
**International Journal of Innovative Technologies in Social Science**

e-ISSN: 2544-9435

**Operating Publisher**
**SciFormat Publishing Inc.**
ISNI: 0000 0005 1449 8214

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Calgary, Alberta, T3E0A7,
Canada
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| **ARTICLE TITLE** | TAURINE, BRANCHED-CHAIN AMINO ACIDS, AND BETA-ALANINE: AN EVALUATION OF THEIR EFFICACY AND APPLICATIONS IN SPORTS AND MEDICAL CONDITIONS. A REVIEW ARTICLE |
| **DOI** | https://doi.org/10.31435/ijitss.3(51).2026.6024 |
| **RECEIVED** | 21 June 2026 |
| **ACCEPTED** | 15 September 2026 |
| **PUBLISHED** | 17 September 2026 |
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# TAURINE, BRANCHED-CHAIN AMINO ACIDS, AND BETA-ALANINE: AN EVALUATION OF THEIR EFFICACY AND APPLICATIONS IN SPORTS AND MEDICAL CONDITIONS. A REVIEW ARTICLE

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**ABSTRACT**

In recent years, the use of dietary supplements has increased substantially, both among professional athletes and individuals engaging in physical activity for recreational purposes. The aim of this study was to critically review the literature available in the PubMed database regarding the efficacy of taurine, beta-alanine, and branched-chain amino acid (BCAAs) supplementation in enhancing athletic performance, as well as their potential applications beyond sport, including in selected medical conditions. Analysis of the available evidence demonstrates that each of these compounds exerts distinct physiological effects and mechanisms of action. Taurine, due to its antioxidant properties and ability to modulate the inflammatory response, may support recovery processes and reduce the concentration of biomarkers associated with skeletal muscle damage. Beta-alanine, by enhancing intracellular hydrogen ion buffering capacity, appears to improve performance during high-intensity physical activity. In contrast, findings related to BCAA supplementation remain inconclusive. Although BCAAs may exhibit anabolic potential and contribute to reduction in post-exercise muscle soreness, current evidence does not demonstrate a consistent or significant effect on muscle strength or overall physical performance.
Interpretation of available data is limited by considerable heterogeneity across studies, including small sample sizes, and the variability in supplementation protocols. Therefore, further studies with high methodological rigor are required to establish definitive conclusions regarding the efficacy and clinical relevance of these supplements

**KEYWORDS**

Taurine, Branched-Chain Amino Acids (BCAAs), Beta-Alanine, Sport Performance

**CITATION**

Jasińska, J., Iskrzyński, D., Bułat, A., Gródek, A., Iglantowicz, J., Sanakiewicz, S., Obajtek, P., Dubiel, W., & Dubiel, M. (2026). Taurine, branched-chain amino acids, and beta-alanine: An evaluation of their efficacy and applications in sports and medical conditions. a review article. *International Journal of Innovative Technologies in Social Science*, 3(51). https://doi.org/10.31435/ijitss.3(51).2026.6024



# 1. Introduction

In recent years, interest in dietary supplementation has increased substantially among both professional and recreational athletes. Particular attention has been given to substances with potential ergogenic effects, including taurine, branched-chain amino acids (BCAAs) and beta-alanine, which are believed to positively impact physical performance, metabolic function, and post-exercise recovery. Although the molecular mechanisms underlying their effects have been relatively well documented, the findings of clinical trials evaluating their efficacy remain inconclusive. Interpretation of available evidence is further complicated by significant heterogeneity across studies - both in study populations and assessed endpoints. In addition to their role in sports nutrition, supplementation with these compounds is increasingly being investigated for potential applications in various medical conditions.

The aim of this study was to provide a critical review of the current literature regarding the effects of taurine, branched-chain amino acids (BCAAs) and beta-alanine on physical performance, as well as their potential clinical applications.

# 2. Methodology

A narrative literature review was conducted using the PubMed database. The search strategy included publications investigating taurine, beta-alanine, and branched-chain amino acids (BCAAs) in the context of physical performance and potential clinical applications. The review primarily considered randomized controlled trials, systematic reviews, and meta-analyses published in English. In addition, relevant experimental and in vitro studies were included to provide complementary insights and contextualize clinical findings. Due to the narrative design of the study, no formal systematic study selection protocol was applied.

