Beta-alanine (BA) is a non-essential amino acid functioning as the precursor to carnosine (1, 2). BA supplementation is utilized as an ergogenic aid based on its effectiveness during exercise performance (3, 4). In vivo, carnosine concentrations directly correlate to BA availability (5), indicating BA intake directly increases carnosine concentrations. These increases delay fatigue and increase power output, resulting in enhanced exercise performance (6, 7).

Baseline levels of intra-muscular carnosine vary amongst populations indicating certain individuals may experience enhanced effects from BA supplementation. When comparing intramuscular carnosine between males and females, a 3.5 : 1.0 ratio exists respectively between genders (8). Females also require lower levels of BA supplementation to obtain similar relative increases in carnosine compared to males (9). In women, BA increases time to exhaustion (10), and decreases feelings of perceived exertion (11). These data, taken together with the fact carnosine loading is further augmented in trained muscles (12), indicates trained females may be more sensitive to BA supplementation with regard to increasing carnosine concentrations. This may lead to performance increases with condensed dosing protocols.

Most studies demonstrating improved performance with BA utilize longitudinal designs (6, 7). BA is typically administered over 1- to 4-wk periods, as chronic supplementation appears necessary for intramuscular carnosine (3). However, it must be noted that BA supplementation is multifaceted as it not only increases the buffering capacity of H⁺, but has alternative mechanisms such as protecting against glycation, anti-oxidant properties, and increasing calcium sensitivity in contractile fibers (7). Furthermore, data indicate that acute doses of carnosine can increase concentrations, causing it to be readily available within muscle (13, 14). These results have not been evaluated with acute doses of BA and it is unclear if the effects of supplementation on carnosine concentrations are similar. Currently, the only data evaluating the acute effects of BA supplementation found no performance improvements when utilizing male participants (15), potentially because the total exercise bout was too short (< 60 s) for BA to be maximally effective (7). In order to determine the efficacy of acute BA supplementation on exercise performance, these effects must be evaluated in populations that experience augmented, more sensitive increases in carnosine such as trained and/or female participants (9, 12).

Previous research demonstrates performance improvements after longitudinal BA supplementation (6, 7) with subsequent decreases in feelings of perceived exertion (16); however, BAs ability to acutely increase performance would potentially reduce the need for this loading phase prior to competition. To date, acute
BA supplementation has only been evaluated in males although females require less BA for similar relative carnosine increases (9). Therefore, research is needed in female populations, as it cannot be ascertained if males and females will respond similarly to acute doses. Combined with the fact that trained muscles seem to respond more efficiently to BA supplementation (12), trained females may experience acute benefits from BA supplementation. Therefore, the purpose of this investigation was to evaluate the effects of BA supplementation on anaerobic performance in trained female cyclists. It was hypothesized female cyclists would elicit increased power output with associated decreases in feelings of perceived exertion when supplementing with BA.

MATERIALS AND METHODS

Participants signed an informed consent prior to testing and measures were approved by the institutional review board in line with the Declaration of Helsinki. Participants for this study consisted of 12 trained, competitively active female cyclists (26.6±0.83 y, 61.08±1.78 cm, 58.67±2.18 kg) training an average of 3.92±0.64 y. As high-intensity exercise, lactate production, and lactate clearance are negatively affected during the follicular phase (17), all testing took place in the luteal phase of menstruation (48-h after self-reported cessation of menses). Participants completed an initial exercise log and maintained the same level of training intensity, time, and volume for the duration of the study. In order to control for increased energy based on dietetic consumption and according for acute increases in post-prandial plasma BA and carnosine levels, participants were required to fast at least 6 h prior to all trials (18). Participants had never ingested supplementary BA and refrained from exercise, alcohol, and caffeine 24-h preceding each trial. All trials were separated by a minimum of 72 h.

