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Research Article

The effect of beta-alanine supplementation and exhaustive activity on carnosine levels, pH, blood lactate and muscle strength of male judo athletes

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Abstract

Background: Beta-alanine supplementation is a precursor to carnosine, which increases intramuscular carnosine, and the buffering effect may reduce lactic acid accumulation and improve performance. This study investigated the effect of beta-alanine supplementation during exhaustive exercise on carnosine levels, pH, blood lactate, and muscle strength in male judoka athletes.

Materials and Methods: 20 judo athletes (mean age 23.26 ± 3.07, body mass index 23.12 ± 2.05) were purposively selected based on inclusion and exclusion criteria, and then the subjects were randomly divided into two groups of 10 people consuming beta-alanine and a placebo group. Performance testing and blood tests were performed before and after exhausting activity (chest press and leg press) with an intensity of 70 to 75% of 1RM in three sets until exhaustion in both groups. The day after the pre-test, supplementation and placebo were started at 6 grams per day at specified hours for 4 weeks, and the post-tests were re-evaluated after the end of the period. A statistical method was used via SPSS21 software. The Shapiro-Wilk test and covariance analysis with a significance level of 0.05 were used to analyze the data.

Results: There was no significant difference between the two groups of beta-alanine and placebo supplementation in performance indicators (P>0/05).

Conclusion: Co Finally, the results of the study showed that beta-alanine supplementation during the study period improved carnosine levels and reduced blood lactate levels after exhaustive exercise, and may have long-term beneficial effects on performance in professional male judokas.

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1. Introduction

Authorized sports supplements have become one of the most significant parts of athlete preparation for competition in recent years. The importance of increasing athletes' performance in competitive sports and approaching records in national and international competitions has made the use of authorized sports supplements one of the most important parts of an athlete's preparation for competition in recent years (1). During intense activity, muscle cells may consume energy more than 100 times, which exceeds the aerobic system's capacity; as a result, muscle cells tend to meet their energy needs from the anaerobic system at an increased rate. Although this system partially meets energy needs during intense activity, with continued activity, many factors such as the accumulation of metabolites and the decrease in substrate reserves of this system will lead to muscle fatigue and decreased performance (2). Meny physiological factors have been stated so far in understanding and justifying the function of this system, including acid-base balance, which seems significant. In such a way that the decrease in the energy output of the anaerobic system and the subsequent decrease in the athlete's performance are considered to be largely related to the decrease in the pH of the cell and its environment. Therefore, it seems that the use of methods that stabilize the acid-base balance of the cell can delay muscle fatigue, allowing the athlete to continue performing at a higher intensity and leading to functional development (3). Carnosine is an intracellular cytoplasmic dipeptide, composed of the two amino acids beta-alanine and L-histidine, found in high concentrations in invertebrate muscles and vertebrate skeletal muscles and is known as the first intracellular buffer (4).

Beta-alanine, in combination with the essential amino acid histidine, causes the formation of carnosine in muscle cells, which can greatly reduce acidosis caused by high-intensity exercise activities in muscles, especially fast-twitch muscle fibers. Overall, carnosine is a multifunctional dipeptide that has many roles such as buffering, fighting free radicals, regulating enzyme activity, and regulating sarcoplasmic reticulum calcium (5). Research shows that beta-alanine as a substrate can limit the carnosine synthesis pathway. Therefore, considering that beta-alanine is not produced in muscle, it has been of interest to athletes in disciplines that cause metabolic fatigue and acidosis (6). Judo is one of the most popular and competitive sports in the world. This sport consists of high-intensity activities and periods of light or moderate intensity activity with short rest periods. Judokas' ability to perform fast movements and explosive power leads to competition success. Anaerobic power and capacity are important for short-term high-intensity performance in this sport. At the start of competition, the body's metabolic process increases rapidly, causing the production of metabolites such as lactic acid. The accumulation of lactate following a judo match can reach more than 10-20 mmol/l, which can disrupt the pH balance and ultimately decrease the athlete's performance (7). Previous studies show contradictory results. For example, some studies have shown an increase in aerobic and anaerobic capacity in athletes, while others have shown the supplement to be ineffective. They have also reported inconsistent effectiveness in trained and untrained individuals. For example, Kim et al. (2018) investigated the effect of beta-alanine consumption on maximum power and blood lactate response in male boxers of the Korean national team.

