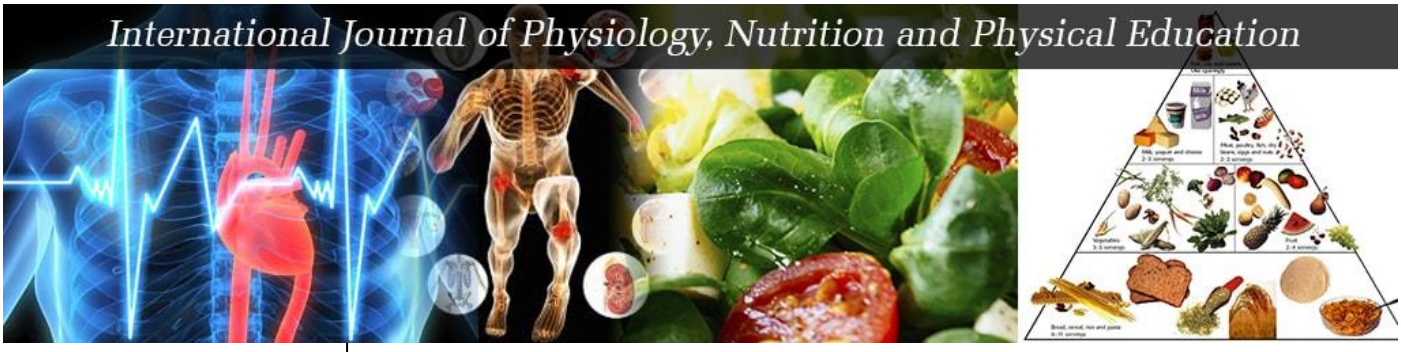

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Essential amino acids as an alternative strategies for sustainable athletic nutrition

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Abstract
Amino acids are major nutrient regulators of muscle protein turnover. After a while ingesting protein, hyper aminoacidemia stimulates higher rates of skeletal muscle protein synthesis, decreases muscle protein breakdown, and encourages net muscle protein accretion. These findings provide the rationale for carefully planning one's protein consumption to encourage long-term lean mass accretion or to prevent lean mass loss. However, in order to evaluate the reported efficacy of long-term studies investigating protein supplementation as part of a dietary strategy to promote lean mass accretion and prevent lean mass loss, factors such as the role of essential and non-essential amino acids are important in mediating the anabolic effects of amino acids on skeletal muscle. This review goes through a few of the positive outcomes. The positive benefits of dietary amino acid supplements on muscle function, exhaustion, and recovery in active athletes are covered in this article. This review paper examined the chemical structure and important elements of both essential and non-essential amino acids, including the branched-chain amino acids lysine, tryptophan, glutamine, arginine, ornithine, and taurine.

Keywords: Muscle function, essential amino acids, non-essential, protein supplements

Introduction
The scientific area of sports nutrition is increasing quickly, and both the academic community and the general public who engage in physical activity have a keen interest in it (Riera *et al*., 2020) [22]. The relationship between sport and nutrition is complex and compelling and there are several sports nutrition products, methods, and theories that might be explored (Burke *et al*., 2019) [23]. The fundamental idea of sports nutrition for athletes calls for good eating habits and a working knowledge of both general nutrition and exercise science. The second step is to learn how nutrition and exercise science are related, underlining that healthy eating and exercise are necessary for producing the best performance possible (Wojtys, 2015) [24]. The final step entails applying the knowledge of sport nutrition to the specific athlete who is engaged in any sport or physical activity (Shirreffs and Sawka 2011) [25]. All levels of athletes utilise dietary supplements, which is in line with how frequently they are used in society as a whole (Bailey *et al*., 2011) [1]. Athletes convey a wide variety of explanations for their supplement decisions and products that fulfil the specifications of "supplement" can target different functions within the athlete's performance strategy (Fennell, 2004) [2]. These include promoting the necessary nutrient intake for maintaining good health, controlling micronutrient deficits, and supplying energy and macronutrient requirements that may be difficult to accomplish by food intake alone.
Other specific uses of supplements mentioned by athletes include enhancing mood, altering physique, relieving musculoskeletal pain, improving performance directly, or the indirect benefits that result from supporting intense training (Garthe and Maughan 2018) [3]. The fundamental organic components of cells, protein and amino acids, are what carry out the majority of life's processes. According to (Yang *et al*., 2015) [4], they perform crucial physiological tasks including enhancing immunity, stimulating muscle growth, and reducing fatigue. Proteins are composed primarily of amino acids in 20 different varieties of natural amino acids used to produce proteins. These amino acids can be divided into three categories from the standpoint of nutrition: essential amino acids, conditional essential amino acids, since the body lacks the necessary metabolic pathways to synthesise essential amino acids, they