Participants completed treatment conditions in double-blind, randomized order. Conditions included: 1) placebo (PLA; 34 g dextrose) and 2) BA (1.6 g BA plus 34 g dextrose). Supplementation values for BA [Powder City; York, PA] were based on previously established doses (19) and were mixed with 16 ounces of water and a calorie-free, carbohydrate-free, flavoring to blind for taste. When consumed acutely in previously published literature (19), 1.6 g BA did not induce any reported feelings of paresthesia. During the consenting process, all subjects were informed of the potential paresthesia side-effect and as experiencing feelings of paresthesia would eliminate the double-blind, this was determined as the threshold for the current investigation. The 34 g dextrose has been previously identified to ensure identical taste even with the addition of beta-alanine (19). In order to ensure that any changes were not based simply on increases in carbohydrate intake (i.e. dextrose), the dextrose amount remained constant between trials with only the addition of beta-alanine being the adjusted variable. Supplements were 3rd party lab tested before use in this investigation.

Each participant reported to the laboratory for three visits. On the first visit, height and mass were measured using a stadiometer and weight beam eye-level scale, respectively (Detecto, Webb City, MO). Body fat and lean mass analysis was determined via dual-energy X-ray absorptiometry (DXA). Based on previous recommendations (20), participants underwent familiarization of the Wingate cycle test on an electronically braked Velotron Dynafit Pro cycle ergometer (Racer Mate, Seattle, WA). Wingate trials lasted 30 s in duration and resistance remained the same for each trial (7.5% body mass). The Wingate is a valid test for anaerobic power ($r=-0.91$), with significant (ICC=0.95–0.97) test-retest reliability (21). Significant test-retest reliability on the Velotron Dynafit Pro cycle ergometer has been reported for mean power ($r=0.90$) and peak power ($r=0.70$) during repeated Wingate trials (22).

Previously published data involving a multi-purpose supplement including BA observed significant performance increases with associated decreases in subjective fatigue after as little as a 20-min rest interval (23). Therefore, to ensure sufficient time for the supplement to be absorbed and utilized, a slightly longer, seated rest period (30-min) was implemented after supplement consumption. The cycle ergometer seat height and handlebar specifications were recorded during the familiarization and maintained constant during each trial. Following the rest period, blood lactate (Accutrend Lactate Monitor, Indianapolis, IN), heart rate (Polar heart rate monitor, Lake Success, NY), and rating of perceived exertion (RPE) via the OMNI scale (24) were recorded. The OMNI scale is a 0–10 scale where 0 indicates no exertion felt and 10 indicates maximal exertion. Participants were familiarized with the scale and established instructions were read before each trial (24). In females, the Omni cycle ergometry scale has established construct validity for measuring RPE compared to the traditional Borg scale ($r=0.96$) and concurrent validity correlating to $VO_{2\text{max}}$ ($r=0.88$) and heart rate ($r=0.83$) measures (24).

Next, participants performed a 4-min warm-up at a self-selected cadence (25). Following the warm-up, a 5 s countdown was given after which participants pedaled as quickly as possible against the predetermined resistance (26). Based on previous recommendations, major points emphasized to participants before testing included that the Wingate: a) starts at a specified pedaling cadence, b) is a maximal sprint, c) requires participants to remain seated during the trial, and d) that participants should not stop until instructed (26). Upon reaching 110 revolutions per minute, resistance engaged and participants pedaled as hard as possible for the 30 s period. Blood lactate, maximal heart rate, and RPE measurements were recorded immediately after completion of the first Wingate trial. Participants recovered for 2 min after each Wingate, pedaling at a self-selected cadence with no resistance. At the end of the 2-min recovery period, lactate, heart rate, and RPE were again recorded. The same protocol was followed for the second and third Wingate tests. Following the 3rd 2-min recovery period, final measurements were taken.
Beta-Alanine in Female Cyclists

Table 1. Wingate measures based on supplement.