It concluded that beta-alanine consumption can improve power and endurance and delay fatigue in athletes (8). Hosseinabadi et al. (2014) also reported that 8 weeks of pyramid training along with beta-alanine supplementation resulted in a significant increase in carnosine and muscle hypertrophy in non-athletic men (9). Alabsi et al. (2023) showed that four weeks of beta-alanine supplementation increased muscle carnosine and reduced fatigue in boxers (10). Halz et al. (2022) found no discernible difference in mean lower limb power between the beta-alanine and placebo groups, while a significant increase in lactate and bicarbonate concentrations was observed after exercise (11). On the other hand, Basinello et al. (2019) concluded that beta-alanine supplementation improves isometric strength but has no effect on isotonic and isokinetic strength in young people who perform recreational strength training (12). Dariush Sheikholeslami-Vatani et al. (2022) also reported that performing maximal repetitive activities leads to a significant increase in lactate, but short-term consumption of beta-alanine supplements at different doses has no effect on neuromuscular fatigue and blood lactate accumulation(13). Depletion of fuel reserves, production of free radicals due to oxidative stress, and the accumulation of several metabolites in the muscles, athletes turn to performance-enhancing drugs and supplements to gain an edge and reduce fatigue-inducing factors or enhance fatigue tolerance during sports competitions. For years, athletes have used beta-alanine and sports drinks that claim to delay or reduce fatigue. Therefore, its consumption as a dietary supplement with the aim of increasing the substrate for carnosine production and combating metabolic acidosis caused by activity, and consequently improving athletic performance and increasing resistance to fatigue, seems logical.

It seems that beta-alanine supplementation can improve judokas' athletic performance. Therefore, this study aims to determine the effect of four weeks of beta-alanine supplementation on judoka performance to determine whether this supplement can have an ergogenic effect on judoka performance by delaying fatigue.

2. Materials and Methods

The present study was an applied, quasi-experimental study with a pre-test and post-test design, in which the effect of beta-alanine supplementation and exhaustive exercise on carnosine, pH, blood lactate, and muscle strength levels in trained male judokas was studied in two groups, taking the supplement and placebo, in a double-blind manner. The statistical population of the present study consisted of elite judo athletes who had at least one history of attending the national judo team selection camp. This research is the result of a master's thesis and has been approved by the relevant university. After medical examinations and obtaining information about the complete health of the subjects, 20 athletes were selected in accordance with the inclusion and exclusion criteria of the study. They were randomly divided into experimental and control groups. Inclusion criteria included having at least one year of experience of being invited to the national judo team selection camp. In addition, there was absence of any pathological symptoms, history of fractures, surgery, or joint diseases in the lower limbs or spine in the past 5 years.

After identifying the research samples based on the inclusion and exclusion criteria and randomization, they were divided into two groups: beta-alanine supplement consumption (10 people) with an average age of 22.90 ± 2.31 years, height 176.37 ± 2.29 cm, and placebo consumption group (10 people) with an average age of 23.70 ± 2.87 years, height 178.66 ± 3.26 cm. Before the start of the exhaustive training, to measure the amount of carnosine, five cc of blood was taken from them 24 hours before the start of the training. This was done fasting. After the blood was taken, the subjects in the experimental group consumed packages containing beta-alanine supplements 6 grams, made by the GNC company and manufactured in the United States. The placebo group consumed packages containing roasted flour for 28 days. According to the research design, after one month, the groups began performing the exhaustive training protocol. They performed chest press and leg press movements in three sets with an intensity of 70 to 75% of one repetition maximum. This was done until reaching voluntary exhaustion. The rest between sets was 90 seconds and between movements was 3 minutes. It should be noted that the amount of weight and the number of repetitions were estimated through the Brzycki equation and the maximum number of repetitions was calculated. After completing the exhaustive training of the two groups, the post-test was also conducted, as in the pre-test. The nutritional status of the subjects was examined in the entry and exit criteria of the study. Those who used another supplement in parallel were excluded from the study. Also, the athletes fasted on the day of the study. After the initial blood draw and before the exercise start, only one banana was given to all athletes.

