Effect of Beta-Alanine Supplementation on 2,000-m Rowing-Ergometer Performance

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Beta-alanine supplementation has been shown to improve exercise performance in short-term high-intensity efforts. However, whether supplementation with beta-alanine is ergogenic to actual sporting events remains unclear and should be investigated in field testing or race simulations.

Purpose: The aim of this study was to assess if beta-alanine supplementation could improve 2,000-m rowing-ergometer performance in well-trained male rowers.

Methods: Participants (N = 16) completed duplicate trials (2 × before supplementation and 2 × after supplementation) of a 2,000-m rowing-ergometer race separated by 28 days of either beta-alanine (n = 7; 80 mg · kg−1 · d−1) or placebo (n = 9; glucose) supplementation. Results: Beta-alanine group (pooled) race times improved by 2.9 ± 4.1 s and placebo group slowed by 1.2 ± 2.9 s, but these results were inconclusive for performance enhancement (p = .055, ES = 0.20, smallest worthwhile change = 49% beneficial). Race split times and average power outputs only significantly improved with beta-alanine at the 750-m (time –0.7 s, p = .01, power +3.6%, p = .03) and 1,000-m (time –0.5 s, p = .01, power +2.9%, p = .02) distances. Blood La− and pH postrace values were not different between groups before or after supplementation.

Conclusions: Overall, 28 d of beta-alanine supplementation with 80 mg · kg−1 · d−1 (~7 g/d) did not conclusively improve 2,000-m rowing-ergometer performance in well-trained rowers.

Keywords: ergogenic aids, buffering, carnosine, power output

Completing a 2,000-m rowing race in ~6–8 min requires a significant energy supply from both aerobic and anaerobic sources to maintain the necessary high power output over the full distance. Using the anaerobic glycolytic energy system can result in rapid rises in H+ levels, leading to a decline in the pH of body fluids, which has been linked with fatigue (Bangsbo & Juel, 2006; Spangenburg et al., 1998).

Beta-alanine (a beta-amino acid) has received recent interest due to its potential effects on muscle pH and exercise performance when loaded over several weeks. Beta-alanine is the rate limiting element for carnosine production, a significant H+ buffer found within muscle fibers (pKa = 6.83). Higher muscle-carnosine concentration may also benefit exercise performance with its antioxidant properties (Kohen et al., 1988) and by increasing the calcium sensitivity of muscle fibers and calcium release channels (Dutka & Lamb, 2004; Dutka et al., 2012) and enhancing vessel vasodilatory effects (Ririe et al., 2000).

Supplementing with doses of beta-alanine ranging from 3 to 6 g/day (~40–80 mg · kg−1 · body mass [BM] · day−1) for at least 4 weeks has increased intramuscular carnosine concentrations by 30–80% (Baguet et al., 2009; Derave et al., 2007; Harris et al., 2006). Higher carnosine levels can increase muscle buffer capacity and potentially improve exercise performance in events requiring significant energy contributions from anaerobic glycolysis (Abe, 2000; Derave et al., 2007; Suzuki et al., 2002; Suzuki et al., 2004). Recently, Baguet et al. (2010) reported that higher (without supplementation) intramuscular carnosine concentrations were positively correlated with rowing-ergometer speed greater than 100 m (r = .60), 500 m (r = .66), 2,000 m (r = .68), and 6,000 m (r = .71) in elite rowers.

Mixed effects of beta-alanine supplementation on exercise performance have been reported. Hill et al. (2007) and Sale et al. (2011) reported similar improvements (12–13%) in total work done and time to exhaustion in participants completing a 2- to 3-min cycle test at 110% of their peak power output after ~6 g/day of beta-alanine ingestion for 4 weeks. In contrast, Hoffman et al. (2008) reported that beta-alanine ingestion (4.5 g/day for 4 weeks) in American football players completing a 60-s Wingate sprint resulted only in a trend for slower fatigue rates with no significant improvement in power output. Similarly, Derave et al. (2007) reported no significant improvement in 400-m-running race time of competitive track-and-field athletes after 4 weeks of beta-alanine supplementation (4.8 g/day; ~60 mg/kg BM). A recent meta-analysis by Hobson et al. (2012) suggested that any ergogenic benefit of beta-alanine supplementation during short (~60 s), supramaximal exercise efforts may be limited, but slightly longer (i.e., 2–3 min) high-intensity exercise efforts typically showed positive results and may

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justifies investigating any potential ergogenic benefit on longer duration (≥5 min) efforts.

