 1; R: race 2; R3: race 3.

Oxygen uptake, carbon dioxide production (VCO_2) and pulmonary ventilation (VE) were continuously measured.

Immediately after each race, rating of perceived exertion (RPE) was obtained. RPE was measured with the Borg 15 point scale (RPE 6–20) and with a 10-point category-ratio (CR10). The value for perceived readiness (1–5 scale) was taken prior to the beginning of every race to assess the grade of recovery from 1-point ("no recovery at all") to 5-points ("completely recovered").

The statistical analyses were conducted using the software IBM SPSS Statistics for Macintosh, Version 22.0. All values are reported as mean and 95% confidence intervals (CI). The studied dependent variables were analyzed using a 2 condition ($NaHCO_3^-$ vs. placebo) × 3 race (R1, R2 and R3) within-participants design. Specifically, the $\%rMSSD_{30s}$ was analyzed using a 2 condition × 3 race × 6 measurement within-participants design, and a 2 condition × 3 race × 2 measurements (pre and post) within-participants design was used to determine differences in the cardiorespiratory

Table 1
Time to complete the race (time), time to reach the peak velocity (time to peak velocity), peak velocity during the race (peak velocity), mean heart rate (mean HR) and peak heart rate (peak HR) obtained for each race in race 1 (R1), 2 (R2) and 3 (R3). Rating of perceived exertion (RPE 6-20 and CR10) immediately after each race and perceived readiness (1-5 scale) before each race.

	R1	R2	R3	Total
Time (s)				
$NaHCO_3^-$	31.42 (30.67–32.17)	31.31(30.55–32.06)	31.39 (30.63–32.15)	31.37 (30.65–32.10)
Placebo	31.46 (30.71–32.21)	31.18 (30.44–31.93)	31.33 (30.57–32.08)	31.32 (30.60–32.05)
Total	31.44 (30.72–32.16)	31.24 (30.52–31.97)	31.36 (30.63–32.08)	
Time to peak velocity (s)				
$NaHCO_3^-$	9.77 (7.13–12.41)	9.92 (7.28–12.56)	10.78 (8.12–13.43)	10.16 (7.87–12.44)
Placebo	11.99 (9.40–14.58)	11.39 (8.80–13.98)	9.90 (7.14–12.67)	11.10 (8.81–13.38)
Total	10.88 (8.63–13.13)	10.66 (8.41–12.91)	10.34 (8.04–12.64)	
Peak velocity ($m\,s^{-1}$)				
$NaHCO_3^-$	12.95 (12.48–13.41)	12.86 (12.39–13.32)	12.90 (12.43–13.37)	12.90 (12.51–13.29)
Placebo	13.05 (12.59–13.51)	12.80 (12.34–13.25)	13.13 (12.63–13.62)	12.99 (12.60–13.38)
Total	13.00 (12.63–13.36)	12.83 (12.46–13.19)	13.01 (12.64–13.39)	
Mean HR (bpm^{-1})				
$NaHCO_3^-$	186.0 (181.7–190.2)	185.6 (181.4–189.9)	183.0 (178.7–187.2)	184.8 (180.8–188.9)
Placebo	183.4 (179.1–187.6)	184.8 (180.5–189.0)	182.9 (178.6–187.1)	183.7 (179.6–187.7)
Total	184.7 (180.6–188.7)	185.2 (181.2–189.2)	182.9 (178.9–187.0)[b]	
Peak HR (bpm^{-1})				
$NaHCO_3^-$	194.1 (189.6–198.6)	193.5 (189.0–198.1)	190.9 (186.3–195.4)	192.8 (188.4–197.2)
Placebo	193.6 (189.1–198.1)	192.9 (188.3–197.4)	189.9 (185.3–194.4)	192.1 (187.7–196.5)
Total	193.9 (189.5–198.3)	193.2 (188.8–197.6)	190.4 (186.0–194.8)[a,b]	
RPE 6–20				
$NaHCO_3^-$	14.5 (13.6–15.4)	14.9 (14.0–15.9)	15.5 (14.6–16.4)	15.0 (14.2–15.8)
Placebo	14.8 (13.9–15.7)	14.9 (14.0–15.9)	15.5 (14.6–16.4)	15.1 (14.3–15.9)
Total	14.7 (13.9–15.5)	14.9 (14.1–15.7)	15.5 (14.7–16.3)[a]	
CR10				
$NaHCO_3^-$	6.2 (5.2–7.3)	5.8 (4.8–6.9)	6.4 (5.3–7.4)	6.2 (5.2–7.1)
Placebo	5.7 (4.7–6.7)	6.0 (4.9–7.0)	6.2 (5.2–7.3)	6.0 (5.0–6.9)
Total	6.0 (5.0–6.9)	5.9 (5.0–6.9)	6.3 (5.4–7.2)	
1–5 scale				
$NaHCO_3^-$	4.8 (4.5–5.0)	4.6 (4.3–4.9)	4.6 (4.3–4.8)	4.6 (4.5–4.8)
Placebo	4.8 (4.5–5.0)	4.6 (4.4–4.9)	4.4 (4.1–4.6)	4.6 (4.4–4.8)
Total	4.8 (4.6–5.0)	4.6 (4.4–4.8)	4.5 (4.3–4.7)[a]	

