Placebo Effect of Acute β-alanine Induced Paraesthesia in Competitive Cyclists.

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ABSTRACT

Purpose: β-alanine is a common ingredient in supplements consumed by athletes. Indeed, athletes may believe that the β-alanine induced paresthesia, experienced shortly after ingestion, is associated with its ergogenic effect despite no scientific mechanism supporting this notion. The present study examined changes in cycling performance under conditions of β-alanine induced paresthesia. **Methods:** Eight competitive cyclists (VO_{2max}= 61.8±4.2 $mL \cdot kg \cdot min^{-1}$) performed three practice, one baseline, & four experimental trials. The experimental trials comprised a 1-km cycling TT under four conditions with varying information (i.e., athlete informed β-alanine or placebo) & supplement content (athlete received β-alanine or placebo) delivered to the cyclist: informed β-alanine/received β-alanine, informed placebo/received β-alanine, informed β-alanine/received placebo, informed placebo/received placebo. Questionnaires were undertaken exploring the cyclists` experience of the effects of the experimental conditions. **Results:** A *possibly likely* increase in mean power was associated with conditions in which β-alanine was administered (±95%CL; 2.2±4.0%), but these results were inconclusive for performance enhancement (p = 0.32, effect size = 0.18, smallest worthwhile change = 56% beneficial). A possibly harmful effect was observed when cyclists were correctly informed that they had ingested a placebo (-1.0±1.9%). Questionnaire data suggested that β-alanine ingestion resulted in evident sensory side-effects & six cyclists reported placebo effects. **Conclusion:** Acute ingestion of β-alanine is not associated with improved 1-km TT performance in competitive cyclists. These findings are in contrast to the athlete's "belief" as cyclists reported improved energy & the ability to sustain a higher power output under conditions of β-alanine induced paraesthesia.

Keywords: BELIEF; DECEPTION; CYCLING; PERFORMANCE.

INTRODUCTION

Both well-trained athletes and recreationally-active individuals routinely use nutritional supplements to improve training and/or competitive performance (Kourie, 1998). A recent addition to the myriad of pre-exercise supplement combinations is β-alanine. Indeed, improved exercise performance during supramaximal cycling has been previously reported following chronic supplementation of β-alanine (1.6-6.4 $g \cdot day^{-1}$ for a period of 4-10 wk) (Hill, Harris, Kim, Harris, Sale, Boobis, Kim, & Wise, 2007; Sale, Saunders, Hudson, Wise, Harris, & Sunderland, 2011). However, due to the lack of mechanistic validation, the effects of acute β-alanine ingestion on exercise performance have not been previously documented. Nonetheless, β-alanine is a common ingredient in "pre-exercise" supplement formulas (i.e., acute supplementation) used by athletes (Gonzalez, Walsh, Ratamess, Kang, & Hoffman, 2011; Kelly, Jenkins, Leveritt, Brennan, & Slater, 2013; Spradley, Crowley, Tai, Kendall, Fukuda, Esposito, Moon, & Moon, 2012).

The acute supplementation of pure β-alanine (>800 mg) has been consistently reported to induce a flushing sensation on the skin (termed paresthesia) (Décombaz, Beaumont, Vuichoud, Bouisset, & Stellingwerff, 2012; Harris, Tallon, Dunnett, Boobis, Coakley, Kim, Fallowfield, Hill, Sale, & Wise, 2006). Paresthesia has been described as an "itching" or "tingling" sensation (lasting ~60 min) and appears to be linked to the rate of plasma β-alanine increase (Décombaz et al., 2012). In the first human study investigating the absorption of orally supplied β-alanine, it was reported that a single dose of β-alanine greater than 10 $mg \cdot kg^{-1}$ body mass (BM) caused increasingly unpleasant moderate to severe symptoms of paresthesia beginning within 20 min and lasting up to 1 h after ingestion (Harris et al., 2006). Although the exact mechanism responsible for β-alanine induced paresthesia is not completely understood, two recent studies have investigated its cause by intradermally