Statistical analysis

Data analysis was performed using SPSS version 21 software. The significance level was set at 0.05. The Shapiro-Wilk test was performed to check the normality of the data distribution, and the Levene test was employed to check the equality of variances between groups. The interaction effect of pre-test and independent variable data was calculated using F by analysis of covariance, and the analysis of covariance (ANCOVA) test was applied to determine the difference between the post-test scores of the experimental and control groups.

3. Results

Data analysis showed that the distribution of pre and post-test data in both control and experimental groups was normal and natural, and the variance of pre and post-test data was equal between the control and experimental groups. The homogeneity of the variance of the dependent variable scores was examined using Levine's test. Finally, the test of the same slope of the regression line was evaluated by analyzing the absence of interaction between the covariance and independent variables. Considering the establishment of the covariance test assumptions, this test was used to examine the difference in post-test scores between the control and experimental groups. Table 1 reports test results the results of the covariance analysis showed that after controlling for the effect of the pre-test (covariate), no significant difference was observed in blood pH, muscle power, maximum wrist strength, pectoralis major muscle, and quadriceps femoris between the two groups ($P<0.05$).

However, plasma carnosine levels ($p=0.001$) were significantly higher in the experimental group than the control group. Blood lactate levels ($p=0.035$) were significantly lower in the experimental group than the control group.

Table 1. Results of the analysis of covariance test to examine between-group differences.

Variable	Placebo		Supplement		F	P	Effect size
	Pre-test	Post-test	Pre-test	Post-test			
Carnosine Mol/kg	٤٤,٦ ±٥٤,٠	٢٣,٦ ±٥٧,٠	۵۶/۶ ۵۲/۰±	۶۰/۰±۶۰/۸	۵۸/۱۹	*۰۰۱/۰	۹۱۸/۰
Lactic acid (mg/dL)	٢٥,٥٠ ±١٧,٦	٦١,٦٢±٠٥,١	± ۱۲/۷ ۸۵/۵۱	۵۴/۱±۸۲/۶۰	۲۶۲/۵	*۰۳۵/۰	۲۳۶/۰
Ph	٨ ± ٠٨,٠	٧٦,٧±٢,٠	±۹۸/۷ ۱۰/۰	۸۱/۰±۸	۹۲۱/۲	۱۰۶/۰	۱۴۷/۰
Claw strength (kg)	۳۰/۷۰ ± ۱۰/۱	۸۰/۶۹ ± ۲۲/۱	±۵۰/۷۲ ۳۸/۱	۲۰/۱ ±۳۰/۷۱	۰۰۹/۰	۹۲۵/۰	۱۵۱/۰
Chest press (kg)	٦٠,٨٩±٤٣,١١	٣٠,٩٧±٩٠,١١	۵۱/۱۵±۹۲	۰۷/۱۸ ±۳۰/۹۷	۰۳۹/۰۱۱	۸۴۵/۰	۰۰۲/۰
Squat (kg)	٣٠,١٢٧±٨٧,٣١	٧٠,١١٧±٦٠,٣٣	۵۹/۱۸±۷۰/۱۱۱	۸۶/۱۷± ۸/۱۰۱	۴۰۱/۰	۵۳۵/۰	۰۲۳/۰
P<0.05							

