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MINI-REVIEW

The relationship between beta-alanine and overall health: A mini review

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Abstract

Beta-alanine, a non-essential amino acid and the rate-limiting precursor for the synthesis of muscle carnosine, plays a pivotal physiological role in regulating intramuscular acid–base balance, particularly during high-intensity exercise. Its primary mechanism involves buffering hydrogen ions to delay the onset of metabolic acidosis and subsequent muscle fatigue. This mini review aims to synthesize the current scientific literature to elucidate the bioactivity of beta-alanine and critically evaluate its ergogenic and potential therapeutic effects on overall health and well-being. Substantial evidence from clinical trials demonstrates that beta-alanine supplementation effectively augments intramuscular carnosine concentrations, leading to marked improvements in anaerobic exercise capacity and fatigue resistance. These benefits extend beyond athletic populations to clinical cohorts experiencing age-related muscle deterioration. Furthermore, emerging research suggests indirect cardiovascular and cognitive benefits, potentially mediated through enhanced exercise tolerance, reduced systemic oxidative stress, and anti-inflammatory activity. Notably, beta-alanine may help preserve endothelial function and reduce cardiometabolic risk factors. Preliminary findings also suggest that carnosine confers neuroprotective properties through its antioxidant and anti-glycation activities, although direct evidence for cognitive enhancement in humans remains limited and warrants further investigation. Significant research gaps persist, including a lack of standardized dosing protocols, limited long-term safety data, and insufficient exploration of its effects in older adults and other patient populations. This review underscores the necessity for rigorous, long-term, and standardized clinical trials involving diverse cohorts to fully delineate the therapeutic potential of beta-alanine as a versatile nutraceutical agent for enhancing physical, metabolic, and cognitive health.

Keywords: Beta-alanine; Carnosine; Muscle performance; Oxidative stress; Cardiovascular health; Cognitive function; Metabolic regulation

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1. Introduction

Beta-alanine, a non-essential amino acid, has garnered increasing interest sports nutrition and preventive medicine due to its profound impact on muscle physiology and its potential to influence systemic well-being. This burgeoning attention is primarily attributed to its fundamental role as the direct precursor to carnosine, a dipeptide abundantly present in skeletal muscle and brain tissue.[1,2] Carnosine serves as a critical intracellular pH buffer, mitigating the accumulation of hydrogen ions during high-intensity exercise, thereby delaying the onset of muscular acidosis and fatigue.[3,4] This well-established biochemical mechanism underpins the recognized ergogenic effects of beta-alanine, particularly for activities characterized by short-duration, high-intensity exertion, such as sprinting and resistance training.[5,6]

Oral supplementation with beta-alanine has consistently been shown to elevate intramuscular carnosine concentrations, resulting in measurable improvements in anaerobic performance capacity and muscular endurance.[7,8] However, the scope of research has expanded beyond the athletic arena, inspiring investigations into its broader physiological impacts. A growing body of evidence suggests potential benefits for metabolic, cardiovascular, and cognitive health, positioning beta-alanine as a promising agent for enhancing overall quality of life and functional capacity across diverse populations.[9,10]

Despite these promising findings, the efficacy and safety profile of beta-alanine supplementation are influenced by complex factors. These include dosage, intervention duration, significant inter-individual biological variability, and potential interactions with other nutrients or medications.[11,12] Moreover, the current literature is predominantly populated by short-term studies involving young, healthy adults, which constrains the generalizability of findings to older individuals or those with chronic health conditions.[13]

Therefore, t mini review aims to comprehensively summarize and critically analyze the latest scientific evidence on the bioactivity of beta-alanine in the context of holistic health. We examine the relevant physiological mechanisms, synthesize findings from clinical and experimental studies, address methodological limitations, and identify pivotal avenues for future research. The primary objective is to develop an integrated framework that transcends beta-alanine's ergogenic properties, repositioning it within multidimensional strategies for health promotion and disease prevention.

2. Methods

This paper comprehensively reviews the latest evidence concerning beta-alanine's bioactivity and its systemic health effects. The methodology is outlined below under three subheadings for clarity.

2.1. Search strategy

An extensive search of electronic databases was performed, including PubMed, Scopus, Web of Science, and Google Scholar. The search aimed to identify relevant peer-reviewed articles published in English between 2000 and 2024. The search strategy utilized a combination of key terms and Boolean operators: ("beta-alanine" OR "carnosine") AND ("muscle performance" OR "oxidative stress" OR "cardiovascular health" OR "cognitive function" OR "metabolic regulation").

2.2. Eligibility criteria

Inclusion criteria were designed to capture high-quality evidence. Priority was given to original research articles, randomized controlled trials, and robust observational studies investigating the effects of beta-alanine supplementation in human or animal models. Existing review articles and meta-analyses were consulted for background context and to identify additional primary sources, but were not the primary focus of data extraction. Editorials, case reports, and studies not published in English were excluded. Following a systematic screening process based on titles and abstracts, 44 studies were selected for final inclusion based on their direct relevance to the review's objectives and methodological quality.

