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# Sodium Bicarbonate Supplementation Does Not Improve Repeated Sprint Performance in Vegans and Omnivores

Alisson Henrique Marinho[1,2], Astrid Pfeiffer[2], Fabiano Tomazini[2], Saulo Juan Senoski[2], Guilherme Giannini Artioli[3], Romulo Bertuzzi[4], Adriano Eduardo Lima-Silva[2]

[1]Laboratory of Applied Sports Science, Institute of Physical Education and Sports, Federal University of Alagoas, Maceió, Alagoas, Brazil
[2]Human Performance Research Group, Federal University of Technology Parana, Curitiba, Paraná, Brazil
[3]Department of Life Sciences, Manchester Metropolitan University, John Dalton Building, Manchester, UK
[4]Endurance Performance Research Group (GEDAE-USP), University of São Paulo, São Paulo, Brazil

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## Abstract

Vegan diets are virtually absent in carnosine, which may result in reduced buffering capacity and performance during sprint interval exercise. Thus, vegans might be more benefited by ingestion of an extracellular buffer for improving sprint performance than omnivores. In the present study, we investigated the effects of sodium bicarbonate ($NaHCO_3^-$) ingestion on performance during a sprint interval exercise in vegans and omnivores. Ten (five males and five females) vegans and nine (four males and five females) omnivores performed four 30-second sprints (5-minute rest between sprints) after ingesting either placebo (cellulose) or $NaHCO_3^-$ (0.1·kg$^{-1}$ body mass at 120, 90 and 60 minutes prior exercise). There was a higher peak and mean power in bout 1 and 2 than bouts 3 and 4 (main effect of sprint, $p = .001$). However, $NaHCO_3^-$ ingestion had no effect on peak and mean power during the four sprints in both vegans and omnivores groups (main effect of condition, $p = .590$ and 0.443). There were also no differences in sprint performance between groups (main effect of group, $p = .621$ and $p = .902$). In conclusion, acute ingestion of sodium bicarbonate does not improve performance during sprint interval exercise in both vegans and omnivores.

***Keywords:*** Buffer capacity, ergogenic aid, plant-based diet, Wingate test

# Sodyum Bikarbonat Takviyesi, Veganlarda ve Omnivorlarda Tekrarlanan Sprint Performansını İyileştirmez

## Öz

Vegan diyetleri neredeyse hiç karnosin içermez, bu da aralıklı sprint egzersizi sırasında tamponlama kapasitesinin ve performansın azalmasına neden olabilir. Bu nedenle, veganlar, sprint performansını artırmak için hücre dışı bir tampon almaktan omnivorlara nazaran daha fazla fayda sağlayabilir. Bu çalışmada, veganlarda ve omnivorlarda aralıklı sprint egzersizi sırasında sodyum bikarbonat ($NaHCO3^-$) alımının performans üzerindeki etkilerini araştırdık. On (5 erkek ve 5 kadın) vegan ve dokuz (4 erkek ve 5 kadın) omnivor, plasebo (selüloz) veya $NaHCO3^-$ (egzersizden 120, 90 ve 60 dakika önce vücut kütlesine göre 0.1 g.kg$^{-1}$) aldıktan sonra dört ardışık 30 saniyelik sprint gerçekleştirdi (sprintler arasında 5 dakikalık dinlenme vardı). 1'inci ve 2'nci sprintin maksimum ve ortalama güç değerleri, 3'üncü ve 4'üncü sprintlerden daha yüksekti (sprint ana etkisi, $p = ,001$). Ancak, $NaHCO3^-$ alımının vegan ve omnivor gruplarda, dört sprint sırasında maksimal güç ve ortalama güç üzerinde hiçbir etkisi olmadı (koşulun ana etkisi, $p = ,590$ ve ,443). Gruplar arasında sprint performansında da fark yoktu (grup ana etkisi, $p = ,621$ ve $p = ,902$). Sonuç olarak, sodyum bikarbonatın akut alımı, veganlarda ve omnivorlarda aralıklı sprint egzersizi sırasında performansı iyileştirmez.