4. Discussion

The aim of the present study was to investigate the effect of one session of exhaustive exercise and beta-alanine supplementation on blood carnosine, pH, and lactate levels and pectoralis major and quadriceps muscle strength in male judokas. The results showed that only significant differences were observed in blood carnosine and lactate levels between the two groups. However, no significant differences were observed in upper and lower limb muscle strength and pH levels between the experimental and control groups. These results were consistent with Sanders et al. (2016) [14], Lilly et al. (2014) [15], Carpentier et al. (2015) [16], Dianati et al(2024) [5], gholami et al(2022) [17], Gharaat et al(2020) [18] ., Kim et al. (2018) [8] , Alabsi et al. (2023) and were not consistent with Sheikholeslami et al (2016). Matthew 19 et al. (2018) [19], Solis et al. (2015) [20], Halls et al(2022)., Zare et al(2021) [21], Donovan et al. (2022) [22]. Rahmanpour et al. (2016) [23]. Studies have shown that beta-alanine supplementation enhances muscle carnosine levels, elevates the anaerobic threshold, and delays fatigue [24]. Carnosine enhances exercise performance by enhancing muscle buffer capacity, calcium release, and improving troponin c sensitivity to calcium ions in muscle fibers [25]. In addition, these studies have also demonstrated that muscle acidosis contributes to fatigue during intense exercise. Increased carnosine concentrations theoretically boost intracellular buffer capacity, delaying fatigue. This could explain the ergogenic effect of beta-alanine supplementation on exercise, which induces **hydrogen ion** formation and muscle acidosis [26]. Beta-alanine supplementation can increase intracellular **hydrogen ion** buffering capacity and improve lactate excretion from muscles. (27).

Black et al. (2018) examined the effect of beta-alanine supplementation for 28 days on muscle pH and muscle power during high-intensity exercise and concluded that beta-alanine supplementation had no significant effect on muscle carnosine levels, intramuscular pH, and performance during high-intensity exercise; although it prevented a decrease in blood pH and improved performance by about 2 to 3% during circuit training, these changes were not statistically significant [19]. There were also large individual differences in muscle carnosine levels in response to beta-alanine intake. The most prominent reasons for differences between studies are the different doses and strategies used in beta-alanine intake (28). Lily et al. (2014) concluded in their review that beta-alanine supplementation for even 2 weeks can lead to increased muscle carnosine levels, which in turn can lead to improved athletic performance [15]. However, since carnosine is probably synthesized in muscles and other tissues from the amino acid alanine-histidine and carnosine synthetase, and since this enzyme has a higher affinity for histidine, and the concentration of histidine in trained muscles is higher than that of alanine, it is clear that carnosine synthesis is greater in the presence of beta-alanine, as a combination of both enzymes is found in trained muscles [8]. Previous studies have shown that in high-intensity exercise, the increase in carnosine is through an increase in the number of actin and myosin contractile proteins and ultimately the optimal action potential, while this increase in carnosine in long-term and continuous resistance exercise is due to the stimulation of muscle fiber recruitment [29]. Therefore, the increase in carnosine levels in the muscles of the subjects in the present study can be attributed to their history of resistance training (at least one year) and stimulation of muscle fiber recruitment, as well as beta-alanine consumption.

The present study was consistent with Matthew Blake et al. (2018) Sheikholeslami-Vatani et al. (2015), Kim et al. (2018), and Munoz et al. (2018) [30] regarding the effect of beta-alanine supplementation on athletes' strength, and inconsistent with Jamshidi Hosseinabadi et al. (2016), and Basinlo et al. (2019).

The reasons for the discrepancy between the results of these studies and the results of the present study can be attributed to the samples tested. These reasons include the method and dosage of beta-alanine supplementation, and the tests used for evaluation. Smith et al. (2012) examined the effect of 8 weeks of beta-alanine supplementation during high-intensity exercise on neuromuscular fatigue, peak strength, body composition, and hypertrophy. At the end of 8 weeks, no changes were observed in body composition and muscle hypertrophy. [31] Kim et al. (2018) concluded that beta-alanine consumption improves strength and endurance.