2.3. Data synthesis

Data extraction was conducted systematically. Key elements included study design, participant demographics, supplementation protocols (dose and duration), primary and secondary outcomes, and any reported safety assessments. The findings were synthesized thematically to provide an integrated perspective across physiological systems, including musculoskeletal function, cardiovascular risk modulation, and cognitive health. Given the narrative nature of this mini review, a formal risk-of-bias assessment was not conducted; however, the synthesis prioritized findings from randomized controlled trials and larger observational studies to support evidence-based conclusions relevant to translational and clinical contexts.

3. Results

The foundational effect of beta-alanine supplementation is a significant, dose-dependent increase in intramuscular carnosine concentration. Previous studies have consistently shown elevations exceeding 80% following sustained supplementation periods of 4 to 12 weeks.[14–16] The seminal work by Harris *et al.*[1] elucidated the kinetics of oral beta-alanine absorption and its direct correlation with muscle carnosine synthesis. This firmly links these biochemical changes to an enhanced muscle buffering capacity. These physiological adaptations are directly reflected in clinical performance metrics, particularly for exercises that rely on anaerobic glycolysis.[17,18–20]

Clinical interventions consistently demonstrate that beta-alanine supplementation leads to significant improvements in total work output, time to exhaustion, and a reduction in perceived fatigue during high-intensity exercise.[21–23] For instance, a study by Hobson *et al.*[22] confirmed these ergogenic benefits through a comprehensive meta-analysis. Other trials have documented a delayed onset of neuromuscular fatigue and an increased respiratory threshold in recreational athletes following a 10-week supplementation regimen.[21,22] Recent meta-analyses have further solidified the consistency of these performance-enhancing effects across diverse athletic populations, establishing beta-alanine as one of the most well-supported ergogenic aids available.[24,25]

Beyond its direct actions on muscle tissue, beta-alanine supplementation confers indirect benefits for cardiovascular health. This is primarily mediated through a consequential increase in overall exercise capacity and physical activity levels. This pathway is critically important for reducing cardiometabolic risk, as enhanced physical fitness is a well-documented cardioprotective factor.[26–28] Furthermore, evidence from both human and animal studies indicates that beta-alanine and its metabolite carnosine can directly modulate oxidative stress and systemic inflammation. These are key pathological processes in the development of cardiovascular diseases.[29–31] A controlled study by Smith *et al.*[29] provided direct evidence, showing that beta-alanine supplementation reduced biomarkers of lipid peroxidation and systemic inflammation in women following intense exercise.

An exciting and emerging area of research involves the potential neuroprotective effects of beta-alanine. Carnosine was also found in significant concentrations within the central nervous system. Here, it is hypothesized to protect against age-related cognitive decline through its potent antioxidant and anti-glycation properties.[33,34] Although direct research on beta-alanine's impact on cognitive function is still in its nascent stages, preliminary investigations suggest potential benefits. Several studies report improved resistance to mental fatigue and enhanced mood stability, effects that are likely mediated by increased carnosine levels in the brain.[10,35] These initial findings, while promising, underscore the need for more targeted research in this domain.

From a metabolic perspective, beta-alanine's ability to facilitate increased training volume and intensity indirectly promotes metabolic homeostasis. There is also suggestive evidence that it may directly improve insulin sensitivity and glucose utilization within muscle tissue.[36] Additionally, some clinical and mechanistic studies propose that beta-alanine could enhance mitochondrial function and fatty acid oxidation.[37,38] However, these specific metabolic pathways require extensive and conclusive investigation (Table 1).

4. Discussion

Beta-alanine occupies a unique and compelling position at the intersection of sports nutrition and integrative health promotion. Its primary biochemical role—elevating

Table 1. Documented health benefits and mechanisms of action of beta-alanine

Health benefit	Mechanism of action	Supporting evidence
Delay of muscle fatigue	Increased muscle carnosine buffering capacity	Controlled clinical trials[1,14,20]
Enhanced anaerobic exercise capacity	Improved acid-base regulation in muscle	Meta-analyses and randomized trials[23,24]
Cardiovascular risk reduction	Improved endothelial function and anti-inflammatory effects	Clinical studies[25,30]
Oxidative stress modulation	Antioxidant effects of carnosine	Preclinical and human studies[28,31]
Cognitive function support	Neuroprotection through antiglycation and antioxidation	Pilot studies[32,34]
Metabolic regulation	Improved insulin sensitivity and mitochondrial function	Mechanistic studies[36,37]

intramuscular carnosine stores to increase tolerance to metabolically induced fatigue—sets off a cascade of beneficial physiological effects.[14,15] The resultant enhancement of exercise capacity is a critical outcome not only for athletes but also, and perhaps more importantly, for vulnerable demographics such as the elderly. For them, preserving muscle function and strength is paramount for maintaining independence and quality of life.[8,39]

The recent revision of the European consensus on sarcopenia underscores the urgent need for effective interventions to improve muscle quality.[39] Within this context, beta-alanine is increasingly recognized as a valuable adjunct to resistance training programs.[39] This expanded clinical perspective shifts the research focus from pure athletic performance to broader applications in functional decline prevention and rehabilitation. In addition to the indirect cardiovascular benefits mediated by increased physical activity, supported by a robust evidence base[26,40], the direct ability of beta-alanine to attenuate markers of inflammation and oxidative stress is a highly suggestive finding. This points to pleiotropic properties that extend beyond pH buffering and warrant deeper mechanistic investigation.[29,31]