injecting β-alanine (Liu, Sikand, Ma, Tang, Han, Li, Sun, LaMotte, & Dong, 2012) and orally ingesting a 3 g dose of β-alanine (MacPhee, Weaver, & Weaver, 2013). These studies indicated that the skin sensations evoked by β-alanine ingestion are mediated by the Mas-related G-protein coupled membrane D expressed in cutaneous sensory neurons. These neurons exclusively innervate the skin and do not excite or modulate skeletal muscle fibres. Furthermore, it has been suggested that the minimal β-alanine supplementation protocol required to modestly elevate muscle carnosine content is 1.6 $g \cdot day^{-1}$ for a period of 2 wk (Stellingwerff, Anwander, Egger, Buehler, Kreis, Decombaz, & Boesch, 2012). This suggests that the acute ingestion of β-alanine does not provide a mechanism to enhance performance.

The inclusion of β-alanine in supplements used by athletes (Gonzalez et al., 2011; Kelly et al., 2013; Spradley et al., 2012) may be due to a belief that β-alanine induced paresthesia, experienced shortly after ingestion, is associated with its ergogenic effect despite no scientific mechanism supporting this notion (Kelly et al., 2013). Placebo or belief effects have been linked to many popular and well-accepted ergogenic aids such as carbohydrate beverages (Clark, Hopkins, Hawley, & Burke, 2000), caffeine (Beedie, Stuart, Coleman, & Foad, 2006) and sodium bicarbonate (McClung & Collins, 2007). Indeed, Beedie et al (2006) reported a *likely beneficial* 2.2% increase in mean power associated with experimental trials in which participants believed they had ingested caffeine. Furthermore, participants produced 1.4% less power than at baseline when they believed they had ingested a placebo. Although there is no current underlying mechanism for enhancing performance that may support β-alanine induced paresthesia, simply believing in a novel and exciting performance-enhancing treatment may produce improvements in performance regardless of introducing a real treatment effect.

Given the increasing popularity of β-alanine use among athletes, and its addition to many pre-exercise supplement formulas, it is plausible that athletes believe and expect that β-alanine induced paresthesia may be a precursor or indicator of the ergogenic aid to improve performance. Surprisingly, no detailed study has documented the effects of β-alanine induced paresthesia on exercise performance. Therefore, the aim of the proposed study is twofold: (i.) to assess the effect of the acute ingestion of a 30 $mg \cdot kg^{-1}$ BM dose of β-alanine on paresthesia symptoms, mood and psychological effects on cycling performance, and (ii.) to investigate whether cyclists given a placebo under the impression it was a potentially performance-enhancing supplement (β-alanine) would perform at a higher level than in control conditions.

METHODS

Subjects

Eight highly-trained cyclists (mean ± SD; age = 27.7 ± 5.9 yr; BM = 65.9 ± 4.1 kg; peak oxygen uptake (VO_{2peak}) = 61.8 ± 4.2 $mL \cdot kg^{-1} \cdot min^{-1}$) volunteered to participate as subjects in the current study. At the time of the investigation, the cyclists consistently accumulated >10 $h \cdot wk^{-1}$ of training and were cycling 250-500 $km.wk^{-1}$ while regularly competing in local criterion and TT (>10 km) cycling races. All cyclists were informed verbally and in writing as to the requirements of the study and all gave their written informed consent. Cyclists had not taken any nutritional supplements in the 3 mo before the study with the exception of three cyclists who were consuming a multi-vitamin supplement and two cyclists who were consuming a fish-oil supplement. All cyclists were naive to β-alanine supplementation before the commencement of the study. The study was conducted in the Griffith University Sport Science Laboratory and was approved by the Griffith University Human Research Ethics Committee.