must be obtained from an external diet (Swennen *et al*., 2011) [5]. There are nine essential amino acids, including Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, and Valine, according to broad consensus, while variances are feasible depending on an individual's metabolic condition. The health of people and athletic performance are significantly influenced by each of the nine essential amino acids (Hou and Wu 2017) [6]. They perform an essential part in a wide range of functions, including the development of new tissue, the synthesis of energy, immune system operation, and nutrition absorption. The optimum balance of amino acids in the human body will be affected by the amount of necessary amino acids ingested through meals.

In addition to their usual physiological roles, essential amino acids can be utilised as dietary supplements and have an immense effect on specific groups (Debnath *et al*., 2019) [7]. Numerous studies have demonstrated that essential amino acids can improve age-related muscle decay, promote the synthesis of muscle protein, slow down the breakdown, speed up recovery after exercise, increase endurance during exercise, and even have a positive impact on bone health (Cuthbertson *et al*., 2005) [8].

Critical role of amino Acids

1. Effect of amino acids in muscle building

According to Derave and Tipton (2014) [9], power athletes typically consume 50% to 100% more protein than inactive people do. Protein supplementation among athletes has a long history, and protein requirements increased with exercise intensity. During exercise, there is a reduction in the quantity of muscle protein developed, and on the other hand, there is an increase in the amount of muscle protein breakdown, resulting in a reduction in the overall amount of muscle protein. Furthermore, muscles might be harmed by vigorous activity. As a result, muscular conditions may deteriorate, which may impair sports performance (Maughan *et al*., 2011) [10]. The rate of muscle protein synthesis must be greater than the rate of breakdown in order to increase skeletal muscle mass. Resistance training and amino acids have been shown to increase protein synthesis; both of these factors work by activating the mTORC1 signalling pathway, which is a key component of protein synthesis (Kimball, 2014) [11].

Borsheim *et al*., (2002) [12] conducted a study and found that a dose of 6 g of orally delivered essential amino acids stimulates net muscle protein balance in healthy volunteers when consumed 1 and 2 hours after resistance exercise, also stated that consuming essential amino acids has a dose-dependent effect on muscle protein synthesis and that non-essential amino acids are not required to enhance muscle protein net balance.

According to Pasiakos *et al*. (2011) [13], increasing the content of leucine in an essential amino acids supplement taken during workout recovery resulted in a 33% (p<0.05) larger increase in muscle protein synthesis (MPS).

Studies have demonstrated that essential amino acids have a positive impact on patients with disease as well as healthy individuals' skeletal muscle protein synthesis. In post-stroke patients with sarcopenia, an eight-week intervention combining a leucine-enriched amino acid supplement with low-intensity resistance training enhanced muscle mass, strength, and physical function (Yoshimura *et al*., 2019) [14].

2. Effect of amino acids on recovery and fatigue

Depending on the type of exercise, exhaustion and fatigue will happen sooner or later. According to Duan *et al*. (2017) [15], it is characterised by a decline in performance related with an increase in the actual or perceived difficulty of a task or activity. Blood urea nitrogen, a metabolite of protein and amino acids, is one of the blood biochemical markers associated with exhaustion (Xu *et al*., 2018) [16]. Anaerobic glycolysis generates blood lactate, which can then be converted to ATP through the tricarboxylic acid cycle or transported to other tissues for oxidation or gluconeogenesis.

