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The effects of a single dose of beta-alanine supplementation on the cardio-respiratory system of well-trained rowing athletes

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ABSTRACT

Purpose: Intensive exercise significantly lowers the pH of muscle and blood; beta-alanine supplementation can increase carnosine levels, the absence of which leads to an early acidosis and fatigue. The aim of our work is to investigate the effect of a single dose of beta-alanine supplementation on well-trained rowing athletes. **Materials/Methods:** The spiroergometric parameters of the participants ($n = 28$) were examined a total of four times (T1,T2,T3,T4). After measurement (T3), participants received a beta-alanine supplementation at a dose of 50 mg/kg⁻¹ body weight. We compared the results of the four measurements as well as the blood lactate values obtained from the fingertip before and after the tests. **Results:** The different load physiological parameters and the lactate values measured after the tests did not show any significant difference. The mean lactate value prior to test (T4) was 1.8 (mmol*L⁻¹), which is significantly higher than the mean-value of the two previous studies: T1 = 1.6 (mmol*L⁻¹); ($P = 0.00$), T3 = 1.55 (mmol*L⁻¹); ($P = 0.04$). **Conclusions:** The higher lactate value measured before test (T4) was probably due to the longer time to return to the baseline values after the series load. In conclusion, a single dose of beta-alanine supplementation has no effect on performance. In order to elicit the ergogenic effect of beta-alanine, the use of short, intermittent diet therapy intervention is not recommended.

KEYWORDS

beta-alanine supplementation, rowing, exercise performance, lactate level

INTRODUCTION

Nowadays, athletes are paying increasingly more attention to their nutrition, as they would be unable to maintain adequate performance without the right intake of macro- and micro-nutrients. The use of various dietary supplements is becoming more and more popular among athletes, one of the most common being beta-alanine (BA).

Beta-alanine is known to get into the body by consuming meats, but not in the same concentration as with a targeted dietary supplement. The body is able to synthesise a dipeptide, carnosine, from two amino acids, beta-alanine and L-histidine. Histidine is a non-essential amino acid that occurs in high concentrations during carnosine synthesis in skeletal muscles [1] beta-alanine is found in much lower concentrations and appears to be a limiting

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factor in carnosine synthesis [2]. Carnosine is able to bind hydrogen ions and has a proton binding effect [2], thereby delaying the decrease in pH in the muscles due to intense sports activities [3]. The reason for the decrease in muscle and blood pH is that lactic acid is produced in the body during intense exercise, a process that contributes to fatigue. Due to the intracellular proton binding effect of carnosine, acidosis and fatigue occur earlier in the absence of carnosine [4]. Due to their structure, at physiological pH, nitrogen atoms located on the imidazole ring are capable of immediate proton binding [5]. The concentration of carnosine in skeletal muscle fibres can be increased by BA supplementation [6–7], while the intake of carnosine itself with a dietary supplement is not effective in increasing carnosine levels in the muscle tissue [8]. With a daily intake of 4–6 g of beta-alanine for two weeks, a 20–30% increase in carnosine levels can be achieved [9] and a dietary supplement of 4–6 g per day for four weeks, a 40–60% increase in skeletal muscle carnosine levels can be achieved [10, 2]. During various high-intensity workouts, increasing carnosine levels can improve performance [11–12]. To further increase carnosine levels, it is advisable to combine beta-alanine intake with an appropriate diet [13].

In the sport of rowing, a sufficient level of endurance is essential for effective racing. The characteristics of the cardiovascular system and the determination of lactate values after exercise play an important role in the analysis of performance. Physiological characteristics such as minute ventilation (VE), absolute and relative oxygen consumption (VO_2 , RVO_2) are quality determinants of cardiovascular system performance.