Experimental Design

Cyclists attended the laboratory on seven separate occasions at the same time of day (± 2 h). Cyclists performed a graded-exercise test to determine VO_{2peak} (i.e., VO_{2peak} test) and a practice trial of the 1-km cycling time trial (TT) on the same day. The cyclists then visited the laboratory (>24 h later) to perform the second practice trial to ensure each cyclist was adequately familiarized with the exercise protocol. The cyclists then performed five 1-km TTs on separate occasions with a minimum of 48 h between each visit. The first 1-km TT acted as the baseline performance (no ingestion) with the four remaining visits comprising a 1-km cycling TT under four experimental conditions each varying in the (i.) information supplied to the subject (i.e., athlete informed β-alanine or placebo), and (ii.) supplement content (i.e., athlete received β-alanine or placebo). The experimental trials were performed on a randomly assigned single-blind basis with all testing being completed within a period of 4 wk.

In the informed β-alanine/received β-alanine condition cyclists were correctly informed that they would receive a 30 mg·kg BM^{-1} dose of β-alanine. In the informed β-alanine/received placebo condition cyclists were informed that this condition would examine the effects of β-alanine and a new additive that would reduce the sensation of paresthesia associated with β-alanine ingestion, but cyclists actually received an inert placebo (30 mg·kg BM^{-1} dose of microcrystalline cellulose). In the informed placebo/received β-alanine condition cyclists were informed that they would receive a placebo that would mimic the effects of β-alanine (paresthesia), but cyclists actually received a 30 mg·kg BM^{-1} dose of β-alanine. In the informed placebo/received placebo condition cyclists were correctly informed that they would receive a placebo (30 mg·kg BM^{-1} dose of microcrystalline cellulose).

This study design allowed the research team to differentiate between the 'real' effects that β-alanine induced paresthesia had on performance compared to the expectancy of a performance enhancement associated with knowingly ingesting β-alanine. Cyclists were not informed of the study design and aim until all cyclists' had completed testing, with later questioning confirming that no participant was aware of the true aim of the study.

Preliminary Testing

The first visit to the laboratory included medical screening, a VO_{2peak} test and the first of two practice trials of the 1-km cycling TT. The cyclists then visited the laboratory on two more occasions at the same time of day (± 2 h) to complete the second practice trial of the 1-km cycling TT and baseline performance trial (no ingestion). The mean difference in performance time between the second practice trial and baseline performance was equal to approximately 0.48 s (70.27 ± 5.95 vs. 69.79 ± 6.0) which was not statistically different (P = 0.37). Similarly, there was no variation in mean power (P = 0.40) and no obvious effect of fatigue (i.e., decrease in performance between trials) or learning (i.e., an increase in performance) between the practice trial and baseline performance.

The VO_{2peak} test was performed on the Velotron Pro cycle ergometer (RacerMate Inc., Seattle, WA, USA) using a protocol that has been described elsewhere (Laursen, Shing, Peake, Coombes, & Jenkins, 2002). Gas exchange variables were measured and recorded every 30 s (Parvomedics Trueone 2400, Utah, USA). A period of 45 min separated the VO_{2peak} test and the practice trial of the 1-km cycling TT. During this time cyclists continued to cycle at 100 W for a period of 5 min, rested for 20 min and began the standardized 20 min warm-up (explained below). Cyclists then performed a practice 1-km TT on the Wattbike air-braked cycle ergometer (Wattbike Pro, Nottingham, UK).

Experimental Trials

Cyclists were asked to abstain from caffeine and alcohol for a period of 12 h and avoid strenuous exercise for 24 h before each TT. Each cyclist recorded a 24-h diet diary leading up to the first TT which was then replicated for each subsequent TT. Adherence to these requests was confirmed by each cyclist verbally prior to each TT.

