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Research Article

Review on Application Prospects of Nutritional Supplement Branched-chain Amino Acids in Competitive Sports

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Abstract: The aim of this study is to review the role of branched-chain amino acids in competitive sports. The data in the existing literature indicated that winning the game not only depends on development of experience and physical ability but also synergetic efforts in such disciplines as physiology, psychology, nutrition, biology, material and athletic training. Only by considering the subjective and objective conditions comprehensively, can athletes constantly break their limits in competitive abilities. Among various measures and methods improving the sports performance, nutrition regulation is the one preferred by athletes and coaches. The supplement Branched-Chain Amino Acid (BCAA for short) has remarkable effects on rapidly relieving fatigue, replenishing energy and enhancing physical abilities after athletes' high-speed and fiercely comprehensive sports. In view of this, this study makes a review on application prospects of BCAA in competitive sports, in hopes of providing theoretical references for analysis on nutritional supplements in athletic sports.

Keywords: Branched-chain amino acids, competitive sports, nutritional supplement, sports fatigue

INTRODUCTION

Branched-Chain Amino Acids (BCAA) is extremely particular in structure; for example, on the carbon of its one end are amidogen and carboxyl, while the carbon chain of its other end features bifurcate structure. That's why it is called BCAA. BCAA, accounting for about 20% of the body proteins, includes leucine, isoleucine and valine, all of which are essential amino acids that cannot be synthesized in vivo but provided by food proteins. As early as the 19th century, BCAA had been purified. Benotti *et al*. (1976) studied the effects of supply of BCAA on avoidance of proteolysis during exercise. In the following decade, scholars' study on BCAA mainly focused on clinical postoperative recovery (Mero, 1999). Newsholme *et al*. (1991) first put forward that 5-hydroxytryptamine (5-HT) was probably the material relieving central fatigue. Only then did the scholars realize BCAA's effects in the exercise on a gradual basis (Tang and Zhang, 2012). BCAA is the amine acid that supplies energy through oxidation outside the liver, particularly at the skeletal muscle. And it is also the amine acid whose degradation is not limited to liver. This is because BCAA metabolism rate limiting enzyme-branched-chain α-ketoacid dehydrogenase complex (BC complex)-has relatively strong activity, which will enhance the muscle's ability in utilizing BCAA (Tian, 2006; Xu and Zhang, 2003). In addition, BCAA can serve as energy and gluconeogenesis substrates and can regulate the metabolism of muscle protein. As a sports nutrition supplement, BCAA has been widely studied in physical training. This study plans to summarize and comment the relationship between BCAA and body movements.

EFFECTS OF BCAA ON SPORTS NUTRITION SUPPLEMENTS

Prevention and alleviation of sports fatigue: In 1880, Mosso first put forward that sports fatigue may include two parts, namely, central fatigue (at central nervous system) and peripheral fatigue (at the periphery, from the junction of nerve and muscle to the mitochondria in the muscle fiber, etc.) (Zhang, 2012). As an essential amino acid, BCAA plays an important role in anti-fatigue, which cannot be replaced by any other nutrients. Studies show that long-time and high-intensity exercises may lead to increase of Aromatic Amino Acid (AAA) in plasma, decrease of BCAA, promotion of AAA's transportation into the brain and increase of 5-HT's

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precursor (monoaminergic inhibitory neurotransmitter) in the brain (Busquets *et al*., 2000). 5-HT is involved in such activities as control of fatigue and restraint of multi-axon nervous reflex and sleep deprivation may result in rise of 5-HT concentration in the brain, which in turn will fatigue the body and change the behavior. Newsholme *et al*. (1991) held that 5-HT was the neurotransmitter of central fatigue and it played an important role in the sports fatigue (Cao and Su, 2011). There is a competitive inhibition between BCAA and AAA, which will restrain AAA's transportation into the brain. Given that, a great many scholars consider that proper increase of BCAA will probably delay fatigue.