***Anahtar Kelimeler:*** Ergojenik yardım, tampon kapasitesi, wingate testi, bitkisel bazlı diyet

## Introduction

There is a growing body of evidence supporting an association between plant-based diet and a lower risk of developing diabetes (Qian et al., 2019), cardiovascular diseases (Kim et al., 2019), and all-cause mortality (Orlich et al., 2013). Vegan diet is considered a more restrictive type of plant-based diet, in which the ingestion of animal-derived food such as honey, eggs, milk, and dairy products is not allowed (Venderley & Campbell, 2006). Although adherence to a vegan diet has been growing in people engaged in exercise programs, there is a limited number of studies that explored the impact of a vegan diet on exercise performance (Barnard et al., 2019; Boutros et al., 2020; Pfeiffer et al., 2021).

The restrictive characteristics of the vegan diet led to a popular belief that it may be detrimental to exercise performance (Venderley & Campbell, 2006). This concern has especially been directed to sprint interval exercise, which are characterized by high-intensity efforts interspaced by short periods of recovery (Billat, 2001; Girard et al., 2011). Sprint interval exercise are heavily reliant on anaerobic

**Corresponding author:** Adriano Eduardo Lima-Silva
**E-mail:** aesilva@utfpr.edu.br



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glycolysis (Hargreaves & Spriet, 2020), thereby being characterized by hydrogen ion ($H^+$) accumulation in the cytoplasm, ultimately impairing contractile function (Fitts, 1994). As intramuscular carnosine acts as an important muscle $H^+$ buffer (Lancha Junior et al., 2015; Wu, 2020), and a vegan diet is virtually absent in carnosine (Everaert et al., 2011), it would be plausible to suppose that the intramuscular buffer capacity of vegans might be reduced (Everaert et al., 2011).

The extracellular buffer capacity via blood bicarbonate ($HCO_3^-$) is another mechanism that indirectly attenuates $H^+$ accumulation in the exercised muscles (Lancha Junior et al., 2015). The potential ergogenic effect of sodium bicarbonate ($NaHCO_3^-$) ingestion is attributed to an increased blood buffering capacity and an increased muscle–blood $H^+$ concentration gradient, thereby enhancing $H^+$ efflux from working muscles to blood and alleviating exercise-induced muscle pH reduction (Heibel et al., 2018; Lancha Junior et al., 2015; Mainwood & Worsley-Brown, 1975). Although no study has been conducted in vegans, studies exploring the effect of $NaHCO_3^-$ on sprint interval performance in omnivores has showed conflicting results, with some studies showing improvements in sprint performance (Carr, Hopkins, et al., 2011; Grgic et al., 2020), while others found no effect (Zabala et al., 2008, 2011). Whether acute $NaHCO_3^-$ ingestion could differently influence performance during sprint interval exercises in vegans and omnivores remains unknown. An investigation exploring the impact of $NaHCO_3^-$ supplementation on performance during a sprint interval exercise might assist vegans enrolled in sports demanding repeated high-intensity efforts to elaborate their supplementation plan.



The aim of the present study was to investigate the effects of acute ingestion of $NaHCO_3^-$ on performance in sprint interval exercise in vegans and omnivores. We hypothesized that acute ingestion of $NaHCO_3^-$ would improve performance parameters assessed during a sprint interval exercise (i.e., peak power and mean power) in greater extension in vegans than in omnivores.