# 3. Taurine

## 3.1 Characteristics and physiological role of taurine

Taurine, or 2-aminoethanesulfonic acid, is a chemical compound belonging to the beta-amino acid group. It is a final product of cysteine degradation and can form conjugates, as well as participate in various molecular modifications. However, it is not incorporated into proteins via ribosomal translation, due to the absence of a specific aminoacyl-tRNA (Huxtable, 1992). Taurine can be found in various foods, particularly in meats like poultry, pork and beef, as well as in dairy products. In plant-based foods, such as seeds, only small quantities of taurine have been detected. Consequently, people who consume meat have a significantly higher level of taurine in their bodies compared to individuals who follow a vegan diet. (Laidlaw et al., 1990)(Manzi & Pizzoferrato, 2013). Taurine is also an essential component of breast milk and is routinely included in infant formula, as deficiency may be associated with impaired development, particularly in preterm infants (Verner et al., 2007). It serves as an important intracellular osmolyte, with the highest concentrations observed in the nervous tissue of children prior to full maturation. It helps regulate neuronal cell volume in response to changes in osmotic pressure (Lien et al., 1990).

Furthermore, it is essential for bile salt formation in the liver, as these compounds are synthesized from bile acids with taurine involvement (Santulli et al., 2023). As a result, it plays an indirect role in the digestion of lipids and the absorption of fats and fat-soluble vitamins from the intestine into the bloodstream (de Aguiar Vallim et al., 2013).

Its influence on calcium signaling and ion channel modulation is also noteworthy (Foos & Wu, 2002). Additionally, taurine exhibits antioxidant properties; in experimental models, low serum taurine levels have been associated with an increase in the NADH/NAD+ ratio, which inhibits biologically relevant dehydrogenase enzymes (Schaffer et al., 2016).

## 3.2 The Role of Taurine in Health and Disease

A correlation has been observed between reduced taurine levels and diseases associated with oxidative stress, including cardiomyopathies, Alzheimer's disease and liver dysfunction (Baliou et al., 2021).

The potential positive association between taurine and athletic performance is mainly attributed to its antioxidant properties. Physical exertion results in an increase of circulating levels of tumor necrosis factor alpha (TNF-alpha), which, among other mechanisms, contributes to the formation of reactive oxygen species through the activation of pro-oxidative pathways (Mangner et al., 2013). Taurine supplementation has been associated with a reduction in TNF-alpha concentrations (MD, -0.35 pg/mL; 95% CI, -0.56 to -0.14), however these findings are characterized by significant heterogeneity and limited overall quality of evidence. Furthermore, reductions in both systolic and diastolic blood pressure, as well as decreased levels of C-reactive protein, have been observed in individuals supplementing taurine (Nie et al., 2025). Evidence from studies conducted in obese populations further suggests a potential positive impact on triglyceride and glycated hemoglobin levels. Nevertheless, these effects are not consistently observed and may depend on the characteristics of the study population and the intervention protocol (Sun et al., 2024).

## 3.3 Taurine in the Context of Physical Activity

Da Silva et al. demonstrated that 21 days of taurine supplementation (50 mg/kg/day) in untrained men resulted in increased eccentric and concentric strength during resistance training compared with a placebo group. The intervention was also associated with a reduction in muscle damage, as signified by lower creatine kinase levels, decreased muscle soreness and higher thiol concentrations in the experimental group. Notably, no significant changes were observed in antioxidant enzyme activity or markers of inflammatory response. (da Silva et al., 2014).