With our study, we want to provide accurate advice to athletes about consuming beta-alanine to improve their performance. Non-curative BA consumption also occurs among both amateur and top-level athletes; previously, the ergogenic effect of BA has only been studied using several weeks of diet therapy intervention. The aim of the present study was to investigate the effect of a single dose of BA on the performance of athletes with sport-specific endurance, $50\text{mg}\cdot\text{kg}^{-1}$ body weight. The question we formulated was “Does a non-curative BA dietary supplement affect the physiological characteristics, pre- and post-load lactate levels of athletes”? The load physiological characteristics that determine performance can be measured. By successive measurements, the possible performance-enhancing effect can be detected.

MATERIALS AND METHODS

Experimental design

The research took place at the Department of Sport Sciences, Faculty of Health and Sport Science, University of Győr (Hungary). To the longitudinal section study ($n = 28$); (19.5 ± 2.2) years old male rowing athletes were included, who all do the same training. All procedures were in line with the 1964 Declaration of Helsinki and its subsequent amendments

to ethical standards. All participants were informed orally and in writing about the research, its risks, and benefits after the explanation of the study, and then a written consent was given by each athlete to participate in the study. The condition to participate in the study was the same as the condition in the competitions: the existence of a valid sports doctor's certificate. Furthermore, they could not consume any dietary supplement in the six weeks prior to the research. In the course of the research, we examined short-term effects after serial loading, in the framework of which the participants were subjected to spiroergometric examination four times. They were measured on two consecutive days; 5 h elapsed between the first study (T1) and the second study (T2) and between the third study (T3) and the fourth study (T4). 24 h elapsed between the first study (T1) and the third study (T3) and between the second study (T2) and the fourth study (T4).

Supplementation protocol

Subjects did not receive beta-alanine on the first day of measurement, and on the second day, they received $50\text{mg}\cdot\text{kg}^{-1}$ body weight of beta-alanine between the two studies shortly after the third measurement (T3). The powdered dietary supplement was given to athletes by personal measurement, which was consumed mixed with water.

Anthropometric measurements and determination of lactate level

Body composition was analysed with an „Inbody 720” (Biospace Co. Inc., Seoul, South Korea) Bioelectrical Impedance Analyzer (BIA). Serum lactate concentration (Accutrend® GC VD-003 GCTL) was measured from a fingertip blood sample before and 3 min after the test.

Spiroergometric examination and protocol

Cardio-respiratory system characteristics were measured on a “Marquette” 2000 treadmill (Pittsburgh, PA, USA) until complete fatigue. The following instruments were used for the measurements: a “Cardiosoft”, (Milwaukee, USA) instrument for resting pulse (HRo), ($\text{beats}\cdot\text{min}^{-1}$) and maximum heart rate (HR), ($\text{beats}\cdot\text{min}^{-1}$); and a Sensor Medics “Vmax 29C” (Yorba Linda, CA, USA) instrument for aerobic capacity (VO_2max), minute ventilation VE ($\text{L}\cdot\text{min}^{-1}$) and for its components. The protocol used in the spiroergometric study was as follows: warm-up 2 min, belt speed $5\text{ km}\times\text{h}^{-1}$ with a slope of 0%, then for 2 min $11\text{ km}\times\text{h}^{-1}$ with a slope of 3%. Next, the slope was increased by 3% every 2 min with the belt speed being $11\text{ km}\times\text{h}^{-1}$ until the end of the study.

Statistical analyses

Statistical analysis was performed using the *Statistica for Windows* software package (version 12.1, StatSoft Inc., Tulsa, OK 74104, USA, 2006). As the first step of the statistical analysis, the descriptive statistical characteristics (mean, standard deviation) were calculated. Differences per

load and per organ system were examined by repeated measures ANOVA, and critical differences were determined by the Tukey HSD method. When interpreting the statistics, the maximum random error was consistently set at 5%.

RESULTS

The anthropometric characteristics of all participants are shown in Table 1.

Different characteristics of the cardio-respiratory system were also compared per study and per intensity zone, as a result of the increasing load, each load physiological indicator showed a linear upward trend during the study. During the four studies, we obtained a picture of the maximal working and oxygen uptake capacity of the study group. The mean and standard deviations of the peak values of each load physiological parameter per measurement are shown in Table 2.

