



Major clinical findings of β -alanine in sports performance: a systematic review

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DOI: <https://doi.org/10.54448/ijn22205>

Received: 02-11-2022; Revised: 04-25-2022; Accepted: 04-26-2022; Published: 05-25-2022; IJN-id: e22205

Abstract

Introduction: Dietary supplements offer ergogenic aid in an attempt to increase energy, improve recovery and modulate body composition, enabling improved performance. Thus, β -alanine is a substrate of carnosine and is becoming an ergogenic aid for sports performance. **Objective:** To carry out a systematic review to highlight the main scientific evidence on the improvement of sports performance with the use of β -alanine. **Methods:** The PRISMA Platform rules were used. The research was developed using the SCOPUS, PUBMED, and SCIENCE DIRECT databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** Studies have shown that β -alanine has an important ergogenic role in sports performance. Weeks of beta-alanine supplementation (4-6g per day) significantly increases muscle carnosine concentrations. The only side effect reported is paresthesia. Beta-alanine attenuates neuromuscular fatigue, particularly in older individuals. Also, combining beta-alanine with other supplements can be advantageous when beta-alanine supplementation is high enough (4-6 g per day) and long enough (minimum 4 weeks).

Keywords: Beta-alanine. Athletes. Performance. Carnosine. Antioxidant.

Introduction

Many of the established positive health benefits of exercise have been documented by historic discoveries in the field of exercise physiology. These investigations generally assess performance thresholds or exercise-induced health benefits [1]. Thus, several important

findings were informed by the study of highly trained athletes. Recent progress has been made regarding skeletal muscle metabolism and personalized exercise regimens [1]. In this context, regular physical training added to dietary supplements has broad health benefits by acting positively on almost all organ systems of the body [2].

In this sense, dietary supplements offer ergogenic aid in an attempt to increase energy, improve recovery and modulate body composition, enabling improved performance [3,4]. Thus, β -alanine (Beta-alanine) (BA) is a non-essential amino acid that can be synthesized in the liver and obtained from the diet, particularly from white meat (poultry and fish) and red meat [5]. endogenous BA derives from the degradation of the pyrimidines thymine, cytosine, and uracil and its transport to skeletal muscle are dependent on sodium and chloride ions [6,7].

Despite this, the entry of BA into cells can be affected by compounds of similar structures (glycine, taurine, gamma-aminobutyric acid) that compete for the same transporter [6]. It is in the skeletal muscle that BA develops its role as an intermediary for the synthesis of carnosine, which is a dipeptide (histidine and BA) responsible for reducing fatigue and buffering the muscles against acidosis [8-11].

Furthermore, the muscle carnosine content is also influenced by muscle contraction and increases with muscle tension [12]. Thus, increasing the availability of BA through dietary supplementation, combined with training, can improve the performance of athletes who perform high-intensity exercise, through increased muscle buffering capacity (acidity reduction) [13-16]. In this regard, the supplementation time between studies seems to vary generally between 4 to 10 weeks and the doses are distributed throughout the day,

making the effect of BA supplementation on exercise still controversial [14,17].

In this scenario, the International Association of Athletics Federations recognizes the importance of nutritional practices in optimizing an athlete's well-being and performance. In this regard, periodized guidelines can be provided for the appropriate type, amount, and timing of food and fluid intake to promote optimal health and performance in different training and competition settings. Thus, the use of medical supplements to address nutrient deficiencies or sports foods to help the athlete achieve nutritional goals is notorious. The most common examples of supplements are caffeine, bicarbonate, beta-alanine, nitrate, and creatine. Special considerations are required for travel, challenging environments (eg heat and altitude); special populations (eg women, youth athletes, and masters); and restricted dietary choice (eg, vegetarian). Ideally, each athlete should develop a personalized, periodized, and practical nutritional plan, in collaboration with their coach and accredited sports nutrition experts, to optimize their performance [18].