Currently, limited research has investigated whether beta-alanine supplementation can improve sustained high-intensity performance efforts lasting ~3–6 min, as would typically be found in rowing, kayak races, and middle-distance running. Recently, Bellinger et al. (2012) found that beta-alanine supplementation alone (without additional sodium bicarbonate) was not conclusively ergogenic to performance during a 4-min cycling time trial, reporting only that a “possible” benefit was recorded. Similarly, Baguet et al. (2010a) found that a 2.7-s improvement in 2,000-m rowing-ergometer performance in elite rowers after supplementation with beta-alanine (5 g/day for 7 weeks) was inconclusive (p = .07), although changes in muscle carnosine concentrations and performance improvements after supplementation were positively correlated (r = .50). This same group (Baguet et al., 2010b) also reported that although beta-alanine supplementation (4 weeks; 2.4 g on first 2 days, 3.6 g next 2 days, then 4.8 g/day until completion) did not improve VO2 kinetics during ~6 min of high-intensity cycling, participants supplementing with beta-alanine had a 19% smaller change in blood pH throughout exercise than the placebo group. This could potentially allow exercise to continue for longer or at a higher intensity before metabolic acidosis becomes limiting to performance. As some of the results of Baguet et al. (2010a) and Baguet et al. (2010b) suggest, there are potential benefits of beta-alanine supplementation for high-intensity exercise of ~6 min in duration; further research is required to confirm this possibility.

Therefore, the purpose of this study was to test if supplementation with beta-alanine could improve 2,000-m rowing-ergometer performance in trained rowers. We hypothesized that supplementing for 28 days with beta-alanine would lead to significant improvements in rowing performance.

Materials and Methods

Participants

Eighteen competitive male rowers (Age World Championships n = 6, Australian National Championships n = 10) were recruited, and two later withdrew due to unrelated injury, leaving 16 who completed the experimental protocol (M ± SD; beta-alanine group: n = 7, age 26 ± 9 years, BM 84.0 ± 5.2 kg, height 186.3 ± 3.5 cm, lightweight n = 1, heavyweight n = 6; placebo group: n = 9, age 26 ± 9 years, BM 82.9 ± 10.4 kg, height 187.3 ± 5.7 cm, lightweight n = 3, heavyweight n = 6). Participants had not supplemented with any nutritional substances in the preceding 3 months or with beta-alanine for the previous 6 months. All were informed of the study requirements, benefits, and risks before giving informed consent. Approval for the study was granted by the research ethics committee of the University of Western Australia.

Experimental Overview

We performed a randomized, placebo-controlled study consisting of duplicate (1 week apart) trials before and after 28 days of either beta-alanine or placebo (glucose) supplementation. We conducted duplicate trials to moderate any variation between trials, and we performed them at the same time of day to control for diurnal variations in performance.

Participants were tested in the morning or evening, depending on their rowing club’s training schedule, with each athlete matched to another member at his club, and this training time was standardized within participants across the trials. They abstained from performing any vigorous exercise and ingesting caffeine 24 hr before each trial and followed the same dietary intake on each testing day. Training diaries were completed 2 days before testing through to the completion of the study, and food diaries were also completed for the 2 days before each testing session to ensure exercise and dietary compliance before each trial.

Trials were performed indoors at the club rowing sheds, with rowing-ergometer races conducted using a Concept II rowing ergometer and slides (Model D, VT, USA) that were assigned to each athlete and maintained throughout the testing period. Rowing Australia national guidelines for drag settings were used and checked before each trial (lightweight male, BM < 72.5 kg, drag rating = 105; heavyweight male, BM > 72.5 kg, drag rating = 115). The computer display on the ergometer was partially covered so that only stroke rate and distance remaining were visible to minimize the potential influence of individual pacing strategies based on split times displayed. Participants completed their normal warm-up before each trial, with warm-up intensities and duration noted and then duplicated during each subsequent trial.

