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The Effects of Short Term β-Alanine Supplementation on Performance in Division III Male and Female Rowers

Original Research

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Abstract

Introduction: Carnosine is an intramuscular buffer, and β-Alanine is the limiting reagent in carnosine synthesis. Thus, β-Alanine supplementation which increases carnosine concentrations, has been shown to have an ergogenic effect. Past studies found improvements in body composition and 2km time trial performance in elite rowers, but there is limited research examining the effects of β-Alanine in collegiate rowers and if sex differences may exist.

Methods: Using a double-blind, placebo-controlled randomized design, the effects of four weeks of 3.2 g/d of β-Alanine, or placebo, on body composition and 2km time were tested in male and female collegiate rowers. Performance was taken one and three weeks into supplementation as well as post-supplementation. Body composition was measured using air displacement plethysmography before and after supplementation.

Results: Body composition and rowing performance were improved over time. However, change in body composition -1.5 ± 1.9 vs -2.7 ± 2.9 %fat, lean mass 2.3 ± 1.3 vs. 1.4 ± 1.8 kg, and 2km time -2.1 ± 7.9 v -4.2 ± 6.5s, were not different between placebo and β-Alanine groups, respectively ($p>0.05$), though improvement in 2km tended to be ~50% better with β-Alanine (effect size = 0.29). There were no apparent sex differences over time or with supplementation.

Conclusions: β-Alanine supplementation did not have a significant effect on 2km rowing time, although the β-Alanine group tended to improve more than placebo, perhaps as a result of improved buffering capacity. However, further work is needed in this population, specifically using longer and higher β-alanine dosing schemes.

Key Words: Carnosine, sex differences, body composition

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Introduction

During moderate to high intensity exercise, there is an increase in intramuscular hydrogen ion (H^+) production, due to a greater reliance on anaerobic glycolysis as an energy system [1]. An increased production of lactate and associated H^+ leads to a drop in intramuscular pH, thereby increasing acidity. Acidosis contributes to muscle fatigue and performance declination, as it negatively affects the excitation-contraction coupling in skeletal muscle [1]. Therefore, if intramuscular pH decline can be prevented or delayed, fatigue may also be delayed. Carnosine is a multifunctioning dipeptide found in many tissues, but most abundantly in skeletal muscle [1-3], and is purported to have many roles including: pH buffering, quenching free radicals, enzyme regulation, and sarcoplasmic reticulum calcium regulation [2]. Carnosine operates as a buffer at more physiological pH than the bicarbonate buffering system, making it a more relevant intramuscular buffering system during high intensity exercise [1].

β-alanine is a naturally occurring amino acid that, along with L-histidine, is a precursor for carnosine, with β-alanine being the rate-limiting precursor. In previous studies, β-alanine supplementation has been shown to increase intramuscular carnosine concentration, delaying fatigue and increasing exercise performance [1,3,4]. Rowing, a sport known to induce severe metabolic strain, is a sport prime for application

of β-alanine. To this end, a study completed with elite Belgian rowers found a strong positive correlation between baseline muscle carnosine content and rowing performance, suggesting that muscle carnosine content is a new determinant of rowing performance [5]. Accordingly, a few studies have investigated the potential ergogenic effect of β-alanine supplementation on rowing performance [5-8], with most studies purporting a likely benefit to performance, an effect which in most studies [5,7,8], but not all [6], did not reach traditional statistical significance. Though, Baguet et al. found that elevating intramuscular carnosine, through seven weeks of β-alanine supplementation, correlated positively to 2km performance enhancement [5]. Some rowing performance benefit has been suggested with β-alanine supplementation with relatively short durations of approximately four weeks [6-8], and with dosages as low as 2.4 g/d [6]. Focusing on studies that used the gold standard of rowing performance assessment, the 2km time trial, revealed an approximate 3-6 s time improvement with β-alanine over placebo [5,7,8], with some studies reporting a slowing of the placebo group [5,7]. However, these studies have been somewhat inconclusive and focused exclusively on male elite (national team) or pre-elite (university level) rowers, leaving the question whether collegiate and/or female rowers, might benefit from β-alanine supplementation, unanswered. Further, the possible effects of β-alanine on lean mass and body composition in rowers is not yet well described.

Accordingly, the purpose of this study was to determine the effect of four weeks of once daily supplementation of 3.2g of β-alanine (5.4 g of supplement) vs. placebo on rowing performance and body composition in male and female collegiate rowers using a double-blind placebo controlled randomized design. It was hypothesized that β-alanine supplementation would improve rowing performance over placebo during an intensive training phase. Finally, given previous work suggesting greater relative impact of β-alanine supplementation in females [9] it was also hypothesized that β -alanine would have more of a significant effect on female than male rowers.

