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Beta-alanine supplementation and anaerobic performance in highly trained judo athletes

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Abstract

Introduction. Previous studies have shown that several weeks of beta-alanine (BA) supplementation increases anaerobic work capacity and decreases muscular fatigue, but limited research was conducted on elite martial arts athletes. Therefore, the purpose of this study was to investigate the effect of chronic BA supplementation on high-intensity intermittent upper and lower-body performance in highly-trained judo athletes. Material and Methods: Sixteen elite judo athletes (21.8 ± 2.5 years old) were randomly assigned to receive either BA (4 g/d over the first 2 weeks and 6 g/d in the last 2 weeks) or placebo for 4 weeks. Before and after BA supplementation, the athletes completed two double 30-s upper and lower limb Wingate tests, separated by 3 min. Blood samples were collected for lactate and di-carbonate concentration at baseline and post-exercise. Results: BA supplementation improved Lower and Upper Limb Total Work ($p < 0.001$) and Upper Limb Mean Power ($p < 0.001$) during Wingate Test. However, there were no significant differences in Lower Limb Mean Power in the BA group and in any obtained results in the placebo group. Additionally, a significant increase in the postworkout lactate and di-carbonate concentration ($p < 0.001$) was observed. Conclusions: Chronic supplementation of BA effectively enhances high-intensity intermittent upper and lower-body performance in highly-trained judo athletes.

Keywords

beta-alanine, sports performance, martial arts, sports nutrition, suplement

Cover Page Footnote

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Article

Beta-alanine supplementation and anaerobic performance in highly trained judo athletes

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Abstract: Introduction. Previous studies have shown that several weeks of beta-alanine (BA) supplementation increases anaerobic work capacity and decreases muscular fatigue, but limited research was conducted on elite martial arts athletes. Therefore, the purpose of this study was to investigate the effect of chronic BA supplementation on high-intensity intermittent upper and lower-body performance in highly-trained judo athletes. Material and Methods: Sixteen elite judo athletes (21.8 ± 2.5 years old) were randomly assigned to receive either BA (4 g/d over the first 2 weeks and 6 g/d in the last 2 weeks) or placebo for 4 weeks. Before and after BA supplementation, the athletes completed two double 30-s upper and lower limb Wingate tests, separated by 3 min. Blood samples were collected for lactate and di-carbonate concentration at baseline and post-exercise. Results: BA supplementation improved Lower and Upper Limb Total Work ($p < 0.001$) and Upper Limb Mean Power ($p < 0.001$) during Wingate Test. However, there were no significant differences in Lower Limb Mean Power in the BA group and in any obtained results in the placebo group. Additionally, a significant increase in the post-workout lactate and di-carbonate concentration ($p < 0.001$) was observed. Conclusions: Chronic supplementation of BA effectively enhances high-intensity intermittent upper and lower-body performance in highly-trained judo athletes.

Keywords: beta-alanine, sports performance, martial arts, sports nutrition, supplement.