Therefore, due to the well-defined role of β-alanine as a substrate for carnosine, and the fact that β-alanine is becoming an ergogenic aid for sports performance, the present study carried out a systematic review to highlight the main scientific evidence on the improvement of sports performance with the use of β-alanine.

Methods

Study Design

The present study followed the systematic review model according to the PRISMA Platform (Transparent reporting of systematic reviews and meta-analysis-[HTTP://www.prisma-statement.org/](http://www.prisma-statement.org/)) [19].

Data Sources and Research Strategy

The search strategies for this systematic review were based on the keywords (MeSH Terms): "*Beta-alanine; β-alanine; L-histidine; athletes; Performance; Muscle acidosis; carnosine; antioxidant*". The research was developed using the SCOPUS, PUBMED, and SCIENCE DIRECT databases, including the National Institutes of Health RePORTER Grant database and clinical trial registries. In addition, a combination of the keywords with the Booleans "OR", AND, and the "NOT" operator were used to target scientific articles of interest. Title and abstracts were examined under all conditions.

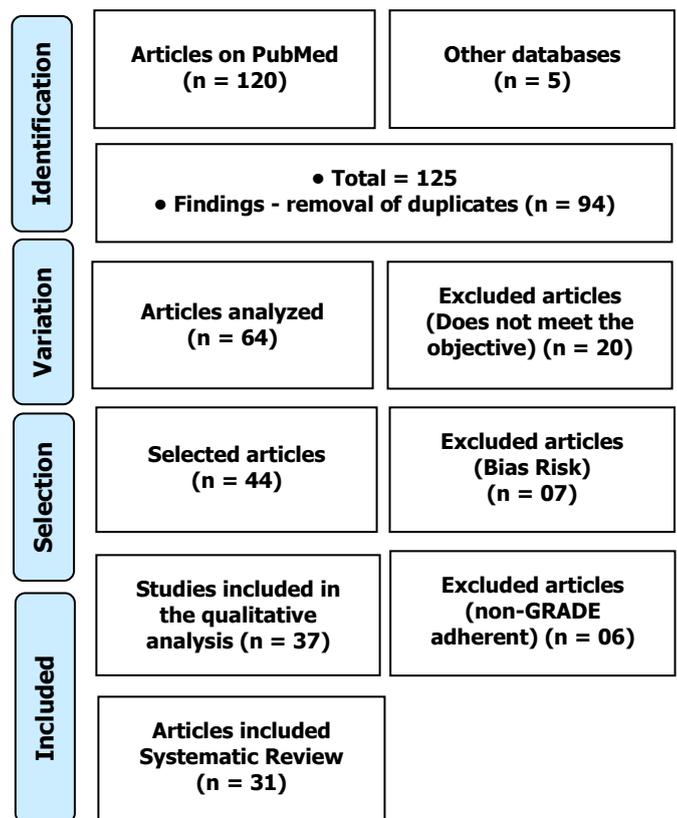
Study Quality and Risk of Bias

The quality of the studies was based on the GRADE instrument [20] and the risk of bias was analyzed according to the Cochrane instrument [21].

Results and discussion

A total of 125 articles were found involving the use of β-alanine to increase the performance of athletes. Initially, article duplication was excluded. After this process, the abstracts were evaluated and a new exclusion was performed, removing the articles that did not cover the theme of this article. In total, 64 articles were fully evaluated and 31 were included and evaluated in the present study (Figure 1). After analyzing the thirty-one (31) articles on the main findings of the use of BA, it was found that most of the articles analyzed presented important scientific quality, according to the rules of GRADE. The main risks of bias were related to the number of participants in each study, as well as the dosage and duration of BA use.

Figure 1. Eligibility of studies.