No significant differences were found in the main characteristics of the cardiovascular system of the subjects during the four measurements. Regarding the time spent on the treadmill, we did not find any real difference between the average results of the measurements. Averages of the measurements: T1 = 590.36 ± 71.9 (s), T2 = 608 ± 79.4 (s), T3 = 597.8 ± 88.4 (s), T4 = 617.8 ± 77.1 (s). The mean time result of the fourth measurement after consumption of BA (T4) is numerically larger than that of all the three previous measurements (T1, T2, T3), but the difference is not significant (T4-T1, $P = 0.57$; T4-T2, $P > 0.99$; T4-T3, $P = 0.82$)

Table 1. Participant characteristics ($n = 28$)

Age (years)	19.5 ± 2.2
Body-height (m)	1.81 ± 0.07
Body-mass (kg)	76.1 ± 9.2
Body-fat (%)	13.1 ± 3
Body-muscle (%)	43.5 ± 2.4

Table 2. Maximum mean $\pm$ standard deviation of performance and cardiovascular system characteristics

Tests	T1	T2	T3	T4
HR ($b \cdot \min^{-1}$)	197.9 ± 2.47	198.6 ± 2.92	197.4 ± 3.5	198.6 ± 3.7
VO ₂ ($L \cdot \min^{-1}$)	4.56 ± 0.63	4.62 ± 0.64	4.52 ± 0.66	4.72 ± 0.56
RVO ₂ ($mL \cdot kg^{-1} \cdot \min^{-1}$)	60.1 ± 6.9	60.9 ± 7	59.5 ± 6.2	62.4 ± 4.9
VE ($L \cdot \min^{-1}$)	152.3 ± 11.5	151.5 ± 12.1	149.8 ± 12.7	152 ± 12.4
RQ	1.06 ± 0.06	1.05 ± 0.05	1.07 ± 0.06	1.08 ± 0.05

HR: heart rate, VO₂: absolute oxygen uptake, RVO₂: relative oxygen uptake, VE: minute ventilation, RQ: respiratory exchange ratio. Data are presented as mean $\pm$ standard deviation. No significant between-group differences reported.

Table 3. Serum lactate values of the subjects before and 3 min after the test during the four measurements (mean $\pm$ standard deviation)

Tests	T1	T2	T3	T4
Pre[La-] _b ($mmol \cdot L^{-1}$)	1.55 ± 0.23	1.72 ± 0.75	1.6 ± 0.25	$1.8 \pm 0.54^*$
Post[La-] _b ($mmol \cdot L^{-1}$)	12.14 ± 1.78	12.9 ± 1.5	12.3 ± 1.65	13.1 ± 1.62

Pre[La-]_b: pre-test lactate value; Post[La-]_b: the lactate value after the test. * = Pre[La-]_b ($mmol \cdot L^{-1}$) T4 was significantly higher for T1: $P = 0.00$ and for T3: $P = 0.04$

(Fig. 1). In terms of running performance, the results also show that athletes performed better during the afternoon measurements.

The lactate values taken from the blood serum during the T1, T2, T3, T4 measurements are shown in Table 3.

The mean of the fourth measurement (T4) showed a significant difference compared to the first (T1), ($P = 0.00$) and third (T3) measurements ($P = 0.04$) and no significant difference compared to the second (T2), ($P = 0.69$) in the mean values of lactate before the test (Pre[La-]_b). The results show that in the afternoon measurements, which were already preceded by a spirometric study, we observed higher pre-load lactate values than in the morning studies.

There was no significant difference in the mean results of lactate values measured 3 min after the test (Post [La-]_b) during the four measurements (T1-T4).