Values are means (95% CI).
[a] Significant difference with R1.
[b] Significant difference with R2.

variables. All statistical analyses were performed using the linear mixed model (auto regression for the covariance of repeated measures). Statistical significance was taken at the level of $p \leq 0.05$. Significant interactions were explained by Holm-Bonferroni post-hoc analyses.

3. Results

The main effect of condition was observed in blood pH ($F_{1,22.01} = 79.15$, $p < 0.001$), $[HCO_3^-]$ ($F_{1,19.86} = 12.76$, $p = 0.002$) and base excess ($F_{1,17.50} = 38.45$, $p < 0.001$). This main effect of condition was due to larger values in the $NaHCO_3^-$ condition than in the placebo condition (Fig. 1). The main effect of condition was not significant for $[La^-]$ ($F_{1,15.22} = 3.19$, $p = 0.09$). In addition, the main effect of race was observed in all acid-base variables ($p < 0.001$; Fig. 1): blood pH ($F_{2,37.12} = 68.99$), $[HCO_3^-]$ ($F_{2,36.49} = 47.48$), $[La^-]$ ($F_{2,35.79} = 103.17$) and base excess ($F_{2,34.70} = 56.94$). The interaction between condition and race for the acid-base variables (all $Fs < 1$) was not significant. Fig. 1 shows the results obtained in the present study.

No significant differences between conditions were found in time, peak velocity and time to peak velocity (all $Fs < 1$) (Table 1). There was not a significant main effect of race for time ($F_{2,38.91} = 1.26$, $p = 0.29$), peak velocity ($F_{2,45.61} = 1.13$, $p = 0.33$) and time to peak velocity ($F < 1$). The interaction between condition and race for the performance variables was not significant. There were not significant differences for mean HR ($F_{1,15.32} = 1.23$, $p = 0.28$) and for peak HR ($F < 1$), between $NaHCO_3^-$ and placebo conditions (Table 1). The main effect of race was significant for mean HR and peak HR ($F_{2,44.49} = 3.46$, $p = 0.04$ and $F_{2,43.38} = 11.07$, $p < 0.001$; respectively). The interactions were not significant. We did not find a significant effect on condition in any scale (RPE 6–20, CR10 and 1–5 scale; Table 1). There was a main effect of race in the 1–5 scale ($F_{2,43.79} = 3.34$, $p = 0.04$) and for RPE 6–20 ($F_{2,42.93} = 3.69$, $p = 0.03$), but not for CR10 ($F_{2,43.11} = 1.35$, $p = 0.26$). The interaction between condition and race was not significant in any of the scales. The mean data (95% CI) and pairwise comparisons are presented in Table 1.