<table>
<thead>
<tr>
<th></th>
<th>PLA</th>
<th>BA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W1</td>
<td>W2</td>
</tr>
<tr>
<td>Absolute peak (W)</td>
<td>597±40</td>
<td>551±42</td>
</tr>
<tr>
<td>Absolute mean (W)</td>
<td>424±14</td>
<td>381±10</td>
</tr>
<tr>
<td>Relative peak (W/kg)</td>
<td>10.37±0.40</td>
<td>9.55±0.44</td>
</tr>
<tr>
<td>Relative mean (W/kg)</td>
<td>7.48±0.20</td>
<td>6.68±0.18</td>
</tr>
</tbody>
</table>

All data are expressed as mean±SE. PLA: placebo, BA: beta-alanine, W1: Wingate 1, W2: Wingate 2, W3: Wingate 3. No significant differences were observed for any variable between trials.

Table 2. Heart rate and lactate measures during Wingate trials.

<table>
<thead>
<tr>
<th></th>
<th>PLA</th>
<th>BA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resting</td>
<td>W1–Post</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>74±4</td>
<td>172±3</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>1.8±0.2</td>
<td>3.4±0.3</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>69±6</td>
<td>173±4</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>1.8±0.1</td>
<td>3.2±0.2</td>
</tr>
</tbody>
</table>

All data are expressed as mean±SE. PLA: placebo, BA: beta-alanine, W1: Wingate 1, W2: Wingate 2, W3: Wingate 3. No significant differences were observed for any variable between trials.

(lactate, heart rate, RPE) and participants cooled down as long as necessary. Upon completion of each trial, participants were asked which supplement they believed they had consumed. Participants were also asked if they experienced any side effects.

SPSS version 20 (Armonk, NY) was used to analyze all data. To assess the effects of supplementation on performance, perceptual, and physiological variables between trials, investigators utilized a 2 (trial) by X (time) repeated measures analysis of variance (ANOVA), where X represented the number of times variables were assessed during trials (X=7 for lactate, heart rate, and RPE; X=3 for peak power, average power, and fatigue index). Fatigue index was calculated as: [(peak power – minimum power)/peak power]×100. Similar analyses were also conducted for mean and peak power expressed relative to each participant’s body mass. For statistically significant F-scores, a one-way repeated measures ANOVA was used and an alpha level of p<0.05 defined significance. Fisher’s exact test evaluated participants’ ability to determine the supplement ingested during trials. Based on the recommendations from Hobson et al. (7), any participant reporting feelings of paresthesia was accounted for in all analyses. Statistical models were completed with and without participants experiencing feeling of paresthesia to ensure results were the effect of the double-blind design.

RESULTS

A 2×3 repeated measures ANOVA revealed a significant main effect of time for decreases in absolute mean power (F=15.53, p<0.001), absolute peak power (F=13.94, p<0.001), relative mean power (F=20.30, p<0.001), and relative peak power (F=19.64, p<0.001) from Wingate 1 to Wingate 3; however, these changes were independent of the supplement ingested (p>0.05; Table 1). A 2×7 repeated measures ANOVA revealed a significant main effect of time for increased heart rate (F=253.34, p<0.001) and lactate (F=97.80, p<0.001), but there was also no significant interaction effect of the supplement ingested (p>0.05; Table 2). A significant interaction was present for RPE based on time and supplement ingested (F=2.98, p<0.001). When consuming BA, RPE was lower than for the PLA trial immediately after the first two Wingates were completed, as well as after each of the three rest periods (Fig. 1).

Fisher’s exact test indicated the participants were unable to accurately assess which supplement they had consumed based on a 2 (supplement trial guess)×2 (accuracy) analysis (p=0.90). Participants correctly guessed the trial they were participating in only 29% of the time. One participant reported feelings of paresthesia during the trials. All analyses were run with and without the participant experiencing paresthesia. No changes were detected for any analysis and therefore the participant was included in the final statistical models.