Black et al. (2018) concluded that beta-alanine supplementation did not significantly affect high-intensity exercise performance. Performance increases were around 2–3% during exercise, but these changes were not statistically significant. Van et al. (2009) examined 10 weeks of beta-alanine supplementation along with resistance training on peak strength, fat mass index, and hypertrophy. At the end of 10 weeks, no changes were observed in peak strength in squats and bench presses. In addition, no changes were observed in fat mass index (2). According to the results of the present study, beta-alanine supplementation only improved blood carnosine and lactate levels and had no effect on pH or strength of the hand and wrist muscles. The explanation given above regarding the lack of an increase in muscle strength and increased hypertrophy is consistent with the study.

The mechanism of hypertrophy changes and strength increases with beta-alanine supplementation and resistance training is unclear. Regarding the findings of the present study, it can be admitted that it is probably due to the fact that beta-alanine supplement is an amino acid and the structure of skeletal muscles is composed of amino acids, and the carnosine present in the supplement as an enzyme helps boost protein synthesis in skeletal muscles and maintain it, and the absorption of beta-alanine in muscles is through intracellular amino acid chloride and sodium transporters. The beta-alanine transport mechanism increases energy metabolism and cellular motility, and subsequently enhances the levels of contractile proteins actin and myosin, which causes muscle hypertrophy. Also, the presence of histidine plays a vital role in protein synthesis in the liver and in sports activities and resistance training that require coordination of neuromuscular parts, as a transmitter of nerve messages from the myelin sheath, and enhances concentration and reduces fatigue, improving training volume and adaptability in resistance training. These adaptations and increased training volume maintain glycogen stores and enhance protein levels in the muscles (32-35). This function in continuous and long-term training creates adaptation to physiological conditions and muscle hypertrophy, followed by improved strength (5,8,10). Therefore, one of the main reasons that may have contributed to the lack of effect of beta-alanine supplementation on athletes' strength in the present study is the initial fitness level of the subjects in the results, because people with lower fitness levels achieve faster adaptations, since in the present study, the subjects had a high level of fitness.

Conclusion

In general, it seems that performing exhaustive training in male judo athletes, such as in real competition or training conditions, may increase the physiological stress caused by training pressure and cause an increase in metabolic metabolites without sufficient return to the initial state, and subsequently result in a decrease in athletes' performance. Overall, based on the results of this study, it can be said that beta-alanine supplementation improved carnosine levels and reduced blood lactate levels, and may have beneficial effects on improving recovery and delaying fatigue in male judokas. Since at high levels of sports competitions, the difference between champion teams or elite athletes is very small, even a small influential factor may determine the outcome of a sports competition. Considering the background and results, it is suggested that further research into beta-alanine supplementation be investigated over a longer period of time to obtain more useful and complementary information. Therefore, male judokas should use appropriate nutritional strategies before competition or training to maintain optimal performance levels and prevent performance decline. Therefore, synergistic use of these supplements is recommended.

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Compliance with ethical standards

Conflict of interest None declared.

Ethical approval the research was conducted with regard to the ethical principles.

Informed consent Informed consent was obtained from all participants.

Author contributions

Conceptualization: R.B, A.A; Methodology: R.B, A.A; Software R.B, A.A ; Validation: R.B, A.A ;Formal analysis: R.B, A.A ;Investigation: R.B, A.A; Resources: R.B, A.A : curation: R.B, A.A; Writing - original draft: R.B, A.A; Writing - review & editing: R.B, A.A; Visualization: R.B, A.A; Supervision: R.B, A.A ;Project administration: R.B, A.A; Funding acquisition: R.B, A.A.

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