Wen *et al*., 2022 [17] conducted a study and found that leucine-enriched essential amino acids had better effects on exhaustion amelioration by increasing the exhaustion time in rats, reducing the accumulation of blood lactic acid and blood urea nitrogen caused by exercise, and increasing the glutathione content to quickly restore the antioxidant capacity. Matsui *et al*., 2019 [18] conducted a randomised, double-blind, placebo-controlled crossover study and concluded that the relative increase of the peak serum Creatine Phosphokinase activity was significantly lower in Leucine-enriched essential amino acids ingestion than in placebo ingestion. Therefore, the results show that consuming essential amino acids that are leucine-enriched reduces the degree of muscle damage and speeds up recovery after exercise in humans (Howatson and Someren 2008) [19].

Effect of essential and non- essential amino acids on sports performance

According to many theories, amino acids can improve performance by increasing the production of anabolic hormones, modifying how fuel is used while exercising, diminishing the adverse effects of overtraining, and eliminating mental exhaustion (Williams, 2005) [20]. The research on the ergogenic effects of individual amino acids, different combinations of amino acids, and various specialised protein dietary supplements are discussed in the discussion as follows.

Essential Amino Acids

1. Branched chain amino acids

Each of the protein-rich diets, especially eggs, poultry, meat, and dairy products, contains significant levels of BCAAs. Leucine can be found in significant amounts in plant-based meals such oats, soy, and lentils. Furthermore, substantial amounts of isoleucine are found in meat, poultry, fish, eggs, cheese, nuts, and lentils, and significant amounts of valine are found in fish, meat, and various vegetables (Master *et al*., 2021) [33]. Leucine, isoleucine, and valine are the three most oxidised branched chain amino acids (BCAA) that are catabolized in skeletal muscle, promote muscle growth by preventing endogenous post-exercise protein degradation, whereas essential post-exercise amino acids may take longer to stimulate skeletal muscle protein synthesis. As a result, athletes are increasingly consuming supplements of protein and amino acids (Bolster *et al*., 2004) [34]. It is considered that when BCAAs were administered to subjects while they were at rest, protein balance was improved by either slowing down protein synthesis, speeding up protein synthesis, or a combination of both (Koopman *et al*., 2005) [37]. It has been determined that consuming leucine along with carbs increases protein synthesis more than consuming the same quantity of carbohydrate without leucine in males who exercised with

resistance training (Campbell *et al*., 2007) [38]. The net rate of protein breakdown has been found to decrease when BCAAs are consumed during aerobic exercise (Dreyer *et al*., 2008) [39].

Many metabolic conditions have been associated with fatigue, including glycogen depletion, hydrogen cation buildup, phosphocreatine depletion, hypoglycemia, and an increase in the ratio of free tryptophan to BCAAs. These conditions can all be treated with BCAA supplements, which can help to reduce fatigue (Kim *et al*., 2013) [40]. With implications for interpreting blood levels of BCAAs and pathophysiological outcomes. Biet *et al*., 2019 study demonstrated that there was a non-linear relationship between ingested BCAAs and blood levels, with a plateau concentration attained despite subsequent increases in protein or BCAA consumption. Following exercise, muscle catabolism and protein breakdown have been demonstrated to be reduced by leucine and its metabolites (HMB b-hydroxymethylbutyrate). Is an amino acid leucine metabolite. Particularly in new and older trainees, HMB decreases protein breakdown and enhances protein synthesis. On trained athletes, it has less of an impact. 3 g is the suggested amount per day. The usage of 15 HMB is regarded as safe because it has no documented negative effects on triglyceride levels, liver, or renal function.

Long-term aerobic exercise increases the concentration of free tryptophan, which causes an increase in tryptophan uptake into the brain. This results in the production of serotonin, which has been linked to the psychological feeling of fatigue. The neurotransmitter serotonin in particular utilises tryptophan as a substrate and promotes calmness, relaxation, and good mood in the human brain. Similar to tryptophan, BCAAs are also transported by the same transport pathway in the brain, and as a result, "compete" for tryptophan's delivery to the brain (Bloomstrand, 2006) [41].