## Method

### Participants

Ten (five males and five females) physically active vegans (32.6 ± 4.0 years, 65.2 ± 10.9 kg, 173.4 ± 5.7 cm, and 17.1 ± 6.3% of body fat) and nine (four males and five females) omnivores (32.7 ± 6.6 years, 68.0 ± 12.2 kg, 168.2 ± 7.7 cm, and 21.0 ± 4.4 % of body fat) participated in this study. Participants were accustomed to high-intensity interval training and with the exercise protocol, as most of them were enrolled in a previous study (Pfeiffer et al., 2021). The required sample size was estimated using G*Power software (Heinrich-Heine-University Düsseldorf, version 3.1.9.2, Düsseldorf, Germany). Adopting an expected effect size of 0.48 in relation to the effect of acute $NaHCO_3^-$ ingestion on peak power during successive sprints (Artioli et al., 2007), an alpha of 0.05 and a beta of 0.95, the effective sample size was estimated to be 18 participants. We recruited a total of 19 participants to guarantee a powered sample size.

Vegans consumed only plant-based foods, without consumption of any animal or dairy products, for at least 1 year before the study (time engaged in a vegan diet 4.3 ± 2.7 years). Omnivores had never experimented an exclusively plant-based diet and consumed any type of food, including fish, meat, and meat products. Participants have not been using performance-enhancing substances such as creatine, β-alanine, and $NaHCO_3^-$ during the 3 months prior the study. All participants were informed about the benefits and risks associated with the experimental procedures before signing a written informed consent form agreeing to participate in this study. The study was conducted according to the *Declaration of Helsinki* and was approved by the Research ethics committee of Federal University of Technology Parana (Date: 06 december 2018, Number: 3.062.793).

### Experimental Design

This was a double-blind, crossover, counterbalanced study. Participants visited the laboratory on three different occasions, with a minimum of 72 hours and maximum of 1 week interval between visits. During the first visit, participants performed anthropometric measurements (body mass, height, and skinfolds), filled out an International Physical Activity Questionnaire to determine their physical activity level (Craig et al., 2003) and practiced the sprint interval exercise protocol for familiarization. On the second and third visits, participants ingested either placebo or $NaHCO_3^-$ prior to the sprint interval exercise. The order of the treatments was counterbalanced, with the participants randomly allocated to a given order using the randomizer.org. Participants were advised to maintain their usual diet (omnivorous or vegan diet) and training routines throughout the study. Moreover, they were asked to follow the same diet in the 2 days prior to the experimental trials. Compliance to the diet recommendation was further confirmed using dietary records. Participants were instructed to avoid exercise, alcohol, and supplements, beverages, and foods containing caffeine during the 24 hours prior each experimental trial.

### Experimental Trials

Participants arrived at the laboratory in the morning (between 6 a.m. and 8 a.m.) and then filled out a gastrointestinal discomfort questionnaire. Thereafter, participants ingested capsules containing either cellulose (placebo) or $NaHCO_3^-$ (0.1 $g \cdot kg^{-1}$ body mass) at 120, 90, and 60 minutes prior to exercise, totaling 0.3 $g \cdot kg^{-1}$ body mass of $NaHCO_3^-$. This split-dose strategy has showed to improve exercise performance and reduce the chance of gastrointestinal discomfort (Carr, Slater, et al., 2011; Felippe et al., 2016). Immediately before exercise, participants again completed the gastrointestinal discomfort questionnaire.

A mechanically braked cycle ergometer (Ergometric, Cefise, Nova Odessa, Brazil) was used for the sprint interval exercise. Participants adjusted the height seat and handlebar during the familiarization session and replicated their positions during the experimental trials. Toe clips were used to avoid feet slipping off the pedals. Participants warmed-up by cycling against the inertial resistance of the cycle ergometer for 5 minutes (80 rpm of pedal cadence), with 4-second all-out sprints in the last seconds of the second and fourth minutes. After 3 minutes of passive recovery, participants accelerated by 2 seconds without any external resistance to achieve the maximum pedaling rate and then a resistance of 0.075 $kg \cdot ^{-1}$ body mass was applied (Bar-or, 1987). Participants were asked to maintain pedaling rate as fast as possible for 30 seconds. This 30-second maximal sprint was performed four times, with each sprint being separated by a 5-minute passive recovery.