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1. Introduction

In judo, as well as in other combat sports, bouts of high-intensity activities dominate during competition. Considering the above statement, anaerobic power and anaerobic capacity determine sports performance and the dominant metabolic pathways in competition. During judo combat, which usually lasts 4 minutes, a decrease in power in repeated explosive movements is primarily attributed to the decompensated acid-base balance, hypohydration, and depletion of muscle glycogen [1, 2]. Factors determining fatigue are complex and include both central and peripheral components [3]. When high-intensity exercise lasts longer than 6–7 s or is repeated without adequate rest, high-energy phosphates cannot supply the needed energy, and a significant shift towards glycolysis occurs [1]. In consequence, hydrogen ions (H^+) begin to accumulate leading to decreased muscle pH, which ultimately leads to a decrease in performance, especially force production. The higher the intensity of exercise during a fight, the greater the reliance on glycolysis and higher production of lactic acid and H^+ [4]. This concomitantly leads to a further decline in intramuscular pH and a drop in performance. The accumulation of H+ in the active muscles due to high-intensity exercise affects metabolic processes, diminishing the rate of phosphocreatine resynthesis, inhibiting the rate of glycolysis and the contractile process as well [5]. Having this in mind, scientists, coaches, and athletes have experimented with different buffering agents that increase the ability to tolerate higher concentrations of H^+, allowing for glycolysis to maintain ATP resynthesis for a longer period of time. Of the many natural ergogenic substances available, the effectiveness of some has been confirmed empirically. These include sodium bicarbonate, creatine, and beta-alanine (BA) [6–9]. The majority of studies on sodium or potassium bicarbonate indicate acute benefits on performance, while creatine and BA require a loading phase, thus chronic changes in performance are reported more often [10–12]. It has been proposed that BA increases carnosine skeletal muscle concentration, which serves as an intramuscular buffer. BA binds with histidine to form carnosine which is stored within skeletal muscles. There is some evidence that several weeks of BA supplementation increases anaerobic work capacity and decreases muscular fatigue [8, 13]. Carnosine itself can be supplemented; however, it is hydrolyzed in the stomach producing BA and histidine. Because BA is a rate-limiting substrate, its supplementation has shown greater effects in increasing carnosine muscle concentration. Carnosine is a naturally occurring compound found in numerous tissues, including skeletal muscles, where its concentration is the highest. It has several significant functions in the human body including buffering, antioxidant properties, enzyme regulation, and calcium (Ca^{2+}) regulation [4, 13]. The concentration of carnosine is significantly higher in fast-twitch muscle fibers, which justifies the fact that animals exposed to sprints or dynamic fighting have higher carnosine muscle content than those with a prevalence of slow-twitch muscle fibers subjected to endurance activities [14]. The same is true for athletes. Those that practice anaerobic sports disciplines, such as sprints and weightlifting, usually have higher intramuscular concentrations of carnosine. Some studies indicate that high-intensity training increases muscle carnosine concentration [15]. Theoretically, increased carnosine concentration through BA supplementation should increase buffering capacity, delay fatigue, and enhance anaerobic performance. However, results from previous studies have given unequivocal results. It seems that the outcome of BA supplementation studies depends on the time and intensity of the exercise protocol, the duration and dosage of the supplementation, and the type of participants (trained and untrained) [11, 13, 16]. Considering the above, the purpose of this study was to evaluate the effects of BA supplementation over 4 weeks on the anaerobic performance of highly trained judo athletes.

2. Materials and Methods

2.1. Participants

Sixteen judo athletes with an average of 5.2 years of training experience participated in the study. Athletes from the heavyweight and lightweight categories were excluded to constitute a homogenous group in regard to age, sports level and body weight, as well as aerobic and anaerobic performance (Table 1). The subjects (n = 16) were randomly divided into two groups: a beta-alanine group (BA group; n = 8), which received BA supplements over 4 weeks, and a placebo group (n = 8), which ingested a placebo. All subjects had valid medical examinations and showed no contraindications to participate in the study. The athletes were informed verbally and in writing of the experimental protocol, the possibility to with draw at any stage of the experiment, and gave their written consent for participation.

The study was approved by the Research Ethics Committee of the Academy of Physical Education in Katowice, Poland.

Table 1. Characteristics of the study participants.

Variables	BA Group (n=8)	Placebo Group (n=8)
Age (yrs.)	20.7 ± 3.2	22.1 ± 2.8
Height (cm)	177.2 ± 2.6	178.3 ± 4.9
Body mass (kg)	81.5 ± 3.9	78.4 ± 5.1
FM (%)	10.9 ± 2.6	9.8 ± 3.2
$W_{t-\text{ upper limbs}}$ (J/kg)	132 ± 14	137 ± 13
$W_{t-\text{ lower limbs}}$ (J/kg)	275 ± 9	281± 14
$P_{max-\text{ lower limbs}}$ (W/kg)	18.3 ± 0.9	19.6 ± 1.6
$P_{max-\text{ upper limbs}}$ (W/kg)	8.7 ± 1.1	8.9 ± 0.9
VO_{2max} (ml/kg/min)	54.5 ± 3.8	52.6 ± 4.9
Age (yrs.)	20.7 ± 3.2	22.1 ± 2.8

Values expressed as mean ± standard deviation. BA – beta-alanine; FM – fat mass; W_t – total work; P_{max} – maximal power

2.2. Study Protocol

The experiment lasted 4 weeks, during which two sets of laboratory tests were carried out to determine anaerobic power and anaerobic capacity of the lower and upper limbs, as well as the acid-base equilibrium, lactate concentration, and buffering capacity. The tests were carried out at baseline and after 4 weeks of supplementation with BA and placebo. The study was conducted during the general conditioning period of the annual training cycle, with a high volume of daily training loads. The participants refrained from exercise for 2 days before testing to minimize the effect of fatigue.