DISCUSSION

The purpose of this investigation was to evaluate the effects of BA supplementation on anaerobic performance in trained female cyclists. Females require less
BA for similar relative carnosine increases compared to males (9) and taken together with the fact that trained muscle experiences greater carnosine responses to BA supplementation (12), it was postulated an acute BA dose would improve anaerobic performance in trained female cyclists. Our hypothesis was only partially correct as power output was similar between trials; however, BA reduced females’ feelings of perceived exertion.

Previous research evaluating the effects of BA supplementation on exercise performance demonstrates improvements when utilizing longitudinal designs (2, 11, 27). The only current data assessing acute effects of a single exogenous BA dose were collected in males and did not result in increased sprint performance (15). This is likely because BA most effectively increases performance during anaerobic bouts lasting longer that 60 s (7) and Invernizzi et al.’s protocol was <60 s (15). Despite using a longer trial duration (90 s), our data indicate acute BA supplementation does not increase peak power or mean power or decrease fatigue in trained female cyclists. These data concur with previous results (15) indicating that acute BA does not increase high intensity exercise performance.

Although acute supplementation did not alter physical performance (e.g., fatigue index or power output), BA decreased participants’ feelings of exertion immediately after the first two Wingates, and also after each 2-min rest interval. This is in line with pervious literature suggesting longitudinal BA supplementation significantly decreases RPE (11, 16); however, these are the first data to demonstrate effects from a single acute dose. The observed decreases in RPE may be the result of increases in carnosine concentrations; however, this is speculative as the dipeptide was not directly measured in this investigation. Interestingly, these decreases in exertion were independent from increases in anaerobic exercise performance. Previous data evaluating BA supplementation have also demonstrated decreased feelings of exertion without concurrent increases in performance (16). These results may indicate that different carnosine thresholds exist for respective changes in RPE and physical performance. Future research should evaluate this concept by evaluating RPE and performance at intermittent time points throughout a longitudinal design.

It is proposed that exercise terminates when feelings of discomfort outweigh the potential rewards of exercise continuation (28) and measures of RPE can predict duration of cycling exercise to fatigue at a constant power output (29). In our study, the pre-determined 30 s duration, stop/start nature of repeated Wingate exercise, and participants’ inability to alter the resistance, potentially precluded the reductions in RPE from affecting power output. RPE can be a guide for the subjective assessment of work and can be used to regulate exercise intensity. During competition, athletes will compare conscious RPE with an expected RPE and adjust pacing strategies based on a particular point in a race (30). Decreased RPE would potentially cause an experienced athlete to increase intensity in order to reach an expected level of exertion. Outside of competition, acute decreases in exertion would allow for longer, more intense training sessions resulting in increased physical fitness and enabling athletes to perform at higher levels.

The fact that no differences were detected in RPE immediately after the 3rd Wingate trial may be attributed to fixed mentalities of maximal exertion adopted prior to exercise. Research indicates participants pre-determine a perceived effort rating for a certain bout of work based on how hard they believe it should be, and that this rating often remains unchanged despite changes in exercise intensity (31). This is observed particularly during maximal efforts where participants...
expect to be at the highest rating of perceived exertion before starting exercise. Our participants’ inability to alter resistance potentially precluded the reductions in RPE from impacting power output as participants may have reported the level of exertion they felt they were expected to feel after the final Wingate. This may have led to similarity in RPE scores at the end of the 3rd Wingate despite decreased RPE after the first and second (31). RPE plays an important role in regulating exercise performance and future designs implementing acute BA supplementation should employ different durations and intensities of exercise to evaluate this concept.

CONCLUSION

In conclusion, acute BA did not improve anaerobic performance in young female cyclists. Acute supplementation of 1.6 g BA did, however, decrease feelings of perceived exertion immediately post Wingate performance and after recovery; these decreases in RPE were present despite a similar power output and fatigue index across Wingates. The acute ability of beta-alanine to decrease feelings of perceived exertion has potential benefits for athletes during exercise training and competition. In order to fully understand these implications, the acute effects of BA supplementation should be evaluated in athletes during time trial events to evaluate pacing strategies and overall effects on in-competition performance.

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