On arrival to the laboratory, cyclist's BM was measured using SECA balance beam scales (Birmingham, UK) and they were informed verbally and in writing as to which experimental trial they would be completing. Exactly 30 min before the start of the TT, 30 $mg \cdot kg^{-1}$BM of β-alanine **(**Pure β-alanine, Body Science, Australia) or placebo (microcrystalline cellulose) was administered in identical gelatin capsules to each subject with 100 mL of water. After capsule ingestion, cyclists rested for 8 min and a blood sample was taken from the earlobe for determination of blood lactate concentration. Cyclists then immediately commenced a standardized 20 min warm-up comprising 5 min of cycling at 2.5 $W \cdot kg^{-1}$, an 8 min progressive build up to peak aerobic power output, 2 min of cycling at a self-selected power output, 2 min of cycling to include three 6 s maximal sprints and finished with 3 min of cycling at a self-selected power output. Cyclists were then instructed to sit passively for a period of 2 min before starting the cycling TT.

During each 1-km TT, cyclists were required to complete the TT in the quickest time possible and they had access to the distance remaining. With the exception of strong verbal encouragement, no other information was provided. The gearing was self-selected by the cyclists on the Wattbike ergometer during the first practice trial and then replicated during each subsequent TT. Saddle and handlebar height and position were also replicated for each

trial. Each 1-km cycling TT was completed on the Wattbike air- and magnet-braked cycle ergometer (Wattbike Pro, Nottingham, UK). The computer attached to the Wattbike cycle ergometer was used to record performance time, mean power, peak power, mean cadence and peak cadence during the 1-km TT. Water only was consumed *ad libitum* on arrival at the laboratory and for the duration of the testing session to allow a pattern of water consumption similar to that followed during competition. This was recorded during the first experimental trial, and replicated for subsequent trials.

Immediately after the TT, a blood sample was taken from the earlobe for determination of blood lactate concentration using the Lactate Pro^{TM} (Arkray KDK, Japan). Cyclists continued to cycle at 100 W for a period of 5 min. Immediately following each testing session, cyclists completed sensory and psychological questionnaires exploring the intensity and nature of paresthesia symptoms (pins and needles, itching, flushing, irritation, numbness, and soreness), changes in mood status and a questionnaire exploring the experience of the effects of the experimental condition on perceived performance.

Sensory and Psychological Questionnaires

The sensory questionnaires that were administered included a Visual Analogue Score (VAS), an Intensity of Sensation Score (ISS), a Qualitative Light Symptoms Inventory (QLSI) and are fully described by Decombaz et al. (2012). The sensory questionnaires assess the perceived intensity and the nature of the sensation.

Mood state was assessed by using the Profile of Mood States (POMS) questionnaire. The POMS is a standardized, widely used inventory of self-reported mood states (McNair, Lorr,

& Droppleman, 1989) which is sensitive to a variety of nutritional manipulations (Lieberman, Falco, & Slade, 2002; Lieberman, Tharion, Shukitt-Hale, Speckman, & Tulley, 2002).

Furthermore, other items on the questionnaire explored the placebo effect and included the questions "Did you think that today's experimental condition affected your performance? If so, how?" "Did you have any expectations about today's trial?" and "Did you approach your trial any differently today due to the experimental condition that you ingested?"

Statistical Analyses

A minimum of eight highly-trained cyclists was determined necessary to detect a worthwhile change of 0.2 of the between-participant standard deviation based on values for typical error previously determined in our laboratory. Furthermore, since the smallest worthwhile change (SWC) in this event can sometimes be much smaller than the typical variation (e.g., 0.5 x CV) (Paton & Hopkins, 2006) we have also reported effects using a smallest worthwhile change of 1.0% and 0.5%.

Data is presented as mean ± SD to represent the average and typical spread of values of variables. Difference scores for performance variables relative to baseline were calculated for each condition, and a factorial ANOVA was conducted to identify main effects for belief and ingestion, and any interactions. The effect size has also been reported as the standardized difference between the experimental condition and baseline. Repeated-measures ANOVA was also used to identify differences between baseline and experimental conditions for performance variables and questionnaires (VAS, ISS, QLSI and POMS) (GraphPad statistical software, GraphPad version 5.0; San Diego, CA). When appropriate, Bonferroni post hoc

comparisons were used to examine differences between groups. Statistical significance was accepted at the $P < 0.05$ level.