Before starting the 2,000-m races and immediately on completion, capillary blood samples (125 μl) were taken from the earlobe using glass capillary tubes (D957G-70-125, Clinitubes, Radiometer Copenhagen) to assess blood lactate concentration (HLa−) and pH. Samples were transported on ice back to the laboratory, where they were analyzed using a blood-gas analyzer/radiometer (ABL625, Radiometer Copenhagen).

After presupplementation testing, participants were matched for rowing club (to match training program) and 2,000-m times before random assignment to either the beta-alanine group or the placebo group. Beta-alanine (slow-release Carnosyn, Collegiate Sport Nutrition, San Marcos, CA, USA) was administered orally in opaque gelatin capsules for 28 days with a dose of 80 mg · kg−1 BM · day−1 (~6–7 g/day) taken as four split doses over each day; the glucose placebo (10 g/day Glucodin, Valeant Pharmaceuticals Australasia, Rhodes, NSW, Australia) was taken similarly to mimic the beta-alanine supplementation. Before the study, pilot testing for 2 weeks on n = 6 volunteers using this daily dose of beta-alanine was well tolerated with no side effects reported.
A dose per kilogram of BM (i.e., 80 mg · kg⁻¹ BM · day⁻¹) that equated to the absolute amount of beta-alanine supplemented in previous studies (Baguet et al., 2010a; Baguet et al., 2010b; Hill et al., 2007; Sale et al., 2011) was preferred here because of the mix of light- and heavy-weight rowers in the sample. Athletes were visited weekly to distribute supplements, discuss dose compliance, and check on health during the study. After 28 days of supplementation, participants returned for postsupplementation testing, conducted in an identical manner.

**Data Analysis**

Total 2,000-m time and race average power output were recorded postrace. Split times, average power output, and stroke rate were recorded every 250 m. Performance results and HLa– and pH values for the duplicate pre-supplementation and postsupplementation trials were combined and averaged for each group, so that one presupplementation and one postsupplementation measure was obtained for each variable.

A one-way repeated-measures ANOVA determined if there was a learning effect between duplicate trials, with no significant effects being found (presupplementation \( p = .52 \), postsupplementation \( p = .13 \)).

Results for each dependent variable (2,000-m or split time, mean power, blood pH and HLa–) were analyzed using a split-plot analysis of variance (SPANOVA), with significance accepted at \( p < .05 \). Post hoc \( t \) tests were used where significant interaction effects were found. Pearson’s correlation coefficients were also calculated on change (\( \Delta \)) in HLa– and pH values and 2,000-m performance. All analyses were carried out using SPSS 17 for Windows (SPSS, Inc., Chicago, IL, USA). Differences in performance were also interpreted using Cohen’s \( d \) effect sizes and thresholds (<.49, small; .5–.79, moderate; ≥.8, strong). Smallest worthwhile change (SWC) in performance scores between the beta-alanine and placebo trials, using the method described by Hopkins (2004), was also determined. A Cohen’s unit of .2 was used to determine the SWC during the two experimental trials. Where the chances of benefit or harm were both calculated to be >5%, the true effect was deemed unclear. When clear interpretation could be made, a qualitative descriptor was assigned to the following quantitative chances of benefit: 25–75%, benefit possible; 75–95%, benefit likely; 95–99%, benefit very likely; >99%, benefit almost certain (Batterham & Hopkins, 2005).