Cycling speed was measured using an inductive sensor and eight magnets placed on the wheel. Power output was calculated by multiplying cycle resistance by speed, with further interpolation for every 1 second. Peak power and mean power were calculated for each 30-second sprint. Peak power was the average power output during the first 5 seconds. Mean power was the average power of a given sprint.

### Gastrointestinal Discomfort

Gastrointestinal discomfort was assessed using a previously validated questionnaire containing 19 items related to gastrointestinal complaints (Jeukendrup et al., 2000). Participants reported values ranging from 1 to 10, where 1 is "no problem at all" and 10 "the worst it has ever been."

### Statistical Analyses

Data distribution was checked using Shapiro–Wilk's test. As the normality in data distribution was confirmed, data are described as mean ± standard deviation. Peak and mean power were compared using three-way mixed-model ANOVA, having condition ($NaHCO_3^-$ and placebo) and sprint (1, 2, 3, and 4) as dependent factors and group (omnivores and vegans) as independent factor. In case of violation of sphericity, Greenhouse–Geisser adjustment was performed. Partial eta squared ($\eta_p^2$) values were calculated, and an effect of $\eta_p^2 \geq 0.01$ was considered small, $\eta_p^2 \geq 0.059$ medium, and $\eta_p^2 \geq 0.138$ large (Cohen, 2013). When necessary, pairwise comparisons were performed using Bonferroni correction. The significance level adopted was $p < .05$. Statistical analysis was performed using the SPSS software (version 25, SPSS Inc., Chicago, Ill, USA).

## Results

There was a main effect of sprint for peak power ($F_{(3,51)} = 20.260$; $p = .001$; $\eta_p^2 = 0.544$), the peak power reduced, without a main effect of condition ($F_{(1,17)} = 0.301$; $p = .590$; $\eta_p^2 = 0.017$) or a main effect of group ($F_{(1,17)} = 0.254$; $p = .621$; $\eta_p^2 = 0.015$). There was no sprint–group ($F_{(3,51)} = 1.847$; $p = .175$; $\eta_p^2 = 0.098$), sprint–condition ($F_{(3,51)} = 0.057$; $p = .982$; $\eta_p^2 = 0.003$), condition–group ($F_{(1,17)} = 1.637$; $p = .210$; $\eta_p^2 = .088$), or sprint–condition–group ($F_{(3,51)} = 0.877$; $p = .982$; $\eta_p^2 = 0.003$) interactions). Peak power was higher in the sprint 1 than in the sprints 2, 3, and 4 ($p < .05$), and higher in the sprint 2 than in the sprints 3 and 4 ($p < .05$). There were no other differences between sprints ($p > .05$).

There was only a main effect of sprint for mean power ($F_{(3,51)} = 23.106$; $p = .001$; $\eta_p^2 = 0.576$), without a main effect of condition ($F_{(1,17)} = 0.617$; $p = .443$; $\eta_p^2 = .035$) or a main effect of group ($F_{(1,17)} = 0.016$; $p = .902$; $\eta_p^2 = 0.001$). There was no sprint–group ($F_{(3,51)} = 0.760$; $p = .522$; $\eta_p^2 = 0.043$), sprint–condition ($F_{(3,51)} = 1.108$; $p = .355$; $\eta_p^2 = 0.061$), condition–group ($F_{(1,17)} = 1.433$; $p = .248$; $\eta_p^2 = 0.078$), or sprint–condition–group ($F_{(3,51)} = 1.166$; $p = .198$; $\eta_p^2 = 0.087$) interactions. Mean power was higher in the sprint 1 than in the sprints 2, 3, and 4 ($p < .05$), and higher in the sprint 2 than in the sprints 3 and 4 ($p < .05$). There were no other differences between sprints ($p > .05$).