Where practical, precision of estimates of outcome statistics are reported as 95% confidence limit (CL) of the difference between conditions, and as probabilities that the true effect is beneficial, trivial, and/or harmful (Batterham & Hopkins, 2005). When clear interpretation is able to be made, a qualitative descriptor was assigned to the following quantitative chances of benefit: 0 – 25%; unclear; 25 - 75%, benefit possible; 75 - 95%, benefit likely; 95 - 99%, benefit very likely; > 99%, benefit almost certain. We also adopted a qualitative approach by summarizing the responses to the questionnaire exploring the experience of the effects of the experimental condition on perceived performance.

RESULTS

Performance Data

The actual ingestion of β-alanine and the belief of β-alanine ingestion as well as the combination showed no significant effect on mean power or the time to complete the 1-km cycling TT compared with placebo. Compared with baseline, there was a *possibly beneficial* effect in the informed β-alanine/received β-alanine condition (mean; 95% CI) (2.4%; -2.7 to 8.0%; $P = 0.38$), and a *possibly beneficial* effect in the informed placebo/received β-alanine condition (1.8%; -1.9 to 5.4%; $P = 0.42$). It was also evident that in the absence of ingested β-alanine and under the belief that β-alanine had not been ingested (informed placebo/received placebo), there was a *possibly harmful* decrement in performance, a negative placebo or “nocebo” effect (-1.0%; -5.3 to 0.7%; $P = 0.48$).

Results of a 2 (supplement: β-alanine vs placebo) x 2 (belief: β-alanine vs β-alanine) factorial analysis of difference scores in mean power were calculated. This approach combines the two conditions in which β-alanine was administered (i.e. informed β-alanine/received β-alanine + informed placebo/received β-alanine) and subtracts the two conditions in which the placebo was administered (i.e. informed placebo/received placebo + informed β-alanine/received placebo). Results suggest that the conditions in which β-alanine was administered were associated with a *possibly beneficial* increase in mean power (± 95% CL; 2.2 ± 4.0%), but these results were inconclusive for performance enhancement (P = 0.32, ES = 0.18, SWC = 56% beneficial). The effect of the belief of β-alanine ingestion was assessed by combining the two informed β-alanine conditions (i.e. informed β-alanine/received β-alanine + informed β-alanine/received placebo) and subtracts the two informed placebo conditions (i.e. informed placebo/received β-alanine + informed placebo/received placebo). The belief of β-alanine ingestion was associated with a *possibly beneficial* increase in mean power (± 95% CL; 1.5 ± 4.3%), but these results were also inconclusive for performance enhancement (P = 0.40, ES = 0.17, SWC = 36% beneficial).

There was no significant difference observed between treatments for absolute performance time in the 1-km TT (P = 0.48). Despite no statistical difference in mean scores, 3 out of 8 participants recorded their fastest times in the informed β-alanine/received β-alanine condition (mean ± SD; -0.76 ± 1.21 s) compared to baseline performance.

Physiological and Psychological Data

Data relating to measured physiological variables by condition are presented in Table 2. No significant differences were observed in peak heart rate or peak blood lactate between conditions. Following the conditions in which β-alanine was administered, the VAS and ISS

scores of maximal intensity and the maximal intensity of the specific sensation recognized as pins and needles (QLSI) were all significantly greater compared to baseline and the conditions in which β-alanine was not consumed. Furthermore, in the conditions in which β-alanine was administered, there was a trend towards increased vigour (P = 0.07 - 0.08) compared to baseline and the conditions in which β-alanine was not consumed (Table 3).

Six cyclists (participants 1, 2, 4, 5, 7 and 8) believed that their performance improved in the informed β-alanine/received β-alanine condition. Participant 1 and 5 reported “improved energy” and thought that “I could sustain my initial effort for a little longer.” Participant 2 and 4 reported that “the TT felt a bit easier in the middle section” and “felt I could go out a little harder”. Participant 7 reported that “I felt I could stay out of the saddle for longer and it made me feel stronger in the legs.” Participant 8 reported “a boost of endurance at the end and definitely felt I came home stronger.”