**Results**

### Performance Data

Rowing-ergometer race times and power outputs are presented in Table 1 and Figures 1 and 2. After supplementation, the beta-alanine group improved their 2,000-m race time by 2.9 ± 4.1 s, whereas the placebo group slowed by 1.2 ± 2.9 s. A significant interaction was found (\( p = .03 \)), but post hoc analysis indicated that improvements in beta-alanine race times compared with placebo-only race times approached significance (\( p = .055 \)). Within groups, only a small ES (\( d = 0.20 \)) and a 49% possible chance of benefit were recorded for the beta-alanine group in 2,000-m race times before and after supplementation (Table 1). The beta-alanine group did significantly (\( p < .01 \)) improve their race split times at 750 m and 1,000 m, whereas the placebo group was significantly slower (\( p < .01 \)) at the same time points (Figure 1). This was supported by a moderate effect size (\( d = 0.57 \), beta-alanine after supplementation vs. placebo after supplementation) along with an 87% likely improvement in performance in the beta-alanine group at 750 m and an 87% and 80% likely detriment in performance in the placebo group at 750 m and 1,000 m, respectively.

Overall, average power over 2,000 m was not significantly different in either group (\( p = .10 \)), with small ES and SWC values also recorded (Table 1). Power output at split times in the beta-alanine group significantly improved by 3.6% (\( p = .03 \)) at 750 m and 2.9% (\( p = .02 \)) at 1,000 m (Figure 2). At 750 m, this was supported by a moderate effect size (\( d = 0.50 \), beta-alanine after supple-

### Table 1  2,000-m Rowing Performance Time and Power Output Before and After Beta-Alanine or Placebo Supplementation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta-Alanine, ( M \pm SD )</th>
<th>Placebo, ( M \pm SD )</th>
<th>Cohen’s ( d ) ES / Mean Change (%) ± 90% CL / % Chance Beneficial (Trivial/Harmful)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time, s</td>
<td>393.9 ± 14.8 / 391.0 ± 14.2</td>
<td>392.2 ± 14.5 / 393.4 ± 14.1</td>
<td>0.20 / –0.7 ± 0.2 / 49 (50/1) / 0.08 / 0.3 ± 0.1 / 49 (94/6)</td>
</tr>
<tr>
<td>Total average power, W</td>
<td>369 ± 42 / 376 ± 40</td>
<td>374 ± 43 / 372 ± 41</td>
<td>.17 / 2.0 ± 0.2 / 38 (61/1) / .05 / –0.5 ± 0.1 / 0 (97/3)</td>
</tr>
</tbody>
</table>

*Note. CL = confidence limits.

*aIf the percentage chance that the effect is beneficial and harmful are both >5%, the true effect was assessed as unclear (could be beneficial or harmful). Otherwise, chances of benefit or harm were assessed as 25–75%, benefit possible; 75–95%, benefit likely; 95–99%, benefit very likely; >99%, benefit almost certain.*
Beta-Alanine and 2,000-m Rowing-Ergometer Performance

339

mentation vs. placebo after supplementation) and an 80% likely benefit to performance. In the placebo group, power output was significantly improved (4.7%: \( p = .05 \)) at 250 m, which was supported by an 82% likely benefit to performance. In contrast, power output was significantly lower at 750 m (–3.2%, \( p = .03 \)) and 1,000 m (–2.8%, \( p = .02 \)) after placebo supplementation.

\( \text{HLa}^- \) and pH

No significant differences in \( \text{HLa}^- \) within or between groups in the before- and after-supplementation trials were found (See Table 2; \( p > .05 \)). Mean \( \Delta \) in \( \text{HLa}^- \) during the races for both pre- and postsupplementation trials were calculated; no significant differences were found between groups, and mean \( \Delta \) in \( \text{HLa}^- \) was not correlated to the change in race time in the beta-alanine group (\( r = .37, p = .41 \)).