In the context of muscle damage, delayed onset muscle soreness (DOMS) also represents a significant concern. It typically manifests 24–72 hours after eccentric exercise and is associated with microtears in muscle fibers and the accompanying inflammatory response. Intervention studies have shown that taurine supplementation may reduce the severity of DOMS and limit the increase in biochemical markers of muscle damage, such as creatine kinase and lactate dehydrogenase (Ra et al., 2015). Additionally, reductions in markers of oxidative stress have been observed, suggesting a potential mechanism related to taurine's antioxidant properties. However, it should be noted that some studies have utilized combined interventions in which taurine was administered together with branched-chain amino acids (BCAAs), making it difficult to unequivocally determine its independent effect (Ra et al., 2013). Available evidence further suggests that

taurine's potential role in reducing DOMS may also stem from its capacity to stabilize cell membranes and modulator the inflammatory response. Nevertheless, the overall strength of the evidence remains moderate due to the limited number of high-quality studies, relatively small sample sizes, and the fact that the results obtained are not fully consistent.

Similarly, other studies have not demonstrated a reduction in post-exercise lactate levels after taurine supplementation (De Carvalho et al., 2018)(Ward et al., 2016). A recent and very significant contribution to the discussion on the efficacy of taurine is a 2025 meta-analysis, which indicated that even a single pre-exercise dose of taurine may improve performance during aerobic exercise. However, due to the heterogeneity and variability of the study protocols, the strength of the evidence remains low (Deng et al., 2025).

### 3.4 Taurine as a component of energy drinks

Taurine is a commonly used ingredient in commercially available energy drinks, where it is typically combined with other active compounds, particularly caffeine. Numerous studies indicate that pre-exercise ingestion of taurine together with caffeine may improve performance in numerous types of physical activities. Reported benefits include improved cycling endurance (Quinlivan et al., 2015), increased swimming speed (Lara et al., 2015), as well as enhanced jumping ability in racquet sports athletes (Gallo-Salazar et al., 2015). Current literature does not provide clear evidence that taurine can be overdosed at commonly consumed levels, nevertheless consuming it in the form of the energy drinks warrants some caution. The risk stems primarily from the high concentrations of caffeine and other stimulants present in these beverages, rather than from taurine itself. These substances have been shown to elevate heart rate and systolic blood pressure, which may partially negate the potential blood pressure-lowering properties attributed to taurine. The combined stimulatory effect of these ingredients has been linked to an increased risk of adverse cardiovascular events, including ventricular arrhythmias, myocardial infarction, and cardiomyopathy (Kaur et al., 2022). Therefore, the safety profile of taurine in energy drinks should be considered within a wider context of its co-consumption with other stimulants rather than in isolation.

## 4. Branched-Chain Amino Acids (BCAAs)

### 4.1 Characteristics of BCAAs and Their Physiological Functions

Branched-chain amino acids (BCAAs) comprise three essential amino acids - leucine, isoleucine, and valine – which are classified as exogenous amino acids, as they cannot be synthesized by the human body and must be obtained through diet (Virgiliou et al., 2021). These compounds have attracted particular interest in the context of sports nutrition research, due to their unique metabolic properties – BCAAs undergo oxidation in skeletal muscle tissue, largely bypassing initial hepatic metabolism (Nemet et al., 2005).

Notably, leucine has a particularly significant regulatory role, acting as a potent activator of the mTOR pathway. This effect occurs through its interaction with Sestrin2, which is a negative regulator of mTOR1C activity (Wolfson et al., 2016). Activation of the mTOR1C pathway promotes protein synthesis and cellular growth, while also inhibiting autophagy, thereby contributing to the regulation of cellular metabolism (Wolfson & Sabatini, 2017).

### 4.2 BCAAs in the Context of Physical Activity

Clinical studies examining the effects of BCAA supplementation have predominantly focused on cyclists (Kephart et al., 2016), runners (Areces et al., 2014), team-sport athletes (Douligeris et al., 2024), and individuals engaging in resistance training (Smith et al., 2018). Although molecular and experimental research has consistently demonstrated potential anabolic properties of BCAAs, findings from clinical trial and recent meta-analyses suggest a limited translation of these effects into meaningful functional outcomes. A 2024 meta-analysis of randomized controlled trials (Salem et al., 2024) demonstrated that BCAA supplementation was associated with a statistically significant reduction in the severity of delayed onset muscle soreness (DOMS) as well as a decrease in creatine kinase (CK) activity, indicating a potentially beneficial effect for post-exercise recovery. However, no significant improvements were observed in muscle strength, athletic performance, or neuromuscular function.