Prior to both placebo and $NaHCO_3^-$ ingestion, participants engaged in omnivorous and vegan diet reported no "problem at all" for all questions of the gastrointestinal discomfort questionnaire. Two hours after the placebo ingestion, participants remained reporting no symptoms of gastrointestinal discomfort, except urge to defecate (2.0 ± 3.0) for omnivores and slight flatulence (2.0 ± 1.2) for vegans. Two hours after $NaHCO_3^-$ ingestion, omnivores reported slightly increased heartburn (2.1 ± 2.6), urge to defecate (2.2 ± 2.9), urge to vomit (2.3 ± 2.6), and diarrhea (3.6 ± 4.0). In addition, vegans reported slightly increased flatulence (3.7 ± 3.2), urge to defecate (3.2 ± 3.4), belching (3.0 ± 3.2), bloating (2.4 ± 2.8), intestinal cramps (2.2 ± 2.3), urge to vomit (2.0 ± 2.0), and diarrhea (2.8 ± 3.6).

## Discussion and Conclusions

While previous studies have explored the effects of acute ingestion of $NaHCO_3^-$ on exercise performance in omnivores (Grgic, 2020; Lopes-Silva et al., 2019), to date no study has explored such effects in vegans. In the current study, we investigated whether the acute ingestion of $NaHCO_3^-$ could improve sprint interval performance in vegans and omnivores. Our findings indicate that acute ingestion of $NaHCO_3^-$ does not improve sprint interval performance in both vegans and omnivores.



The lack of positive effect of $NaHO_3^-$ on peak power (Figure 1) is in accordance with two recent meta-analyses that showed no significant effect of acute $NaHCO_3^-$ ingestion on peak power during repeated sprint interval exercise in omnivores (Grgic, 2020; Lopes-Silva et al., 2019). From a physiological standpoint, the energy to support peak power is mainly supplied through the intramuscular adenosine triphosphate store and phosphagen energy system (Gastin, 2001; Smith & Hill, 1991). Due to the short time to reach peak power (from 3 to 5 seconds), a significant $H^+$ accumulation via augmented production from glycolytic pathway is improbable (Grgic et al., 2020). In addition, despite both muscle and blood pH are still reduced 5

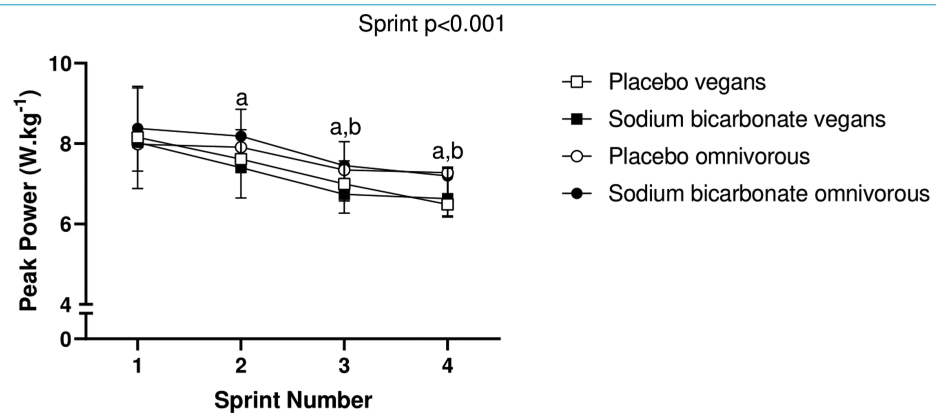


**Figure 1.**
*Peak Power During Four 30-Second All-Out Sprints Performed on a Mechanically Braked Cycle Ergometer Using a Resistance of 0.075 kg·kg$^{-1}$ Body Mass (5-Minute Passive Recovery Between Sprints) After Acute Ingestion of Sodium Bicarbonate (3 × 0.1 g·kg$^{-1}$ Body Mass) or Placebo in Vegans and Omnivores. Letter "a": significantly lower than the first sprint regardless of the condition (p < .05). Letter "b": significantly lower than the second sprint regardless of the condition (p < .05).*

minutes after a 30-second all-out sprint (Bogdanis et al., 1995; Lancha Junior et al., 2015; Lopes-Silva et al., 2019), the restoration of peak power from one sprint to another during repeated sprints has been positively correlated with PCr resynthesis, but not with intramuscular pH recovery (Bogdanis et al., 1995; Mendez-Villanueva et al., 2012). This may explain the lack of ergogenic effect of $NaHCO_3^-$ ingestion on peak power, and our findings expand this notion to vegans.