Five cyclists (participants 1, 2, 4, 5 and 8) reported links between β-alanine induced paresthesia and their perception of how they felt during the TT. Participant 1, 2 and 5 reported that “the tingling sensation made me feel more alert” following both the experimental conditions during which β-alanine was consumed. Participant 4 reported that “I felt the tingles so I thought it was working and I felt it was a little easier.” while participant 8 reported that “the skin sensation made me feel a bit more lively.” following both the experimental conditions during which β-alanine was consumed.

Three cyclists reported negative placebo, or ‘nocebo’, effects in the informed placebo/received placebo condition (participant 2, 4 and 7). Participant 2 and 4 reported feeling a little “deflated” when they were told they would be receiving the placebo condition.

Participant 7 reported that “although I wasn’t receiving the treatment today I still gave it all I had, not sure I went as well as previous trials though.”

DISCUSSION

This investigation was the first to examine the effects of acute β-alanine on performance during a 1-km cycling TT. Collectively, our results indicate that the acute ingestion of β-alanine did not produce a clear benefit to the performance of a 1-km cycling TT performed in a laboratory. This finding is in contrast to the athlete’s “belief” as cyclists reported improved energy and the ability to sustain a higher power output with β-alanine ingestion and the presence of β-alanine induced paresthesia.

Acute supplementation of β-alanine has recently been promoted in some sporting circles as an ergogenic strategy for competition preparation (Kelly et al., 2013). While cyclists who ingested β-alanine produced 2.4% (inform β-alanine trial) and 1.8% (inform placebo trial) greater mean power than at baseline, this result did not approach significance and was not supported by moderate-large ES or ‘likely’ or ‘very likely’ SWC values. Therefore, no conclusive evidence of any performance enhancement was apparent. This finding is in contrast to previous research that has reported improved performance in participants who had ingested a placebo under the impression it was performance enhancing (Ariel & Saville, 1972; Beedie, Coleman, & Foad, 2007; Beedie et al., 2006). In the current study, large interindividual performance responses may have accounted for the 2.4% (inform β-alanine trial) and 1.8% (inform placebo trial) increase in mean power output following β-alanine ingestion. Indeed, the acute ingestion of β-alanine does not seem provide a mechanism to enhance performance. It has been suggested that it takes a minimum of 2 wk of β-alanine supplementation (1.6 $g \cdot day^{-1}$) to modestly elevate muscle carnosine content and augment

muscle buffer capacity (Stellingwerff et al., 2012). Furthermore, the skin sensations evoked by acute β-alanine ingestion exclusively innervate the skin and do not excite or modulate skeletal muscle fibres. This suggests that the acute ingestion of β-alanine does not provide a mechanism to enhance performance.

The current study employed a balanced placebo design (Rohsenow & Marlatt, 1981). This design allowed the research team to examine the potential placebo effects of acute β-alanine ingestion. This approach combines the two informed β-alanine conditions (i.e. informed β-alanine/received β-alanine + informed β-alanine/received placebo) and subtracts the two informed placebo conditions (i.e. informed placebo/received β-alanine + informed placebo/received placebo). Relative to baseline, it could be suggested that the belief of β-alanine ingestion produced worthwhile *possibly beneficial* effects on cycling performance 1.5% (95% CI; -1.7 to 4.8). Furthermore, given that participants produced a *possibly beneficial* greater power output in the informed β-alanine/received placebo condition, it could be suggested that a placebo effect was evident. However, there was a *possibly harmful* effect on cycling performance (-1.0%; 95% CI; -5.3 to 0.7) in the informed placebo/received placebo condition and performance was only marginally improved compared to baseline in the informed β-alanine/received placebo condition (0.6%; 95% CI; -3.3 to 5.2). These results suggest that in the absence of β-alanine, the detriment of negative belief on performance was greater than the positive effect of positive belief. Previous research has reported a negative or "nocebo" effect on performance when participants believed they had ingested an inert substance or that the experimental treatment was likely to have a negative impact on performance (Beedie et al., 2007; Bottoms, Buscombe, & Nicholettos, 2013; Maganaris, Collins, & Sharp, 2000). In the current study, the *possibly harmful* effect on performance observed in the control trial/receive placebo condition may be explained by the demotivation