Importantly, while leucine is known to activate the mTORC1 signaling pathway, the absence of other essential amino acids limits the capacity for complete muscle protein synthesis. This finding is reflected in the results of intervention studies evaluating isolated BCAA supplementation. Consequently, current evidence indicates that BCAA supplementation is not more effective than complete protein sources or formulations containing all essential amino acids (EAAs) in the promotion of muscle hypertrophy and long-term training adaptations.

### 4.3 The Role of BCAAs in Health and Disease Processes

Beyond its application in sports nutrition, BCAA supplementation has also been investigated for its potential therapeutic role in conditions such as hepatic encephalopathy and age-associated sarcopenia. In hepatic encephalopathy, increased concentrations of neurotoxic aromatic amino acids (AAAs) are often observed. By competing with AAAs for transport across the blood-brain barrier, BCAAs may potentially reduce the neurotoxic effects associated with this condition (Colosimo et al., 2023). The strongest evidence supporting this effect comes from a meta-analysis of randomized controlled trials and a Cochrane systematic review from 2017 (Gluud et al., 2017). The analysis consisted of 16 studies involving 827 patients. It demonstrated that BCAA supplementation significantly reduced the severity of hepatic encephalopathy symptoms compared with the control group, indicating moderate efficacy in improving neurological function. However, no significant effects were observed in regard to mortality, quality of life or nutritional status. These findings suggest that BCAAs may be beneficial in alleviating the clinical symptoms of hepatic encephalopathy, but they do not appear to influence major clinical outcomes. Therefore, their use should be considered as an adjunctive component of standard treatment rather than a standalone intervention.

In the context of sarcopenia in older adults, BCAA supplementation has also been extensively investigated as a potential supportive intervention. Sarcopenia is characterized by the gradual decline of skeletal muscle mass, strength and motor function, contributing to a significantly increased risk of falls, reduced physical performance and diminished quality of life, which can increase the risk of falls, reduce mobility, and negatively affect quality of life. Among the BCAAs, leucine plays a particularly important role by activating the mTOR1C pathway in skeletal muscle, thereby stimulating muscle protein synthesis and reducing muscle protein breakdown (Bai et al., 2022). Evidence from a systematic review and meta-analysis of randomized controlled trials demonstrated that supplementation with BCAA-rich formulations was linked to moderate improvements in muscle mass and muscular strength, as well as improved motor function in older adults, compared with control groups. Subgroup analyses further suggest that some of these benefits, particularly improvements in handgrip strength, were often more pronounced than those observed with isolated whey protein supplementation, although differences in overall muscle mass remained less conclusive. In addition, the interventions were generally well tolerated and did not result in significant adverse effects.

Overall, these findings indicate that BCAAs may serve as a valuable addition to nutritional and exercise-based strategies in the prevention and management of sarcopenia. Nevertheless, supplementation should not replace a comprehensive therapeutic approach that incorporates regular physical activity and adequate dietary protein intake.

## 5. Beta-Alanine

### 5.1 Characteristics of Beta-Alanine and Its Physiological Role

Beta-alanine is a nonessential β-amino acid, commonly found in nature, with numerous applications in the pharmaceutical, chemical, and food industries (Song et al., 2023). In humans, beta-alanine can also be synthesized endogenously through pyrimidine catabolism (Hoffman et al., 2018). Interest in this amino acid initially stems from its role in the synthesis of carnosine, which is a dipeptide composed of a beta-alanine and L-histidine. Carnosine is highly concentrated in skeletal muscle tissue and, to a lesser extent, in nervous system tissue, where it performs several important physiological functions. These include direct and indirect antioxidant activity, anti-glycation effects through the inhibition of advanced glycation end products (AGEs) formation, as well as metal ion chelation and intracellular pH buffering (Berezhnoy et al., 2019). Through these mechanisms, carnosine may contribute to the protection of cells against oxidative stress and metabolic disturbances.