Prerace blood pH values were slightly but significantly higher (\( p < .05 \)) in the beta-alanine group after supplementation (Table 2). No other significant differences in pH within or between groups in the pre- and postsupplementation trials were found, although a strong ES (\( d = 2.37 \)) was recorded between the postrace values in the beta-alanine group, which recorded a lower value after supplementation. Mean \( \Delta \) in pH during the races for the pre- and postsupplementation trials were also calculated and were significantly (\( p = .001 \)) greater (–13%) in the beta-alanine group after supplementation only. The mean \( \Delta \) in pH was not correlated (\( r = .51, \)

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*Figure 1* — 2,000-m rowing performance split times (s) before and after (A) beta-alanine and (B) placebo supplementation. *1Significantly different from pretest (\( p \leq .05 \)). *Moderate effect size (\( d = 0.50–0.79 \)) for difference between beta-alanine and placebo after supplementation. #Likely (75–95%) chance of benefit. **Likely (75–95%) chance of detriment.*
Figure 2 — 2,000-m rowing performance split average power outputs (W) before and after (A) beta-alanine and (B) placebo supplementation. ¹Significantly different from pretest (p ≤ .05). aModerate effect size (≥ .49) for difference between beta-alanine and placebo after supplementation. #Likely (75–95%) chance of benefit.

Table 2  Blood Lactate and pH Before and After the 2,000-m Rowing-Ergometer Trials Before and After Beta-Alanine and Placebo Supplementation, M ± SD

<table>
<thead>
<tr>
<th></th>
<th>Beta-Alanine Group</th>
<th>Placebo Group</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-supplementation</td>
<td>Postsupplementation</td>
<td>Pre-supplementation</td>
<td>Postsupplementation</td>
</tr>
<tr>
<td>Blood lactate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>1.6 ± 0.7</td>
<td>1.4 ± 0.6</td>
<td>0.9 ± 0.3</td>
<td>1.1 ± 0.5</td>
</tr>
<tr>
<td>after</td>
<td>11.4 ± 2.6</td>
<td>12.5 ± 2.5</td>
<td>12.2 ± 2.1</td>
<td>12.4 ± 3.2</td>
</tr>
<tr>
<td>mean change</td>
<td>9.8 ± 2.1</td>
<td>11.2 ± 2.3</td>
<td>11.2 ± 2.0</td>
<td>11.3 ± 2.9</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>7.391 ± 0.020</td>
<td>7.409 ± 0.017*</td>
<td>7.406 ± 0.024</td>
<td>7.408 ± 0.019</td>
</tr>
<tr>
<td>after</td>
<td>7.117 ± 0.044</td>
<td>7.099 ± 0.047*</td>
<td>7.090 ± 0.059</td>
<td>7.087 ± 0.072</td>
</tr>
<tr>
<td>mean change</td>
<td>0.274 ± 0.055</td>
<td>0.310 ± 0.062*</td>
<td>0.315 ± 0.071</td>
<td>0.321 ± 0.081</td>
</tr>
</tbody>
</table>

¹Beta-alanine before vs. after supplementation, d = 2.37.
*Significantly different than before supplementation (p = .001).
participants supplemented with beta-alanine had a 19% due to improved buffering over this intense period of times over the second and third 500-m race distances sine concentrations were correlated with faster rowing et al. (2010a) reported that higher intramuscular carno-
slow power and speed in the final 500 m. In the beta-alanine group after supplementation.

Discussion
The purpose of this study was to examine whether 28 days of beta-alanine supplementation could improve 2,000-m rowing-ergometer performance in well-trained rowers. While rowers (n = 7) supplemented with beta-alanine completed the race 2.9 s faster than before supplementation, and rowers on placebo were 1.2 s slower, this result only approached significance (p = .055) and was not supported by moderate to large ES or likely or very likely SWC values. Therefore, no conclusive evidence of any performance enhancement was noted.

These results are consistent with those of Baguet, Bourgois, et al. (2010), who also reported an inconclusive (ns: p = .07) improvement of 2.7 s in 2,000-m rowing-ergometer performance in elite rowers (n = 8) supplemented with a slightly higher total dose of beta-alanine (245 g vs. 188 g) over a longer, 7-week period. For both studies, it should be acknowledged that a larger sample size (than n = 7 and 8, respectively) may have produced more convincing results, as p values were near significance. At present, there remains very limited evidence that beta-alanine supplementation improves competition performances of well-trained athletes. Our rowing study and that of Baguet et al. (2010a) have not found conclusive evidence of performance enhancement after supplementation in 2,000-m (6–7 min) ergometer time trials. Furthermore, in cycling, Bellinger et al. (2012) reported only a possible beneficial effect in a 4-min time trial, and Hoffman et al. (2008), only a trend for slower fatigue rates in a 60-s Wingate test. In running, Derave et al. (2007) found no improvement in 400-m (~60 s) track times. Only Hill et al. (2007) and Sale et al. (2011), using less specific performance tests (2–3 min at 110% of cycling peak power output), have reported conclusive benefits (in work done and time to exhaustion) after beta-alanine supplementation.