As a corollary of scientific development, the International Society of Sports Nutrition (ISSN) has shown that four weeks of beta-alanine supplementation (4-6g per day) significantly increases muscle carnosine concentrations. Also, beta-alanine supplementation currently appears to be safe in healthy populations at

recommended doses, however, the only reported side effect is paresthesia, but studies indicate that this can be alleviated using smaller divided doses (1.6 g) or using a sustained release formula. In addition, daily supplementation with 4 to 6 g of beta-alanine for at least 2 to 4 weeks has been shown to improve exercise performance, with more pronounced effects in open-ended/time trial tasks lasting 1 to 4 minutes. Beta-alanine attenuates neuromuscular fatigue, particularly in older individuals, and preliminary evidence indicates that beta-alanine may improve tactical performance. Also, combining beta-alanine with other supplements can be advantageous when beta-alanine supplementation is high enough (4-6 g per day) and long enough (minimum 4 weeks) [22].

In this setting, an eight-week randomized double-blind crossover study aimed to verify the effect of BA intracellular versus extracellular buffering agent supplementation (alkaline-ALK agents) combined with the usual treatment of branched-chain amino acids (BCAAs) and creatine malate (CM) under natural training conditions. Thirty-one elite athletes (11 sprinters and 20 endurance athletes) participated in the study. After BA-ALK-BCAA and CM supplementation, the total fat-free mass increased in sprinters. No other differences were found in body composition, respiratory parameters, aerobic capacity, blood lactate concentration, and hematological indices after supplementation with BA-ALK-BCAA and TCM/ALK-BA-BCAA and CM. Maximum post-exercise blood ammonia concentration (NH₃) decreased in both groups after supplementation with BA-ALK-BCAA and CM. In addition, lower concentrations of NH₃ were observed in endurance athletes in the post-exercise recovery period. Thus, the results of our study indicate that combined BCAA, CM, and BA supplementation is more effective than combined BCAA, CM, and ALK supplementation for an increase in fat-free mass and exercise adaptation, but not for improvement of aerobic capacity [23].

In this context, despite the widespread use of BA, understanding of potential adverse effects is limited. Thus, a systematic study and risk assessment meta-analysis was performed. In total, 101 human and 50 animal studies were included. Paresthesia was the only side effect reported and had an estimated OR of 8.9 with supplementation versus placebo. β -alanine supplementation in animals caused a small increase in circulating alanine aminotransferase concentration, although the mean data remained within the clinical reference ranges. Meta-analysis of human data showed no main effect of β -alanine supplementation on skeletal muscle taurine or histidine concentration. Therefore,

the results indicate that β -alanine supplementation did not adversely affect [24].

Furthermore, a randomized, double-blind, placebo-controlled study investigated the influence of β -alanine supplementation during a high-intensity interval training (HIIT) program on repeated sprint (RSA) skill performance. Eighteen men performed an incremental run-to-exhaustion (IRTE) test at baseline and followed by a 4-week HIIT (10 \times 1 min runs 90% of maximum IRTE speed [1-minute recovery]). Then, participants were randomized into two groups and performed a 6-week HIIT plus supplementation of 6.4 g/day of β -alanine (BA) or dextrose (placebo group). The results showed that BA supplementation during HIIT increased muscle carnosine and attenuated neuromuscular fatigue, which may contribute to an RSA performance enhancement. Furthermore, the improvement in muscle carnosine content induced by β -alanine supplementation may have contributed to an attenuation of central fatigue during repeated sprints [25].

Also, to sarcopenia, increased systemic carnosine levels may result in increased antioxidant, neuroprotective, and pH buffering capabilities. Thus, a study of twelve healthy adults (mean age = 60.5 \pm 8.6 years, weight = 81.5 \pm 12.6 kg) was randomized and received 2.4 g/d of β -alanine (BA) or Placebo (PL) for 28 days. As a result, BA supplementation increased exercise capacity and eliminated resistance exercise-induced declines in executive function observed after recovery. Similar PRE vs POST lactate production indicates an improvement in the BA's ability to extend exercise duration [26].

Furthermore, a systematic review and meta-analysis study analyzed the effects of BA supplementation on exercise capacity and performance. A total of 40 individual studies employing 65 different exercise protocols and totaling 70 exercise measures in 1461 participants were included in the analyses. Meta-regression demonstrated that exercise duration significantly moderated effect sizes. Subgroup analyses also identified exercise type as a significant moderator of effect sizes within a 0.5-10 min exercise period, with larger effect sizes for exercise capacity versus performance. There was no moderating effect on training status, intermittent or continuous exercise, or the total amount of BA ingested. Furthermore, co-supplementation with sodium bicarbonate resulted in the largest effect size when compared to placebo [27].