### 5.2 The Importance of Beta-Alanine in Health and Physical Activity

Precisely, due to its buffering capacity, carnosine may contribute to improved athletic performance. During high-intensity physical activity, particularly when energy production relies on anaerobic metabolism, accumulation of lactate and hydrogen ions ($H^+$) results in decreased intramuscular pH and development of fatigue (Cairns & Lindinger, 2025). By enhancing intracellular buffering capacity, carnosine helps reduce local intramuscular acidosis and, consequently, fatigue (Saunders et al., 2017). Beta-alanine is promptly absorbed – reaching maximum blood concentration (Tmax) approximately 30–45 minutes after ingestion, with a half-life of around 20–30 minutes. Following a single dose, serum concentrations of beta-alanine return to baseline

within a few hours, indicating it does not accumulate acutely in circulation (Harris et al., 2006). However, regular supplementation for four weeks, typically with 4–6 grams of beta-alanine, has been shown to increase concentrations of carnosine in muscle tissue (Trexler et al., 2015). It is worth noting that carnosine distribution is not uniform across different muscle fiber types (Kalbe et al., 2023). Significantly higher concentrations are found in type II muscle fibers compared with type I fibers (C. Harris et al., 1998). Type II fibers are particularly well-developed in athletes engaging in sports requiring high explosive power, such as interval training, suggesting that elevated carnosine levels may be especially beneficial for them (Cimadevilla-Fernández-Pola et al., 2024).

There is a growing body of research examining the effects of beta-alanine supplementation on the performance of martial arts athletes. A 2023 systematic review showed significant improvements in performance measures associated with muscular strength, power output, and overall exercise capacity following beta-alanine supplementation (Cimadevilla-Fernández-Pola et al., 2024). Notably, no substantial differences in lactate concentrations were observed, implying that ergogenic effects of beta-alanine should not be attributed to reduced lactate production, but rather to an enhanced buffering capacity for H+ ions.

Beyond its effects on athletic performance, carnosine has also been investigated for its potential neuroprotective properties. In particular, researchers have explored its possible role in reducing the incidence of neurodegenerative diseases. Carnosine is a compound capable of chelating metal ions, including the ability to bind zinc ions, dysregulation of which may result in neurotoxic effects (Kawahara et al., 2018). Nevertheless, research in this area remains in its early stages. Although results from animal models are promising (Zhang et al., 2011) (Davis et al., 2016), further clinical research is required to confirm these potential therapeutic effects.

## 6. Summary

All of the supplements discussed appear to be generally well tolerated. However, their safety profiles have initially been assessed in short-term trials, and high-quality data regarding the effects of long-term use remains limited. Among these supplements, beta-alanine demonstrates the most consistently documented ergogenic effect, particularly during high-intensity exercise. These benefits are largely attributed to its role in increasing intramuscular carnosine levels and enhancing the buffering of hydrogen ions. Taurine may provide a moderate effect in supporting post-exercise recovery and reducing oxidative stress, however the current evidence remains inconclusive. In contrast, BCAAs show the least convincing evidence for improving performance and muscular strength, despite well-described molecular mechanisms, including the activation of anabolic signaling pathways such as mTORC. Moreover, current findings do not demonstrate a clear advantage of BCAA supplementation over complete dietary protein sources or formulations containing essential amino acids. Nevertheless, both taurine and BCAAs have potential applications beyond sports nutrition, particularly in the management of certain medical conditions, including hepatic encephalopathy and metabolic disorders.

The ability to draw more definitive conclusions is limited by several methodological weaknesses within the currently available literature. Most studies are characterized by small sample sizes, significant heterogeneity in study protocols, and the frequent use of combined interventions, all of which complicate the interpretation and comparison of findings.
Further research in this area is therefore required, particularly in the form of large-scale, well-designed, randomized controlled trials conducted with homogeneous populations. Such studies would allow for a better understanding of the clinical and ergogenic significance of supplementation with these compounds, while also helping to identify the populations most likely to benefit from their use.

**Acknowledgments:** This research received no external funding.
**Conflicts of Interest Statement:** The authors report no conflict of interest.

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