According to Salinas-Garca *et al*. (2014) [42], BCAA supplementation reduced perceived exertion and mental exhaustion, and enhanced the immunological and anabolic response during the recovery period. It also caused only modest muscle damage and soreness. Recent research by Plotkin *et al*. (2021) [43] showed that the majority of the scientific literature does not support the use of BCAA supplements as ergogenic aids in increasing muscle strength and hypertrophy. However, the authors suggested that more study on the topic in older individuals is necessary based on early findings. In conclusion, BCAAs have been proved to support exercise recovery mechanisms, including promoting protein synthesis, replenishing muscle glycogen, delaying the onset of muscular exhaustion, and preserving mental performance during aerobic activity.

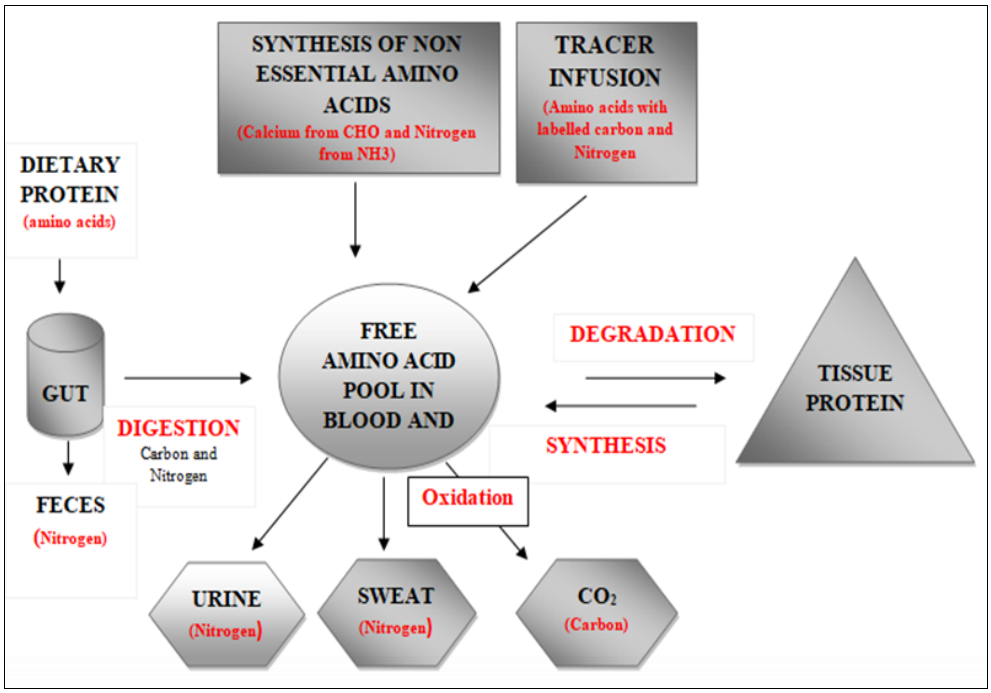

Fig 1: Amino acids metabolism

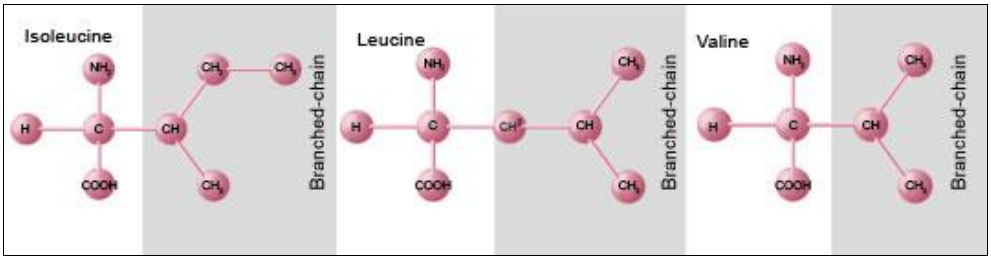

Fig 2: Chemical structure of Branched chain amino acids

2. **Lysine:** As an essential amino acid, lysine is one of the most important branched chain amino acid. Plasma levels indicate the level and extent of an individual's immunological proficiency. This indicates that it is essential for the synthesis of every immunological protein, including antibodies, cytokines, growth factors, and antigens. Low levels are an indicator of immunological systemic dysfunction. According to