In addition to these findings, recent evidence suggests that high levels of carnosine can improve cognitive performance and increase stress resilience.

These benefits are believed to result from carnosine's potential role as an antioxidant [28]. Also, a review study analyzed the available evidence on supplementation optimization, the link between beta-alanine and exercise performance, and the ergogenic mechanism. The factors that determine the loading process, as well as the mechanism of the ergogenic effect, are still debated. Based on its biochemical properties, several functions are attributed to carnosine, of which the intramuscular pH buffer and the calcium regulator are the most cited. In addition, carnosine has antiglycation and antioxidant properties, suggesting that it may have the therapeutic potential [29].

Another review study explored the use of BA supplementation as an ergogenic aid to improve performance and fatigue resistance in athletes and non-athletes. Twenty-three studies were selected. Most of them included physically active individuals. The mean intervention period was 5.2 ± 1.8 weeks, and the mean dose of BA was 4.8 ± 1.3 g/day. BA supplementation seems to improve the perception of exertion and the biochemical parameters related to muscle fatigue [30].

Besides, one study looked at whether BA supplementation could attenuate acidosis and improve judo performance. Twenty-three highly trained judokas were randomly assigned to receive either BA (6.4 g/day) or placebo (dextrose, same dosage) for 4 weeks. BA supplementation improved the number of pitches per series and the total number of pitches. Placebo did not change these variables. Blood pH and HCO_3^- decreased after exercise, with no differences between groups. However, lactate response to exercise increased in the BA group compared to placebo [31].

Furthermore, a randomized, placebo-controlled (P) study with thirty-three male soccer players analyzed the effects of creatine © and creatine plus beta-alanine (CBA) on strength, power, body composition, and endocrine changes during a training program. of 10 weeks resistance. Changes in lean body mass and body fat percentage were greater in CBA compared to C or P. Significantly greater strength improvements were observed in CBA and C compared to P. Therefore, the results demonstrate the effectiveness of creatine and creatine plus beta-alanine in strength performance. Furthermore, creatine and beta-alanine supplementation appear to have the greatest effect on lean tissue accumulation and body fat composition [32].

Moreover, another meta-analysis study showed that BA improved the outcome of exercise measures to a greater extent than placebo. Following the claimed mechanisms for an ergogenic effect of BA

supplementation, exercise lasting 60-240 s was improved in BA compared to placebo, as was exercise lasting longer than 240 s. However, no benefit of BA was observed in exercises lasting <60 s [33].

Finally, carnosine plays an important role in exercise performance and skeletal muscle homeostasis. Dietary supplementation with the rate-limiting precursor of BA leads to an increase in skeletal muscle carnosine content, which further potentiates its effects. Physiological roles in human skeletal muscle include acting as an intracellular pH buffer, modulating energy metabolism, regulating Ca handling and myofilament sensitivity, and eliminating reactive species. New evidence shows that carnosine can also act as a cytoplasmic Ca-H exchanger and form stable conjugates with exercise-induced reactive aldehydes [34].

Conclusion

Studies have shown that β -alanine has an important ergogenic role in sports performance. Weeks of beta-alanine supplementation (4-6g per day) significantly increases muscle carnosine concentrations. The only side effect reported is paresthesia. Beta-alanine attenuates neuromuscular fatigue, particularly in older individuals. Also, combining beta-alanine with other supplements can be advantageous when beta-alanine supplementation is high enough (4-6 g per day) and long enough (minimum 4 weeks).

Acknowledgement

Not applicable.

Funding

Not applicable.

Ethics approval

Not applicable.

Informed consent

Not applicable.

Data sharing statement

No additional data are available.

Conflict of interest

The authors declare no conflict of interest.

Similarity check

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