The subjects had their somatic measurements taken, and body composition was evaluated in the morning, between 8.00 and 8.30 am by the electrical impedance technique (Inbody 720, Biospace Co., Japan). Anaerobic performance was evaluated by the 30-s Wingate test protocol for lower and upper limbs respectively, with a passive rest interval of 3 minutes between the bouts of exercise. The test was preceded by a 15 min warm-up which included pedaling and cranking on the ergocycle and stretching. First, the athletes pedaled for 5minwith a resistance of 100 W and a cadence within 70–80 rpm for lower limbs and then cranked for 3 min at 40 W and 50–60 rpm for the upper limbs, followed by stretching. Following the warm-up, the test trial started, in which the objective was to reach the highest cadence in the shortest possible time, and to maintain it throughout the test. The lower limb Wingate protocol was performed on an Excalibur Sport ergocycle with a resistance of 0.8 $Nm \cdot Kg^{-1}$ (Lode BV, Groningen, Netherland). The upper body Wingate test was carried out on a rotator with a flying start with a load of 0.45 $Nm \cdot Kg^{-1}$ (Brachumera Sport, Lode, Netherland). Each subject completed 2 test trials with an incomplete rest interval in between the trials. The variables of peak power – P_{max} (W/Kg) and total work performed – Wt (J/Kg) were registered and calculated by the Lode Ergometer Manager (LEM, software package, the Netherlands).

2.3. Diet and Supplementation Protocol

Energy intake, as well as macro and micronutrient intake of all subjects, was determined by the 24 h nutrition recall 3 weeks before the study. The participants were placed on an isocaloric (3255 ± 336 kcal/d) mixed diet (55% carbohydrates, 20% protein, 25% fat) before and during the investigation. Three hours before testing, the athletes consumed a light carbohydrate meal and ingested 0.5l of water. During the experiment and 3 weeks before the commencement of the study, the participants did not take any medications or supplements. The 16 judo athletes were divided into 2 equal groups, matched to their anaerobic performance. The BA group received the supplement over 4 weeks while the second group received placebo. The BA was ingested 3 times per day with meals with a dose of 4g/d over the first 2 weeks which was increased to 6 g/d in the last 2 weeks of the experiment. A placebo design was chosen rather than a crossover study due to the washout time of BA which has been estimated to last 6 to 10 weeks. This would have prolonged the time of the experiment, with some of the elite athletes not available due to international competitions.

2.4. Biomechanical Assays

To determine lactate concentration (LA) and acid-base equilibrium, the following variables were evaluated: LA (mmol/L) and $HCO_{3\text{-std}}$ (mmol/L). The measurements were performed on fingertip capillary blood samples at rest and 3 minutes after the cessation of both Wingate tests. The tests were performed at baseline and after the 4 weeks of intervention. Determination of LA was based on an enzymatic method (Biosen C-line Clinic, EKF-diagnostic GmbH, Barleben, Germany). The remaining variables were measured using a Blood Gas Analyzer GEM 3500 (GEM Premier 3500, Germany).

2.5. Statistical analysis

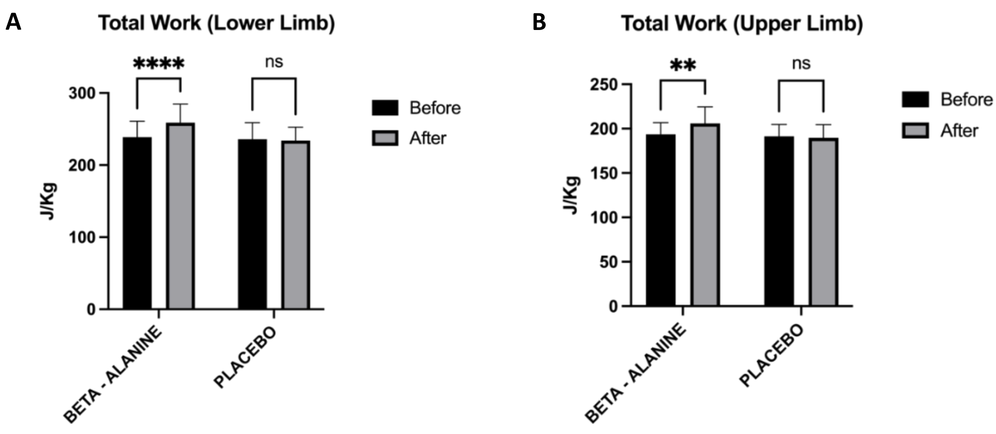
The Shapiro-Wilk, Levene and Mauchly's tests were used to verify the normality, homogeneity, and sphericity of the sample's data variances, respectively. Verifications of the differences between analyzed variables before and after BA supplementation and between the BA and placebo groups were performed using ANOVA with repeated measures. Effect sizes (Cohen's *d*) were reported where appropriate. Parametric effect sizes were defined as large for $d > 0.8$, as moderate for *d* between 0.8 and 0.5, and as small for $d < 0.5$ [17, 18, 19]. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using Statistica 9.1 and Microsoft Office and were presented as means with standard deviations.