The main effect of condition was significant for $\%rMSSD_{30s}$ ($F_{1,69.56} = 5.05$, $p = 0.02$), with higher values in the $NaHCO_3^-$ condition (11.09%, CI: 14.53–7.65%) than in the placebo condition (7.98%, CI: 11.42–4.54%). The main effect of measurement was also significant for $\%rMSSD_{30s}$ ($F_{5,291.74} = 4.36$, $p = 0.001$), with an increment over time. The interaction between condition and race was not significant ($F_{2,94.84} = 1.4$, $p = 0.25$). None of the remaining terms in the analyses reached statistical significance.

There was not a main effect of condition on VO_2 ($F < 1$), VCO_2 ($F < 1$) and VE ($F_{1,111.61} = 1.82$, $p = 0.18$) (Fig. 2). There was a significant difference between the pre and post measurements for all respiratory variables ($p < 0.001$): VO_2 ($F_{1,33.44} = 988.41$), VCO_2 ($F_{1,32.30} = 1168.93$) and VE ($F_{1,18.70} = 88.82$). There was a main effect of race for VCO_2 ($F_{2,93.38} = 12.98$, $p < 0.001$). We found an interaction effect between race and measurement for VCO_2 ($F_{2,113.62} = 7.59$, $p = 0.001$). None of the remaining terms in the analyses reached statistical significance. Data and pairwise comparisons are illustrated in Fig. 2.

4. Discussion

The aim of this study was to investigate the effect of $NaHCO_3^-$ ingestion during a field condition in a simulated BMX competition.