From a neurological standpoint, carnosine itself is the subject of intensive research as a potential neuroprotective agent. It can neutralize free radicals and advanced glycation end products implicated in the pathogenesis of neurodegenerative diseases.[33] While the direct evidence base for beta-alanine supplementation in cognitive health is still limited, the mechanistic plausibility is strong. Promising findings are anticipated from future clinical trials assessing its efficacy in populations with cognitive impairment.[34,35]

It is crucial to acknowledge the limitations that currently hinder the universal adoption of beta-alanine supplementation. The pronounced inter-individual variability in physiological responses, influenced by factors such as baseline carnosine levels and diet, necessitates the future development of personalized supplementation strategies.[11,12] Furthermore, the long-term effects and safety of sustained supplementation remain incompletely characterized, as the majority of clinical trials have study periods of less than three months.[13,41] A significant knowledge gap also exists concerning potential interactions with pharmaceutical agents. This is a critical consideration for older populations who often receive polypharmacy.[42] Finally, methodological inconsistencies across studies—particularly regarding dosing regimens, timing of administration, and sample sizes—complicate the synthesis of evidence and the formulation of definitive clinical guidelines.[17,23]

5. Limitations of the current evidence

The existing body of evidence on the systemic efficacy of beta-alanine is constrained by several important limitations. The overwhelming predominance of study participants who are young, healthy, and physically active significantly limits the generalizability of the results to older adults, sedentary individuals, or those with chronic comorbidities, such as metabolic syndrome or cardiovascular disease.[13,39] This demographic bias underscores the critical need for future research with larger, more diverse, and clinically relevant sample populations.

Substantial heterogeneity in supplementation protocols, including wide variations in daily dosage (typically 3–6 g/day) and total intervention duration, precludes establishing definitive, universally applicable dosing guidelines.[17,24] Moreover, most research has been focused on physical performance outcomes. There is a comparative paucity of data examining more complex clinical endpoints, such as the incidence of cardiovascular events, progression of cognitive decline, or all-cause mortality.[41]

Regarding safety, while side effects such as transient paresthesia (tingling) are generally mild and self-limiting, comprehensive long-term safety data beyond one year of continuous use are lacking in the literature.[43,44] Finally, the potential for interactions between beta-alanine and commonly prescribed medications has not been systematically studied. This represents a substantial gap in the risk-benefit profile, especially for clinical populations.[42]

6. Implications for future research and clinical practice

To fully realize the therapeutic potential of beta-alanine, future research priorities must be strategically aligned. There is a clear and pressing need for large-scale, randomized, placebo-controlled trials that specifically enroll older adults, patients with metabolic syndrome, neurodegenerative conditions, and established cardiovascular disease. These studies must incorporate long-term monitoring to assess sustainability and evaluate clinically meaningful outcomes, not just surrogate markers.[39,41]

Concurrently, efforts must be made to standardize supplementation protocols to determine optimal dosages and effective timing strategies, and to identify reliable biomarkers that predict individual responsiveness.[11,12] Dedicated pharmacological studies investigating potential interactions with common medications are essential to ensure safe integration into clinical care, particularly for patients on complex drug regimens.

As research into its direct neuroprotective effects intensifies, the logical next step is to evaluate beta-alanine within multidisciplinary intervention programs. Combining it with structured exercise, dietary modification, and other lifestyle counseling could yield synergistic benefits, maximizing overall efficacy and patient safety. For this to be implemented effectively, it is crucial that healthcare professionals, including physicians and clinical dietitians, remain abreast of the evolving evidence. This will enable them to provide informed, personalized recommendations while vigilantly monitoring for both effectiveness and individual tolerability.

7. Conclusion

In conclusion, the body of research reinforces beta-alanine's status as a supplement with robust ergogenic properties and reveals a promising, broader therapeutic potential for systemic health. Its well-documented capacity to enhance high-intensity exercise performance through increased muscle carnosine storage has meaningful implications not only for athletes but also for countering functional decline in aging and frail populations. The emerging recognition of its potential to confer indirect cardiovascular benefits and direct protection against oxidative stress and inflammation further positions it as a noteworthy agent for supporting metabolic and cognitive health.

However, the current evidence is tempered by significant limitations. These include a predominance of short-term studies in homogeneous, healthy populations. This has fostered a widespread consensus within the scientific community on the necessity for more rigorous, long-term, and inclusive research.[13,41] Such endeavors are crucial for developing evidence-based guidelines for use, clarifying long-term safety, and paving the way for personalized supplementation strategies. Future trials must address critical gaps in standardized dosing and the long-term safety profile, particularly in vulnerable populations.[11,42] Ultimately, the integration of beta-alanine into broader preventative health paradigms represents a compelling frontier. With continued interdisciplinary research, it has the potential to become a key component of strategies to enhance health span, functional vitality, and overall quality of life.

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