In considering the 2,000-m split times recorded here, the rowers recorded the highest power outputs and speeds in the first 250 m of the race, followed by the adoption of a slower race rhythm with a steady decline in speed and power up to 1,500 m before increasing power and speed in the final 500 m. In the beta-alanine group, performance was only improved at the 750- and 1,000-m race splits (500–1,000 m: 1.5–3 min). At these corresponding time points, the placebo group recorded slower times and lower power outputs. Recently, Baguet et al. (2010a) reported that higher intramuscular carnosine concentrations were correlated with faster rowing times over the second and third 500-m race distances (500–1,500 m) and hypothesized that this could be due to improved buffering over this intense period of the race. Baguet et al. (2010b) have also reported that participants supplemented with beta-alanine had a 19% smaller change in pH throughout 6 min of high-intensity cycling, compared with a placebo group. In our study, using the same calculation, we found that the change in pH was only 3.4% lower in the beta-alanine group. Within groups, we also found that the change in pre- to posttest pH was ~13% greater after supplementation with beta-alanine, whereas previous studies (Baguet et al., 2010a; Baguet et al., 2010b; Derave et al., 2007; Sale et al., 2011) have reported similar mean changes in HLa– and smaller changes in pH after supplementation with beta-alanine. A moderate but nonsignificant (r = .51, p = .24) correlation was recorded here between the improvement in race time and the mean change in pH after supplementation with beta-alanine. Given these mixed results reported, further investigation of the changes in muscle and/or blood buffering during high-intensity exercise efforts after beta-alanine supplementation are needed to determine if a consistent relationship exists between beta-alanine supplementation and changes in pre- to postexercise pH and HLa–.

Supplementing with beta-alanine can produce higher levels of muscle carnosine, which should improve muscle buffer capacity (pKa = 6.83; intramuscular concentration postsupplementation = 30–40 mmol/kg DM) and therefore potentially improve high-intensity, short-term exercise performance (Abe, 2000; Derave et al., 2007; Suzuki et al., 2002; Suzuki et al., 2004). Although it was not possible to measure muscle carnosine levels in this study, we calculated that our dosing strategy would have increased intramuscular carnosine concentrations by ~44%, based on the linear relationship between total dose and intramuscular carnosine presented by Stelingwerff et al. (2012). This is slightly lower than in studies using similar dosing protocols (i.e., 6.4 g/day for 4 weeks), which have reported increases of 50–60% (Kendrick et al., 2008; Kendrick et al., 2009), but still well within the range (30–80%) reported by Baguet et al. (2009), Derave et al. (2007), and Harris et al. (2006). On the basis of these data, we are confident that our total dose of beta-alanine administered to the participants was adequate to improve muscle carnosine levels sufficiently to potentially improve exercise performance and is not a reason why inconclusive results were recorded.

Conclusions and Practical Application
In conclusion, supplementing with beta-alanine (80 mg · kg–1 · BM · day–1 ~6–7 g/day) for 28 days did not conclusively improve 2,000-m rowing-ergometer race times of well-trained rowers. This result matches that of Baguet et al. (2010a), who also reported an inconclusive improvement in 2,000-m rowing-ergometer times in elite rowers after 7 weeks of supplementation. Until future research can further examine the relationship between supplementation protocols, intramuscular carnosine concentrations, and sporting performance using larger samples of trained athletes, beta-alanine should not be regarded as ergogenic for high-intensity events of ~6–7 min duration.
Acknowledgments

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References


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