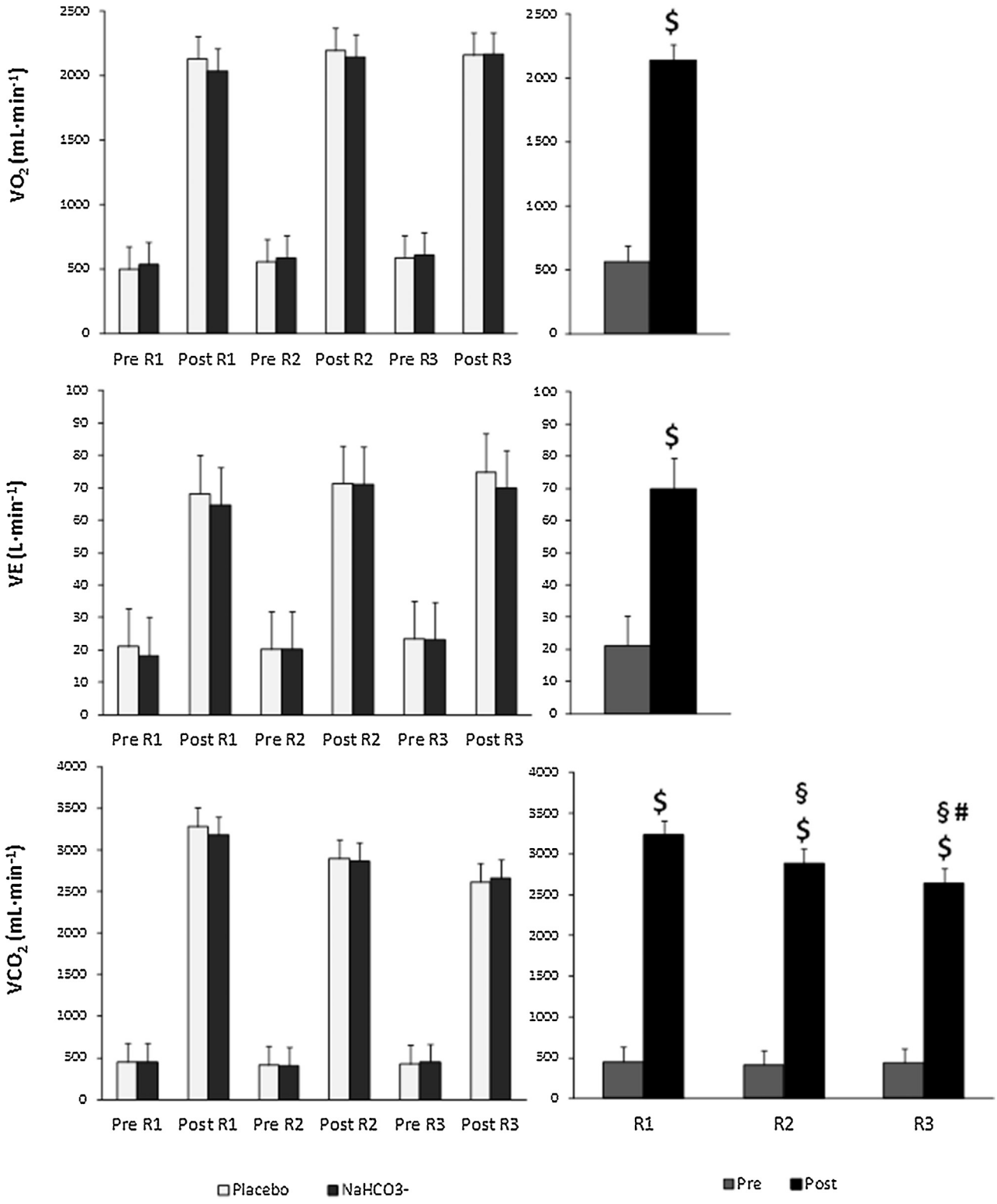

Fig. 2. Oxygen uptake (VO_2), Carbon dioxide production (VCO_2) and Pulmonary ventilation (VE). Values are means ± 95% CI. § Significant difference with R1; # Significant difference with R2; $ Significant difference with pre. R1: race 1; R: race 2; R3: race 3.

As far as we know, this is a novel study in BMX cycling investigating the physiological response in a sport-specific test, which elicited physical stress on elite athletes similar to that during competition. The main findings of this study were: (1) $NaHCO_3^-$ ingestion statistically significantly altered blood acid-base balance, although the induced alkalosis did not improve BMX performance; (2) the ingestion of $NaHCO_3^-$ induced larger relative $rMSSD_{30s}$, which might be suggestive of a higher parasympathetic reactivation post-race.

The change in the blood pH of our athletes was within the range previously described after the ingestion of $NaHCO_3^-$.[1,7] Thus, the protocol used here was effective to change blood pH in elite athletes. However, even though we found significant blood alkalo-

sis, there was no ergogenic effect of $NaHCO_3^-$ on performance,[5,7] in contrast to previous findings that have reported a moderated ergogenic effect with $NaHCO_3^-$ ingestion.[8–10]

It has been shown previously that the induced metabolic alkalosis may improve H^+ efflux from contracting muscle[21] and thereby limiting the effects of the reduced intracellular pH (pH_i).[2] Others have highlighted that induced alkalosis would not affect pH_i until blood pH is above 7.5, so skeletal muscle's properties would not be changed to produce a gain in performance.[22] In our study, blood pH was lower than 7.5 and blood lactate concentration was not significantly higher in $NaHCO_3^-$ than in placebo condition, compared with other studies showing an increase in lactate production. This could explain the lack of effect on physical performance in our study. Several studies have related the improvement in repeated-sprint ability with an increased anaerobic energy contribution with induced alkalosis,[22,23] due to the increase in lactate efflux from the muscle to the blood stream.[21] Another factor that may explain the contradictory findings about $NaHCO_3^-$ and physical performance relates to the physical fitness level of the participants. Untrained subjects may benefit more from the improved extracellular buffering which enhances the efflux of H^+ and $[La^-]$ from the working muscles and avoids partially the subsequent increased blood pH during high intensity exercise.[1] Highly trained athletes (elite athletes in the present study) have training induced adaptations, such as improved muscle buffering capacity,[24] which seems to be more effective than $NaHCO_3^-$ ingestion. Further work is required to clarify this issue in integrative studies.