A second finding of the present study was that $NaHCO_3^-$ ingestion did not influence mean power for both groups (Figure 2). The mean power is strongly influenced by the glycolytic energy system (Minahan et al., 2007; Smith & Hill, 1991), an energy system that is the main responsible by intramuscular $H^+$ accumulation during sprint interval exercise (Hargreaves & Spriet, 2020). Thus, it could be expected that $NaHCO_3^-$ should have improved mean power. In omnivores, the effect of acute $NaHCO_3^-$ ingestion on mean power is contradictory, with a meta-analysis showing no significant effect of acute $NaHCO_3^-$ ingestion on mean power in bouts 1, 2, and 3 (Lopes-Silva et al., 2019), while another meta-analysis showing a positive effect of acute $NaHCO_3^-$ ingestion on mean power in bouts 2 and 4 (Grgic, 2020). Interestingly, when considering studies that used shorter rest intervals between repeated sprints (≤3 minutes), a significant effect of $NaHCO_3^-$ was also found on mean power in bout 3 (Artioli et al., 2007; Grgic, 2020). This last finding suggests that $NaHCO_3^-$ ingestion may be more effective during successive sprints with short recovery time between sprints, in which muscle pH is consequently more disrupted (Bogdanis et al., 1995). The 5 minutes of recovery used in the present study may have been sufficient to substantially restore muscle pH, thereby attenuating a possible ergogenic effect of acute $NaHCO_3^-$ ingestion on mean power. Our findings suggest therefore that acute $NaHCO_3^-$ ingestion does not improve mean power during successive 30-second all-out sprints with 5-minute recovery in vegans and omnivores.



Contrary to our hypothesis, acute $NaHCO_3^-$ ingestion was not more ergogenic in vegans compared to omnivores. Instead, acute $NaHCO_3^-$ ingestion failed to improve sprint interval performance in both vegans and omnivores. We hypothesized that acute $NaHCO_3^-$ ingestion would be more ergogenic in vegans rather than omnivores because vegan diet is virtually absent in carnosine (Everaert et al., 2011), which could impair intramuscular buffer capacity. The lack of differences between vegans and omnivores and a similar no ergogenic effect of acute $NaHCO_3^-$ ingestion on sprint performance suggest that a vegan diet does not impair sprint ability.

The occurrence of gastrointestinal discomfort has been associated with the ingestion of $NaHCO_3^-$ (Carr, Slater, et al., 2011). Although the participants in our study have presented some side effects after $NaHCO_3^-$ ingestion, the split dose strategy used in the present study appeared to have attenuated the severity of the gastrointestinal discomfort caused by $NaHCO_3^-$, which seems to be in accordance with previous reports (Carr, Slater, et al., 2011; Felippe et al., 2016). Furthermore, recent meta-analyses showed that the influence of side effects after $NaHCO_3^-$ ingestion on exercise performance is still unclear (Grgic, 2020; Grgic et al., 2020). Thus, it seems that the minor side effects reported by the participants have likely played no significant role on the lack of improvements in performance after $NaHCO_3^-$ ingestion in our study.