Krasniqi *et al*. (2016) [44], it also supports young children's bone development and calcium absorption. Lysine is crucial for healthy development and is involved in the creation of carnitine, a nutrient that converts fatty acids into energy and lowers cholesterol. This amino acid, one of the essential components of muscle tissue, is often used by athletes to support the development of lean mass and the overall health of muscle and bone (Agarwal *et al*., 2016) [45].

3. **Tryptophan:** Tryptophan is a precursor to serotonin, a brain chemical thought to reduce pain. To create serotonin, free tryptophan traverses the brain cells. As a result, tryptophan supplementation has been utilised to raise serotonin levels in an effort to boost pain tolerance during strenuous exercise. According to one study, significant decreases in the rating of perceived exertion were observed together with improvements in the time to exhaustion at 80% of peak oxygen consumption (Jenkins *et al*., 2016) [46]. In an experimental study, it was found that tryptophan may not be as important for reducing fatigue during draught load exercise as other processes, such as substrate depletion, the accumulation of metabolic products in the periphery, different neurotransmitters, or other mechanisms leading to an increased 5-HT level in brain (Vervuert *et al*., 2005) [47].

Non-essential amino acids

Glutamine: According to research conducted a few years ago, the body has large amounts of glutamine that are also extremely volatile. More than any other amino acid, the concentration of glutamine decreases the most during the course of an illness, correlates with the severity of the underlying illness process overall, and is only completely recovered late in the healing process (Hakimi *et al*., 2012) [48]. Lack of glutamine in the muscles has been hypothesised to impair immune defence against viral infection by slowing lymphocyte proliferation in response to antigens (Michalski *et al*., 2021) [49]. Recent research indicates that resistance training reduces protein catabolism, but an anabolic (muscle growth) response requires the ingestion of essential amino acids (dietary protein) during the recovery period after exercise. By enhancing the muscle's absorption of amino acids, this increases the rate of tissue protein synthesis without affecting the rate of protein degradation. If the protein being taken already includes the 8 essential amino acids, taking supplements of specific non-essential amino acids at this time is unlikely to be beneficial (Häberle *et al*., 2012) [51]. Usually, 3-6 g/d of glutamine are obtained by dietary protein (based on a daily protein intake of 0.8-1.6 g/kg bm for a 70 kg person). Short-term Glutamine supplementation of 20-30 g within a few hours has not been shown to have any negative effects on healthy athletes (Koo *et al*., 2014) [52].

Even though there is less data on glutamine supplements' effects on strength and performance in the athletic group, it's reasonable to assume that they would be helpful for people who engage in extensive physical activities. As stress increases, glutamine levels in muscles decrease proportionately. Plasma glutamine levels also decrease before and after vigorous exercise (Chen *et al*., 2020) [50]. Furthermore, while under stress, skeletal muscle produces more glutamine than can be seen in the intracellular pool and is incorporated into proteins. Conversely, glutamate may encourage skeletal muscle hydration, resulting in an increase in cellular volume. According to Zhang and Bishop (2020) [53], an increase in cell volume may act as an anabolic signal for muscle cells, increasing muscular strength.