associated with knowingly not receiving the experimental condition. The exact mechanisms that control the placebo/nocebo response to the beliefs and expectations of a particular experimental condition are likely to be far more complex and warrant further investigation to broaden our understanding of how the brain can govern athletic performance.

In the current study, ingestion of 30 mg·kg BM^{-1} (~2.1 g) of pure β-alanine was associated with symptoms of paresthesia most appropriately described as tingling and/or pins-and-needles. Previous research has reported that for most individuals, consuming an acute 400 mg dose of pure β-alanine is symptom free with this dose frequently used in previous studies (Baguet, Reyngoudt, Pottier, Everaert, Callens, Achten, & Derave, 2009; Derave, Özdemir, Harris, Pottier, Reyngoudt, Koppo, Wise, & Achten, 2007; Harris et al., 2006). With 500 mg doses, no symptoms were reported and participants could not differentiate between β-alanine and placebo (Van Thienen, Van Proeyen, Vanden Eynde, Puype, Lefere, & Hespel, 2009). With 800 mg doses (10 mg·kg^{-1}), Harris et al. (2006) reported ‘‘mild symptoms of flushing’’ in two out of four participants; beginning within 20 min and lasting for up to 1 h. With a 1.6 g dose, symptoms were recorded as ‘‘significant’’ in three of four participants (Harris et al., 2006). Further work by Harris et al. (2006) has reported that a single β-alanine doses of 3.2 g (40 mg·kg^{-1}) results in side-effects that are perceived as “unpleasant.” The available literature suggests that the incidence and severity of the symptoms appears to follow in a dose dependent fashion. The symptoms observed in this study after the acute ingestion of 30 mg·kg^{-1} BM β-alanine were limited to “tingling, pins and needles.” A broader array of symptoms has been reported following the ingestion of larger acute doses of β-alanine (40 mg·kg^{-1} BM), including an unpleasant steady burning and electric shock sensations (Harris, Jones, & Wise, 2008). Two of the participants in the current study reported feelings of being uncomfortable or unpleasant following the ingestion of β-alanine.

It is often suggested that the placebo effect is a factor in sports performance, especially in relation to the use of ergogenic aids. The main finding from the present study was that highly-trained cyclists may "believe" that the acute ingestion of β-alanine provides a benefit to a short maximal cycling TT. However, no clear effect on performance was evident. This perception on performance may have manifested from a powerful belief effect providing the basis for this retrospective evaluation of performance. Future research should continue to examine the impact of belief on exercise performance, either controlling for, or treating as independent variables, the beliefs of participants in intervention studies. This may assist in elucidating the mechanisms underlying the ergogenic effects of nutritional supplement aids. We would advise coaches and sport scientists to acknowledge the placebo and nocebo effects and their potential to impact sports performance, which may enable their athletes to harness the power of belief which has been shown to be a powerful modulator of exercise performance.

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Figure 1 - Change in mean power (%) relative to baseline for the 1-km cycling TT grouped according to which experimental condition they were told. *Symbols* indicated what the experimental condition actually was. Data are means; *bars* are 95% CI.

Table 1 - Effects of experimental conditions on mean power output.

Table 2 - Effects of experimental conditions on peak heart rate and blood lactate concentration during the 1-km cycling TT.

Table 3 - Changes in intensity scores of sensory descriptors and Profile of Mood States indexes for each experimental condition. Questionnaires were administered following the completion warm down of the 1-km cycling TT.