DISCUSSION

The tests (T1, T2, T3, T4) meet the criteria of the vita maxima test, according to which the maximum heart rate

Fig. 1. Mean and standard deviation of the time results of the subjects during the four measurements (T1; T2; T3; T4): AP (s); There is no significant difference between the mean results of the measurements (T1-T4)

per person approached the value of $220 \text{ (b} \cdot \text{min}^{-1}) - \text{age}$, during the increasing load, the RQ value was greater than 1, the duration of the test exceeded 6 min in the case of each participants and lactate values measured after the load also indicated adequate blood acidity. Thus, the results thus obtained are the ones that best show the current fitness status of the subject. In untrained persons, at maximum load the relative oxygen uptake is $\text{RVO}_2 \leq 40 \text{ (mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1})$, the oxygen uptake is $\text{VO}_2 \leq 3 \text{ (L} \cdot \text{min}^{-1})$, and minute ventilation $\text{VE} \leq 100 \text{ (L} \cdot \text{min}^{-1})$ [14]. Based on these and considering the data of the examined persons, we can state that they were in good fitness, so we measured the effect of the non-curative BA dietary supplement in groups with good endurance with a dose of $50 \text{ mg} \cdot \text{kg}^{-1}$ body weight.

In terms of running capacity, the mean time result of T4 was not affected by the use of the single-dose of BA. However, our study did not show a negative effect of series loading on performance either, as four *vita maxima* tests within 30 h are a serious load even for well-trained athletes. Contrary to our results, previous research studies using a 4–6 week dietary intervention of 4–6 g per day have observed the ergogenic effect of BA in trained or young adults [7, 15–17]. Also, 4–6 weeks of 0.8–2.4 g daily beta-alanine supplementation increases exercise performance and endurance in middle-aged and elderly people [18–20]. Although in the case of the elderly, the goal may no longer be to increase training performance, but rather to curb the decline in aerobic capacity as much as possible, thereby preserving their health.

It can be concluded that the values of lactate (Post[La-]_b) measured after the test in the subjects were not affected by the single-dose BA dietary supplement. Another study using curative BA consumption found similar results for post-exercise lactate values, but a performance difference was also observed there, as a performance-enhancing effect of beta-alanine [21–22]. In contrast, observations from previous studies using a 4–6 week dietary intervention have reported decreased lactate levels after exercise [11, 23–25]. However, lactate values after exercise (Post[La-]_b) should be evaluated in conjunction with maximum heart rate and running performance. After all, if the athlete does not achieve maximum performance, the reduced post-load lactate value is not due to the dietary supplement but simply does not reach the maximum load zone, so the body's metabolic response is also smaller. Regarding the pre-load lactate values (Pre[La-]_b), the result of T4 measurement was significantly higher compared to the measurement of T1 and T3. This result may have been due to the longer time to return to baseline after series loading.

Beta-alanine supplementation had no effect on the aerobic capacity ($\text{VO}_{2\text{max}}$) or relative aerobic capacity ($\text{RVO}_{2\text{max}}$) of the subjects. Observations from previous studies have reached similar results [26, 27]. Respiratory minute volume (VE) did not differ during the studies, thus aerobic capacity could not change either, as tidal volume is one of the greatest limiting factors of aerobic capacity in addition to the oxygen-carrying capacity of the blood.

CONCLUSIONS

Summarising the results of our study, we found that a single dose of $50 \text{ mg} \cdot \text{kg}^{-1}$ body weight beta-alanine dietary supplement in the sample had no effect on load physiological characteristics, pre- and post-exercise lactate levels. In our opinion, the correct dosage depends on the person's age, gender, and level of fitness, but a longer-term, 4–6-week dietary supplement is absolutely necessary to achieve an ergogenic effect. With our study, we would like to emphasise that more attention should be paid to dietary intervention planning of beta-alanine and that its irregular, non-curative use should be avoided in order to achieve a performance-enhancing effect.

Ethical approval: All procedures were in line with the 1964 Declaration of Helsinki and its subsequent amendments to ethical standards.

Author's contribution: LS: Conceptualisation, Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Visualisation, FI: Investigation, Resources, Data Curation, ZSZ: Investigation, Resources, Data Curation, DN: Investigation, Resources, Data Curation, ZA: Investigation, Resources, MVB: Methodology, Validation, Writing – Review & Editing, Supervision, EM: Conceptualisation, Methodology, Validation, Formal analysis, Writing – Review & Editing, Supervision. All authors approved the final version of the revised manuscript.

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