Arginine: Since arginine a non-essential amino acid plays a role in nitric oxide generation and bioavailability has shown a vasodilator effect (Kerksick *et al*., 2018) [54]. In order to increase their athletic performance, athletes have used arginine supplements (Pahlavani *et al*., 2017) [55]. Although arginine is a non-essential amino acid for adults because it is absorbed through dietary proteins and synthesised in the small intestine from proline, glutamate, and glutamine (Curis*et al*., 2005) [56], some research has shown that supplementation may be advantageous in enhancing athletic performance (Ojeda *et al*., 2019) [57]. The main advantages of arginine relate to its synthesis and its function as a cell signalling molecule with physiologically significant consequences. Arginine has also been shown to promote the production of growth hormone (Forbes *et al*., 2015) [58], which helps in promoting cell growth and regulating the mobilisation of fuels in the body that support greater muscle mass and hypertrophy (Tang *et al*., 2011) [59]. Additionally, ammonia, lactate, fatty acids, and fat oxidation levels have been shown to decrease with arginine supplementation. Similarly arginine showed an increase in glycerol post-exercise, with increased carbohydrate oxidation and oxygen efficiency (Forbes *et al*., 2013) [60], considering these possible advantages in endurance sport performance. Thus, arginine has shown impacts on several physiological and metabolic pathways that may enhance athletic performance in both endurance (and "aerobic") and high intensity (or "anaerobic") sports.

Ornithine: Ornithine is a free amino acid that neither contributes in protein production nor is it transcribed for by DNA. Ornithine stimulates the pituitary gland, promoting the release of growth hormone. According to Demura *et al*. (2010) [61], growth hormone stimulates the metabolism of lipids, proteins, and carbs. Ornithine is also one of the by-products of the enzyme arginase's reaction with arginine to produce urea. As a result, ornithine plays a crucial role in the urea cycle, which enables the elimination of extra nitrogen (Rodwell, 2003) [62]. Ornithine is therefore thought to prevent the rise in blood ammonia levels brought on by physical exertion. Ornithine is expected to boost energy production effectiveness and encourage ammonia detoxification. Sugino *et al*. (2008) [63] explored a cycle ergometer to perform 10-second maximum-pedalling trials during the fatigue-inducing physical tests. They found that ornithine improved females' physical performance during the workload tests that caused fatigue, as well as their ability to recover more quickly.

Taurine: According to Hadiari *et al*. (2019) [64], the free amino acid pool is made up of between 50-60% of the sulphur-containing amino acid taurine, which is produced during the metabolism of cysteine. Skeletal muscle comprises a lot of taurine (Wen *et al*., 2019) [65]. Consuming animal proteins provides rich supplies of dietary taurine (Waldron *et al*., 2018) [67]. According to Carvalho *et al*. (2020) [68], taurine has favourable effects on a variety of metabolic and physiological processes, including the control of glucose and lipids, energy metabolism, anti-inflammatory modulation, and antioxidant properties. Taurine supplementation for 21 days in male volunteers led to decreased muscle soreness (lower than those of the placebo group on days 16 and 18) (Silva *et al*., 2014) [66]. Taurine probably contributes to a reduction in the degree of muscular soreness during the healing process also support in membrane healing and stabilization as well.

Conclusion

Athletes continually seek nutritional aids that will offer them a distinct advantage over competitors and are prepared to go far lengths to find these types of supplements. This explains some of the reports of widespread utilisation of illegal substances in sports, but it's challenging to locate substances that boost performance without breaking the law. Additionally, any chemical substance used in this way needs to not cause any negative side effects. A popular dietary supplement provided to athletes is amino acids. Supplementing with amino acids has been suggested to speed up recovery after workouts in strength athletes, increase the availability of vital amino acids, and stimulate anabolic processes that promote tissue growth. It has been suggested that providing amino acid supplements to endurance athletes will enhance their physiological and psychological reactions to long-distance training and exercise. Preliminary findings show that amino acid supplementation has an impact on the physiological and psychological reactions to endurance exercise. Individual protein types can potentially influence muscle growth through altered nutritional availability because of differences in amino acid content, digestion, or absorption rates. It is clear that consuming protein and amino acids in close proximity to exercise training sessions can significantly improve both muscle growth and exercise effectiveness.

Conflict of interest: Author declares no conflict of interest.

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