Methods

Participants

A total of 25 college-aged Division III collegiate rowers were recruited for this study, 14 females and 11 males, from the Saratoga Springs NY area. Rowers were excluded if they had any musculoskeletal injuries that prevented them from rowing training (n=1). The athletes were in the preparatory phase of training periodization nearly to transition into competitive phase. Thus, the rowers trained six times a week for two hours, each training session had a combination of a rowing specific endurance work as well as rowing drills to refine rowing technique. Along with the 12 hours a week of rowing training, participants also had two, one-hour weight lifting sessions. Rowers were excluded from the study if they missed more than three practices or missed two consecutive lifting sessions (n=2). Each participant provided written informed consent prior to participation and the study was approved by the Human Subjects Institutional Review Board of Skidmore College (IRB#1902-792). All experimental procedures were performed in accordance with the Federal Wide Assurance and related New York State regulations, which are consistent with the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research and in agreement with the most recent revisions to the Declaration of Helsinki.

Protocol

Prior to supplementation, participants' height was collected using a stadiometer, and body weight and composition were collected using air displacement plethysmography (BodPod, Cosmed). The BodPod has been shown to be a reliable measure of weight and body composition with typical intraclass correlation coefficients of 0.99 between trials [10-13]. The BodPod was calibrated according to manufacturer guidelines prior to each test. As a baseline, peak power was measured through 10 sets of a 10-stroke test at the highest damper setting on a Concept2 rowing ergometer in the Skidmore College Rowing Center. This particular rowing ergometer has previously been shown to be accurate and reliable in the measurement of peak power [14]. Prior work from our laboratory suggests high reliability across even three trials [15] and the peak power is achieved within 10 strokes [16]. The highest rowing power was recorded in watts, which has been shown to correlate with 2km rowing performance [8]. The Concept2 rowing ergometer has been shown to be a valid and reliable piece of equipment in conducting 2km rowing tests [17]. The participants were then randomized into two groups based on baseline peak rowing power performance. In a double blinded fashion, participants were given either 3.2g of sustained release β-alanine (5.4 g of SR CarnoSyn, Inner Armour Sports Nutrition, Berlin, CT) per day or a relatively isocaloric placebo in a single dose in the evening. A slow release formulation was chosen to mitigate the

incidence of paresthesia [18]. This dose was chosen to be in accordance with manufacturer label suggested intake, thus representing typical use, and is likely a safe dose for human consumption [18-20]. Further, such modest dosing has been found to significantly increase muscle carnosine concentrations within two to four weeks, similar to the length of the current study, though may not achieve peak concentrations [21]. To achieve double blinding, a trained person independent to the study mixed the β-alanine with powdered lemonade mix (70 Kcal), where the placebo was just the lemonade mix (60 Kcal), thus the drinks were of similar taste, appearance, texture, caloric content, and macronutrient composition. The mix containing either the supplement, or placebo, was given to the participants in person by a member of the research team in the evening after training for consistency purposes, which was added to 12 oz of water in both groups (isovolumetric) for four weeks, a period suggested long enough for observable increases in intramuscular carnosine [21] and improvements in exercise performance [6,18]. The study was conducted in the spring, in preparation for the sprint racing season but was limited to four weeks to focus on when training had a significant anaerobic component where β-alanine could benefit, but was constrained to before critical on the water competitions began.

Participants' performance was tracked over the five weeks, with a 2km time trial during the first, third week of supplementation, and after supplementation, and peak power before the supplementation, during the third and fifth week, and after supplementation. All time trials and peak power were performed on a Concept2 ergometer in the Skidmore Rowing Center.

Statistical Analysis

Statistical evaluations were completed using SPSS (SPSS v. 25.0 IBM INC., Armonk, NY). In order to examine if any significant differences between the supplementation and placebo groups at the beginning of the study, an independent samples t-test was performed. A two-way ANOVA (2x2) was conducted among all dependent variables to see if there was a significant difference between supplementation groups over time, and sex was included as a covariate. Change in the dependent variables between groups was also examined using independent samples t-tests. The level of significance was established a priori as $p < 0.05$, and all data are expressed as mean ± standard deviation.

Results

Subject Characteristics

At baseline prior to supplementation there were no differences between groups for age, height, weight body composition, or peak rowing power (Table 1). There was also an even distribution of males and females between groups.