Some limitations must be taken in account when interpreting our results. First, we were unable to measure blood $HCO_3^-$ and pH; thus, we cannot ascertain whether $NaHCO_3^-$ supplementation resulted in an improved blood buffer capacity. However, a previous study demonstrated that a split-dose protocol, similar to that utilized in the present study, increased $HCO_3^-$ in the blood (Carr, Slater, et al., 2011). Nevertheless, we cannot fully disregard a potential influence of a lower increase in blood $HCO_3^-$ with the split-dose protocol on the lack of ergogenic effect of $NaHCO_3^-$ ingestion. Second, in the present study, we tested the effect of acute $NaHCO_3^-$ ingestion. A recent meta-analysis has, however, suggested that chronic ingestion of $NaHCO_3^-$ may be more ergogenic during sprint interval exercises (Lopes-Silva et al., 2019). Furthermore, although a sub-analyses separating males and females have found no different outcomes (data not shown), females has less type II muscle fibers (Porter et al., 2002; Simoneau & Bouchard, 1989) and lower glycolytic capacity (Russ et al., 2005; Tarnopolsky, 2000) than males, which may become females less susceptible to the ergogenic effects of $NaHCO_3^-$ (Durkalec-Michalski et al., 2020). Further studies measuring blood buffer capacity, testing different forms of $NaHCO_3^-$ supplementation (different doses, timing, and chronic ingestion), and recruiting large sample size of males and females will expand our understating about the impact of $NaHCO_3^-$ ingestion on sprint interval exercise performance in vegans.

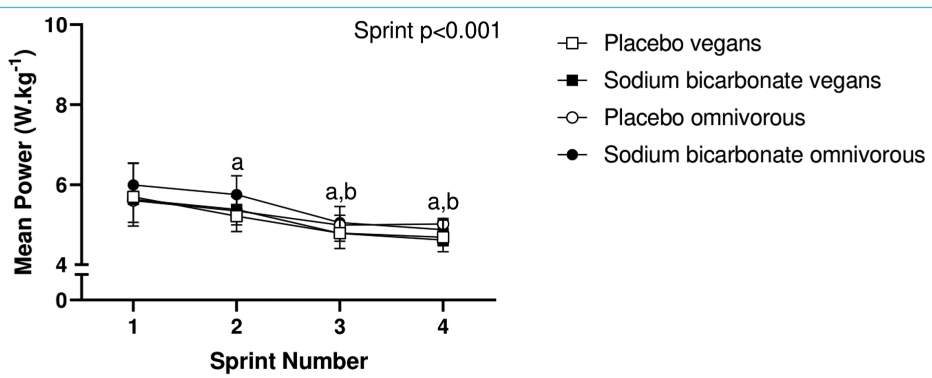


**Figure 2.**

*Mean Power Achieved During Four 30-Second All-Out Sprints Performed on a Mechanically Braked (0.075 kg·kg$^{-1}$ Body Mass) Cycle Ergometer (5-Minute Passive Recovery Between Sprints) After Acute Ingestion of Sodium Bicarbonate (3 × 0.1 g·kg$^{-1}$ Body Mass) or Placebo in Vegans and Omnivores. Letter "a": significantly lower than the first sprint regardless of the condition (p < .05). Letter "b": significantly lower than the second sprint regardless of the condition (p < .05).*

In conclusion, the acute ingestion of $NaHCO_3^-$ failed to improve peak and mean power during a sprint interval exercise in vegans and omnivores.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Federal University of Technology Parana (Date: 06 december 2018, Number: 3.062.793).

**Informed Consent:** Written informed consent was obtained from all who participated in this study.

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**Author Contributions:** Concept – A.H.M., A.E.L-S., A.P., R.B.; Design – A.E.L-S., A.P., R.B.; Supervision – A.E.L-S.; Resources – A.H.M., A.E.L-S., A.P., R.B.; Materials – A.E.L-S., A.P., F.B., S.J.S.; Data Collection and/or Processing – A.H.M., A.E.L-S., A.P., F.T., S.J.S.; Analysis and/or Interpretation – A.H.M., A.E.L-S., A.P., F.T., S.J.S., G.G.A.; Literature Review – A.H.M., A.E.L-S., A.P., F.T., S.J.S., R.B., G.G.A.; Writing Manuscript – A.H.M., A.E.L-S.; Critical Review – A.H.M., A.E.L-S., A.P., F.T., S.J.S., R.B., G.G.A.; Other – A.H.M., A.E.L-S., A.P., F.T., S.J.S., R.B., GGA.

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