3. Results

All participants completed the described testing protocol. The 2-way ANOVA analysis (group x time) revealed significant differences between the baseline and post-intervention period–4 weeks ingestion of BA (BA group) or placebo (placebo group) in the following variables: Lower and Upper Limb Total Work, Upper Limb Mean Power and post-exercise concentration of lactate and di-carbonate in blood plasma.

3.1. Anaerobic performance lactate and acid-base balance parameters

Tests revealed a statistically significant increase in Lower Limb Total Work (from 239.0 to 258.8 J/kg, with $p < 0.0001$), Upper Limb Total Work (from 193.5 to 205.9 J/kg with $p = 0.0023$), and Upper Limb Mean Power (from 7.2 to 8.3 W/kg with $p < 0.0001$) in the BA group (Fig. 1), when baseline and post-intervention values were compared.



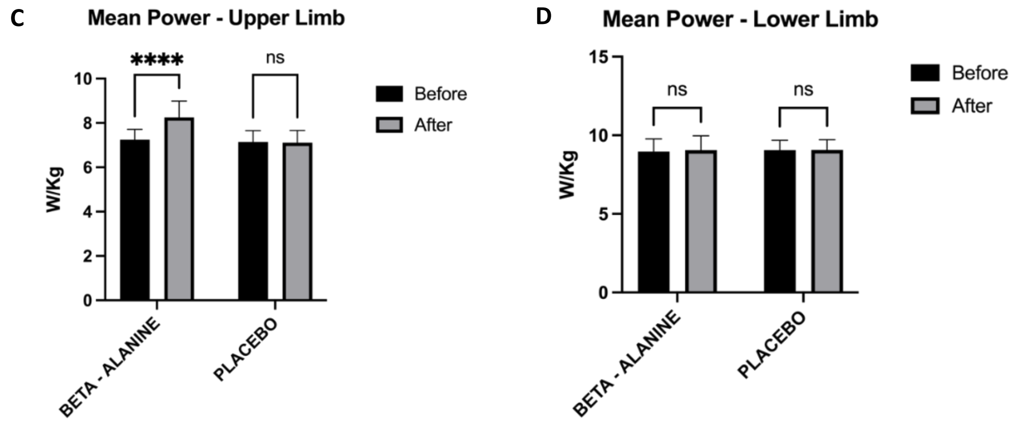


Fig. 1. Effects of BA or placebo supplementation on Total Work and Mean Power during Upper and Lower Wingate test.

By contrast, the Placebo group did not reveal any statistically significant results. There were no statistically significant differences in Lower Limb Mean Power when baseline and post-intervention values were compared in the BA and Placebo groups.

A significant increase in post-exercise LA concentration ($p = 0.0008$) and HCO_{3rest} concentrations ($p < 0.0001$) was observed.

Table 2. The differences in POST exercise blood plasma lactate concentration as well as the resting concentration of di-carbonate before and after BA ingestion in the BA and placebo groups.

Variables		BA group Mean ± SD	Placebo group Mean ± SD
LA_{max} (mmol/l)	before	15.52 ± 1.06	15.61 ± 0.44
	after	17.56 ± 1.04*	15.45 ± 0.94
HCO_3^- rest (mmol/l)	before	27.33 ± 0.07	27.11 ± 0.07
	after	28.86 ± 0.09*	27.06 ± 0.05

BA – beta-alanine; PLA – placebo; LAmax – maximal lactate concentration; HCO_3^- rest – di-carbonate concentration

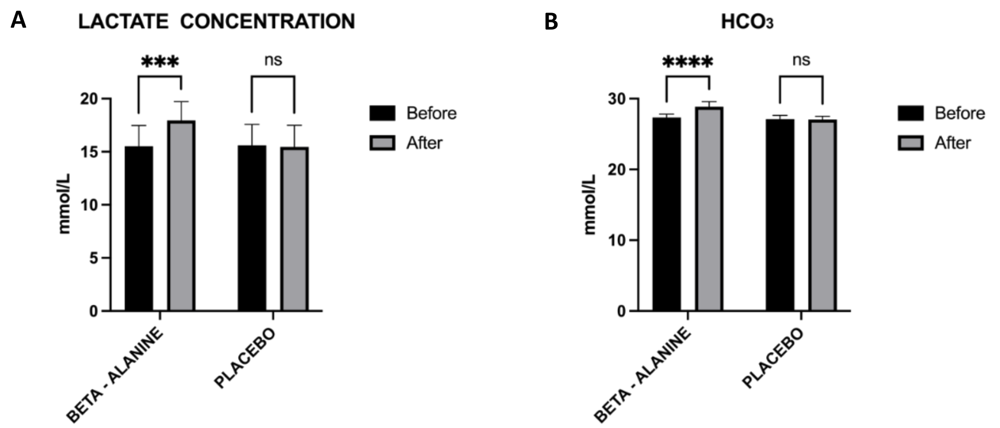


Fig. 2. Effects of BA or placebo supplementation on blood plasma lactate and di-carbonate concentration before and after intervention.