Table 1. Baseline Subject Characteristics

	Placebo (n=12)	β-Alanine (n=10)
Age (years)	19.3 ± 1	19.4 ± 1
Sex (male/female)	6/6	5/5
Height (cm)	173 ± 9	173 ± 7
Weight (kg)	72.1 ± 13	71.5 ± 8
Body Fat (%)	20.9 ± 8	19.9 ± 8
Peak Rowing Power (Watts)	518 ± 168	529 ± 149

Data are mean ± SD.

Rowing Performance

Baseline rowing performance, as assessed by peak rowing power, was not different between groups, and baseline peak power correlated significantly with week one 2km times ($r = 0.93$, $p=0.000$). Focusing on pre-post changes, there was no significant interactions between group and time ($p=0.52$) or group, time, and sex ($p = 0.28$), though, expectedly, rowing performance was nearly significantly improved ($p=0.06$) by ~3 seconds on average irrespective of group (Figure 1). Between the 2km trial week one and week three, there was an approximately 47% difference between placebo and β-alanine in 2km time improvement (Figure 1). Between the 2km trial week three and post supplementation, there was, on average, an approximate ~72% difference. In terms of total change from week one and post

supplementation, there was an on average 50% difference in improvement over the study period, and corresponded to an effect size of 0.29 (Cohens d), or 'small' effect. Even though the β-alanine group on average had a larger decrease in time between all three 2km trials and total time, there was no statistically significant differences between groups for time difference between any of the time trials, nor the total time change.

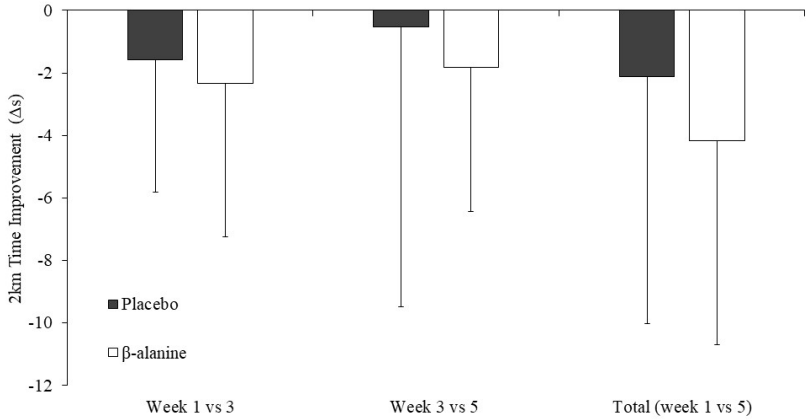

Figure 1. Change in 2km Rowing Performance between Placebo (n=12) and β-alanine (n=10) supplemented groups. Data are mean±SD.

Looking into possible sex differences in response to β-alanine supplementation, using group comparisons of those supplemented with β-alanine, between the 2km week one and week three, males on average decreased rowing time by 3.24 ± 4.33s, while females only decreased by 1.44 ± 4.53s (Figure 2). Between week three and post males decreased by 1.44 ± 11.98s, while the females decreased by 2.2 ± 3.12s ($p > 0.05$). For total change between week one and post times, males decreased time by 4.68 ± 10.06s, and females decreased by 3.64 ± 3.85s, but were not different ($p > 0.05$).

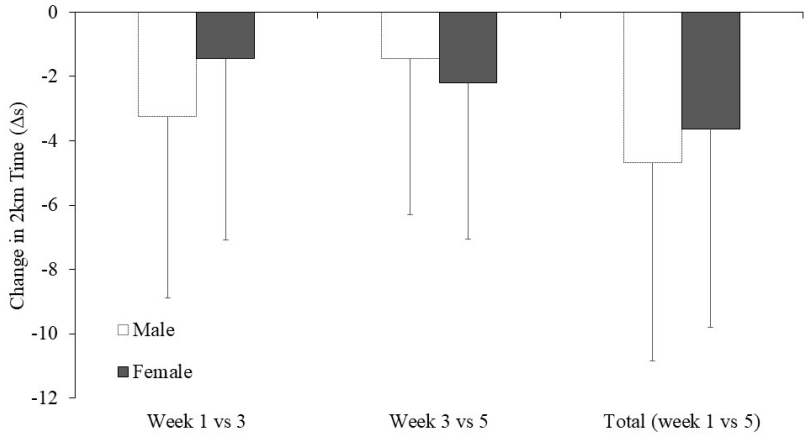

Figure 2. Change in 2km Rowing Performance in β-alanine supplemented males (n=5) and females (n=5). Data are mean±SD.