The results of our exploratory HRV analysis showed a larger relative $rMSSD_{30s}$ during $NaHCO_3^-$ compared with placebo condition, which may indicate an increase of parasympathetic reactivation. This novel result suggests that bicarbonate ingestion might induce a faster post-exercise recovery.[20] During high intensity exercise, the time course of $rMSSD_{30s,}$ has been found highly impaired in comparison with submaximal or continuous bout.[19] In our study, participants reached high peak HR, suggesting that they performed a high intensity exercise. However, after the ingestion of $NaHCO_3^-$, participants showed an increase of ~4% in $rMSSD_{30s}$ after each race which could have led to a better recovery before the next race. This suggests that $NaHCO_3^-$ ingestion may have a positive effect on recovery after a short duration, high-intensity effort. However, these findings should be taken with caution since the increment in $\%rMSSD_{30s}$ was not accompanied by any performance enhancement. Furthermore, the $\%rMSSD_{30s}$ has shown large discrepancies at the time to assess post-exercise parasympathetic reactivation, which should be taken into account when interpreting theses indices.[25] Therefore, future research should clarify whether the $NaHCO_3^-$ intake truly induce post-race parasympathetic reactivation and the potential role of post-race parasympathetic reactivation on subsequent performance.

It is unknown whether $NaHCO_3^-$ ingestion might affect the cardiorespiratory response, during a high-intensity exercise performance. Previous results have shown that cardiorespiratory parameters tended to be similar in both conditions, alkalotic and placebo, at submaximal intensity.[26] In the present study, the cardiorespiratory parameters were similar in both conditions during a high-intensity exercise. This contrasts with the results found in an experiment involving a group of Nordic skiers performing a high-intensity protocol.[27] They were supplemented during seven successive days with alkalizing tablets (1 tablet/22.7 kg body mass/day). The results showed a lower cardiorespiratory stress post-exercise in the alkalosis condition. Another study has also found that serial $NaHCO_3^-$ loading (0.3–0.4 g kg^{-1} body mass) was an effective method for improving VO_{2peak} during 4-km time-trial and a good alternative to acute loading in order to avoid potential side effects.[10] The different loading protocols used in these and our study makes the comparison difficult. In addition, it has been suggested that alkalosis could affect blood pH by providing better oxygen delivery to cells.[28] Pre-exercise alkalosis of blood can cause an acceleration of the primary component of the pulmonary VO_2 kinetic at the onset of a high-intensity exercise.[29] One of our limitations is that we only measured cardiorespiratory variables pre and post-race. Given that our research was conducted in field condition and due to security reason (cyclists had to wear the compulsory helmet), we were not able to measure cardiorespiratory variables during the whole protocol, thus we cannot establish whether the primary component of VO_2 kinetic was modified or not.

One of the strengths of our study, and at the same time one of the weaknesses, was the sample. The sample was composed of twelve subjects, which may be not large enough to detect a change in performance variables. However, more often than not, research in this area is conducted on non-elite athletes making projections into the population most likely to use this ergogenic aid (elite athletes) speculative. In addition, the study was conducted in field condition to elicit stresses similar to those that may occur during competition, thus cyclists faced a comparable scenario in which they are used to competing and training.

5. Conclusion

In conclusion, $NaHCO_3^-$ ingestion does not seem to be an effective way to improve performance in elite BMX cyclists during a simulated test studied in a similar condition to BMX competitions. Exploratory analysis showed that ingestion of $NaHCO_3^-$ induced larger post-race $\%rMSSD_{30s}$, which could be taken as an index of a better post-exercise autonomic function recovery. More studies in field conditions are required to clarify the effect of $NaHCO_3^-$ ingestion on sport performance.

Practical Implications

- For the first time a field condition study demonstrated that induced alkalosis did not improve performance during BMX competition.
- Bicarbonate ingestion could induce a larger post-race $\%rMSSD_{30s,}$ which may be taken as an index of parasympathetic reactivation and, therefore, better post-exercise recovery.
- Coaches and trainers should interpret with caution laboratory results and from studies with non-athletes.

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