4. Discussion

The main purpose of this study was to investigate the effect of 4 weeks of chronic BA supplementation (in a dose of 4 g/day over the first 2 weeks and 6 g/day in the last 2 weeks) on performance during 2 trials of double 30s Wingate test for the upper and lower-limbs in highly-trained judo athletes. The results of the presented study indicate that the ingestion of BA supplementation significantly increased Lower and Upper Limb Total Work and Upper Limb Mean Power during the Wingate test between baseline and post-intervention measurements. However, the BA supplementation had no performance benefits on Lower Limb Mean Power when comparing baseline and post-intervention values. Additionally, there was a significant increase in LA and di-carbonate concentration between baseline and post-exercise measurements in the BA group. By contrast, in the placebo group no statistically significant differences were observed. Collectively, these outcomes indicated that chronic consumption of BA was effective in improving upper and lower body intermittent performance in highly-trained judo athletes.

Numerous previous studies analyzed the effectiveness of chronic BA intake on Wingate test performance in athletes [20–30], while only a few were conducted on martial art athletes [21, 24, 25]. Results of those studies present conflicting findings and indicated a positive [21] as well as a neutral effect of chronic BA supplementation [24, 25]. In only one study conducted on judo athletes, BA improved the Total Work in the Upper Limb Wingate test [21], which is in line with the current results, where significant improvement of lower (+19.8 J/kg) and upper limbs (+12.4 J/kg) anaerobic capacity was observed. The improvement in Total Work during the Wingate test in the presented study can be explained by ergogenic properties of BA associated with anaerobic endurance [26]. The positive impact of BA supplementation is related to the regulation of the acid-base balance [27], showing intracellular buffering capacity, which improves excitation-contraction processes in the muscle tissue [28]. It has been demonstrated that at least 4 weeks of BA supplementation may improve performance in sports characterized by a marked glycolytic demand [27, 29]. Indeed, the results of the present investigation showed an increased level of LA and di-carbonate between baseline and post-exercise values in the BA group. Therefore, it can be concluded that in the present study BA increased the buffer capacity of blood and tissues [11, 21, 30, 31] and, consequently, increased anaerobic capacity.

It is worth noting that the results of the presented study showed a significant effect of BA supplementation on Upper Limb Mean Power during the Wingate test, without performance benefits on Lower Limb Mean Power. Similarly, in studies conducted on boxers, BA supplementation did not improve Mean Power during the Upper Wingate test [24, 25] and the Lower Wingate test [24]. However, to the best of our knowledge, this is the first study, which evaluated the impact of BA supplementation on the combined Wingate test (upper and lower limbs) in elite martial art athletes. Interestingly, the athletes' sports level may have had an impact on the obtained results because the ergogenic effects of BA supplementation in highly trained athletes are less clear than in non-trained individuals [22]. It has been suggested that athletes might be less responsive to BA supplementation [32, 33]. Nevertheless, the results of this study may be important for elite judo athletes as they need to perform multiple high-intensity intermittent efforts to throw the opponent to the ground or to control him on the mat [34]. The approximate duration of judo combat is ~3 min, during which efforts of ~30 s are interspersed with ~10 s of rest intervals [35]; thus, the high intensity is a similar to the 30 s Wingate test [36] included in the current experiment.

There are some limitations of this study that must be indicated. First, the main limitation is the small number of participants (n=16). Second, our findings were limited only to males, and translating these findings to females should be made with caution. Therefore, further similar research should be conducted on females. Finally, in this study, we did not analyze the muscle tissue to confirm the efficacy of BA in increasing muscle carnosine. However, all previous studies [37–39] confirm the effectiveness of using a dose of 1.6–6.4 g BA daily for 4 weeks or more in increasing muscle carnosine by up to >40% [14, 27, 29, 37].

5. Conclusions

Results of the current investigation confirmed that chronic BA supplementation (in a dose of 4 g/day over the first 2 weeks and 6 g/day in the last 2 weeks) enhances high-intensity intermittent upper and lower-body performance in elite judo athletes. BA supplementation may be particularly useful for judo athletes, where high upper and lower body anaerobic capacity is needed. This investigation indicated the positive effect of long-term BA supplementation on performance in a sample of highly trained athletes.

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