Body Composition

There were no significant interactions of group by time, or group, time, and sex for percent body fat, body mass, or lean body mass (all $p > 0.05$, Table 2). There were also no significant main effects for group (all $p > 0.05$). However, there were significant time effects, with lean mass on average increasing from 57.4 ± 12.2 at baseline to 59.4 ± 12.6 kg at the end of the study period ($p < 0.05$). As body mass only non-significantly increased from 71.8 ± 10.7 kg at baseline to 72.3 ± 10.5 kg at post-testing ($p > 0.05$), body composition on average decreased from 20.5 ± 8 at baseline to 18.4 ± 9 % body fat at post-testing ($p < 0.05$, Table 2).

Table 2. Body Composition Changes

	Body Mass (kg)	Lean Mass (kg)	Body Fat (%)

Placebo	Male	Baseline	78.5 ± 13	67.4 ± 12	14.1 ± 4
		Post	80.1 ± 14	70.2 ± 12	12.3 ± 4
	Female	Baseline	65.6 ± 10	47.3 ± 7	27.8 ± 5
		Post	67.0 ± 9	49.2 ± 6	26.5 ± 5
β-Alanine	Male	Baseline	77.2 ± 5	67.0 ± 4	13.2 ± 2
		Post	75.5 ± 4	68.5 ± 2	9.2 ± 3
	Female	Baseline	65.7 ± 7	48.1 ± 4	26.5 ± 6
		Post	66.0 ± 6	49.4 ± 5	25.0 ± 5

Data are mean ± standard deviation.

Discussion

The purpose of this study was to examine the effect of four weeks of once daily supplementation of 3.2g/d of β-alanine vs. placebo during the preparatory phase on rowing performance in male and female collegiate rowers using a double-blind placebo controlled randomized design. It was hypothesized that β-alanine supplementation would improve rowing performance over placebo, and that this effect would be more pronounced in female rowers than male rowers. However, in this short-term β-alanine supplementation study, using rigorous study design, we found no statistical difference in rowing performance during the preparatory phase, despite a trend for a 50% greater improvement with supplementation (~2 s). There were otherwise no sex specific effects of β-alanine supplementation, or effects on body composition, at this dose and supplementation length. More research is needed to ascertain potential benefits of β-alanine supplementation in male and female collegiate rowers.

Rowing Performance

β-alanine supplementation has been found to increase muscle carnosine levels [1,2,5,8,9,22-27], and though some studies find conflicting evidence, reviews on supplementation have concluded that β-alanine supplementation is an effective ergogenic aid [2,4,22]. β-alanine supplementation may not directly improve maximal strength but increases buffering capacity, likely improving work capacity and training stimulus. Kendrick et al. in 2008 examined the effects of β-alanine supplementation on whole-body strength for college students over the course of a 10-week training program [27]. They found that β-alanine did not contribute to improving maximal strength [27]. This is not surprising as acidosis does not affect maximal strength performance. However, in a similar study Hoffman et al., found that though β-alanine does not improve maximal strength performance, but found that the supplementation group increased total work volume in training sessions than the placebo group [26]. With this, β-alanine seems to have an effect on improving anaerobic threshold. A study by Hill et al. in 2007 studied β-alanine supplementation for four and 10 weeks on cycling performance at 110% VO_{2peak} [24]. They found that after four weeks of supplementation the supplementation increased total work done by 13% during cycling test, and after six weeks total work done increased by 20% during the test [24]. However, for a rowing modality, specifically 2km time trials (high intensity performance test), there have been relatively inconclusive results of beta-alanine on improving performance [5,7,8]. Baguet et al. looked at muscle carnosine content and rowing performance in Belgian elite male rowers [5]. They found a positive correlation between baseline carnosine concentrations and rowing performance, as well a positive correlation in supplementation-induced change in carnosine concentrations to changes in rowing performance [5]. In the present study there was no statistically significant difference in 2km change over the course of the supplementation, total decrease in time between week one 2km and post supplementation 2km for the β-alanine group was almost twice as large than the placebo group's decrease in time and is similar to previous work in terms of the magnitude of the, albeit small, effect [7]. This suggest a possible trend, and possibly with a higher dose of β-alanine and/or a longer supplementation period there would have been significant results, as the Baguet study supplemented with 5g/day for seven weeks [5]. On the other hand, Beasley et al. documented improvements in 30-minute rowing distance with 2.4 g/d over four weeks of β-alanine supplementation. Thus, the impact of β-alanine supplementation may be task dependent.

Similar to our results, Hobson et al. studied the effects of beta-alanine and/or sodium bicarbonate supplementation on male, well-trained club rowers on 2km time trials [8]. The rowers supplemented

6.4g/day of β-alanine for 28 days, and .3g/Kg of sodium bicarbonate on day 28 and day 30, completing 2km time trial tests pre and post supplementation, with two post for sodium bicarbonate effect [8]. They found that β-alanine has a positive beneficial effect on performance, but was not significant against the placebo. It was also found that sodium-bicarbonate with β-alanine was more beneficial than beta-alanine alone, but they did not find significant differences between times [8]. This is similar to the findings in this study, as a similar trend of increased performance for 2km was found with the β-alanine group, even though there was no significant difference from placebo times[8]. The Hobson study supplemented twice as much β-alanine than this study and also had no significant results, however the intervention period four weeks, same as the protocol in this study. This suggests that period of supplementation may have a greater effect than quantity of daily dosage [8], or as suggested by others a total exposure [21]. In 2013, Ducker et al. also found similar results to the present study and Hobson et al.[8], with 80mg/kg β-alanine for four weeks [7], supports the idea that supplementation period length has a greater effect. Alternatively, given the volume and intensity of training the rowers were undergoing during the supplementation period, it is possible that muscle carnosine levels were already undergoing optimization and thus supplementation perhaps reached a ceiling effect for improving muscle carnosine [28].

Previous rowing studies however have looked into male rowers, not female rowers or a sex difference for the effect of beta-alanine supplementation. In a previous study Stegen et al. in 2014 looked into sex and body mass for determinants of β-alanine induced carnosine loading, and the appropriate dosage for maintaining elevated carnosine levels [29]. They found that body mass and sex are determinants of the relative increase in carnosine levels from β-alanine supplementation [29]. For females, given the lower baseline of carnosine, it was found that their relative increases in intramuscular carnosine levels were greater, likely indicating that females needed less β-alanine for the same relative increase as men [29]. Knowing that higher carnosine levels means improved exercise performance, especially for increasing the anaerobic threshold [23], females would have a greater improvement with the same dosage as males. In this study however, there was no significant difference between males and females for time difference between 2km trials in the β-alanine group. The Stegen study [29] used the same dosage of daily β-alanine, however the supplementation period was 46 days, nearly twice the period than the protocol in this study, again supporting the notion that supplementation period length likely has a greater effect.

Previous studies have shown that β-alanine supplementation increases lean body mass more than a placebo [30,31], with minimal effect on body composition [27,32]. This was not the case in the current study. This may be due to a number of factors. Since the current study did not control for participants' diet, it is unknown as to whether they were consuming adequate protein in order to gain lean mass. Furthermore, the resistance training that the participants were undergoing during the course of the supplementation period was not specifically designed for hypertrophic development, while past studies have included hypertrophy-focused training during their supplementation period [22,31], perhaps explaining this discrepancy. Further, it is also possible given the volume and intensity of rowing training, might have blunted any possible hypertrophic effects of β-alanine supplementation. Interestingly, *in vitro* evidence suggests that β-alanine may induce mitochondrial biogenesis and increase oxygen consumption [33], perhaps contributing to an energy deficit, which could also complicate hypertrophic effects of β-alanine, but further work is needed to clearly delineate this hypothesis.

Limitations

This study did not control for, or record, participants' diet, sleep, stress levels, or any training they might have done outside of regular team training. Controlling, and/or recording, diet across participants would help to more accurately assess the potential effects of β-alanine, rather than possible differences in dietary intakes (caloric and/or macronutrient intakes) between groups and/or sexes. We also did not control for menstrual cycle phase or oral contraceptive use, though from a practical perspective this lack of control perhaps better reflects the reality of training and possible supplementation in this group. Coupled with relatively low numbers of males and females in each group likely reduces the likelihood of revealing sex differences. Future studies may benefit from keeping diet and sleep logs of participants, controlling for menstrual cycle, increasing number of participants, as well as planning the 2km time trials to occur around times of low academic stress. Additionally, it was not possible in the current study to measure baseline, or possible supplementation-induced changes in, intramuscular carnosine content, thus it is unknown to what extent, if any, β-alanine increased carnosine content.

Conclusions

Supplementation with 3.2g/d of β-alanine, in combination with rowing training, while on average improved 2km time more than the placebo group (~50% greater improvement post-supplementation), there was no statistically significant ergogenic effect or any effect on body composition, and neither appeared overtly sex-dependent. Future studies are needed with higher doses and/or longer supplementation to adequately determine if β-alanine supplementation is effective in modifying intramuscular carnosine content, body composition, and performance in collegiate rowers.

Media-Friendly Summary

Short term supplementation with beta-alanine, an ergogenic aid designed to improve muscle buffering capacity, did not significantly improve rowing performance or body composition. Using a dose consistent with labeling over four weeks was not capable of significantly improving rowing performance in division III collegiate athletes during an intensive training phase. Future studies using higher dose and/or longer supplementation might yield a positive effect.

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