Qiu (2002) confirmed that supplement of BCAA+CHO could avoid density decrease of receptor 5-HT resulting from endurance exercises and it also played a positive role in delaying fatigue during the rat's 3-week endurance training. Hu *et al*. (1997) found that oral administration of BCAA or creatine could help the mouse delay fatigue, reduce blood lactate acid density at exhaustion and postpone occurrence of sports fatigue in the body movement. According to Chen Chengxiang's study, exogenetic supply of BCAA could increase the activity of mouse with quantitative load, reduce 5-HT in the brain tissue and tryptophan's proportion to cAA and remarkably delay the occurrence of exhaustion (Chen and Zhang, 2014). Mittleman *et al*. (1998) indicated that supply of BCAA could prolong the moderate-strength movement time in thermal environment. Calders *et al*. (1997) draw the conclusion that supply of BCAA could improve the endurance performance. In terms of tests on humans, many scholars supplied those athletes participating in long-time and high-intensity sports events (e.g., marathon, cross-country skiing and football match) with BCAA before or during the competition by regarding it as a nutrition science promoting measure in their studies (Zhang, 2012; Blomstrand *et al*., 1991; Nie, 2003; Newsholme *et al*., 1991; Blomstrand and Saltin, 2001), according to which they found supply of 7.5-22g BCAA each time could remarkably improve some players' sports performance and lower the mental fatigue. Meanwhile, long-term supply of BCAA could increase endurance and athletic ability, cut down central fatigue reaction and dwindle athletes' dislike of running in the second half of long-distance race.

Stimulation of relevant hormone's secretion and regulation of protein synthesis: Since long-time exercise will lead to reduction of about 18% of protein synthesis in the skeletal muscle, the body's demands for protein will increase during this process. Studies show that BCAA's catabolism in muscles is very active and BCAA can serve as the functional substance in addition to regulating protein synthesis (He and Liu, 2004). Also, exogenetic supply of BCAA can help the central nervous system main its excitability in long-time and high-intensity exercises, which can inhibit degradation of endogenous protein and promote synthesis of endogenous protein (Lai *et al*., 1994). According to the studies of Blomstrand and Saltin (2001), supply of BCAA in drastic endurance exercise led to remarkable increase of concentration of BCAA in plasma and muscles as well as inhibition of the raise of tyrosine and phenylalanine in muscles and blood; after 2 h of the exercise, concentration of amino acid in muscles of BCAA group declined by 46% whereas that of control group reduced by 25%; the results show that supply of BCAA in the exercise can save proteins. Zhao *et al*. (1999), a scholar, adopted 15N-Glycine and 3H-Leucine isotopic tracer technique and found that protein synthesis rate of skeletal muscle was higher than that of myocardium in exercises and supply of BCAA could reduce exercises' effects on metabolism of cardiac troponin and that could facilitate synthesis of skeletal muscle protein or reduce proteolysis. Shimomur pointed out that supply of BCAA before exercises could slow the degradation of muscle protein and promote protein synthesis of skeletal muscle. Garlich *et al*. held that BCAA could promote the secretion of hormones (e.g., insulin and growth hormone) generated by the body and thus expedite synthesis of muscle protein and avoid degradation of muscular tissue.

In addition, 3-Methylhistidine, tyrosine and phenylalanine can also be used to reflect the degradation of proteins in muscles, wherein the 3-Methylhistidine is the product deriving from histidine methylation at degradation of actin and myosin in muscles and upon generation it will be excreted with urine, without being reused or further metabolism, so 3-Methylhistidine is the key indicator used to evaluate protein metabolism. Peng (2013), a scholar, found that after nasal feeding of BCAA, the bed-ridden patents' protein metabolism increased and they reached positive nitrogen balance in the body and showed remarkable increase in plasma preprotein, transferrin and retinol blinding protein; meanwhile, the patients' showed remarkable decline in protein degradation, which was reflected by dramatic decrease of urea nitrogen and 3-Methylhistidine in the urine. As AAA, tyrosine and phenylalanine can only form through degradation of muscle protein and it cannot be resorbed by skeletal muscle and its level in serum and muscle can reflect the degradation of proteins (Busquets *et al*., 2000). Blomstrand conducted a range of tests like 30 km cross-country race, full marathon and power bicycle test, the results of which showed that supply of BCAA in exercises can save proteins (Xia *et al*., 2006; Blomstrand and Saltin, 2001). According to the animal experiment of Guo Yurong, BCAA could inhibit the degradation of muscle protein (He and Liu, 2004). However, there are still uncertainties in mechanism of BCAA's influence on protein metabolism.

Protection effects: To inhibit the Delayed Onset Muscle Soreness (DOMS). Strenuous exercise will lead to slight damage of skeletal muscle cell, which will result in DOMS and reconstruction of skeletal muscle

after exercise. Since the reconstruction starts with repair of proteins damaged in the exercise, supply of BCAA cannot only promote the recovery of muscle glycogen storage but also provide raw materials for muscle repair. Some scholars deemed that supply of soy protein (containing BCAA) could inhibit the activity of calpain and relieve muscle injury (He and Liu, 2004; Bai, 2007). Wang and Liu (2015) held that BCAA could inhibit and reduce 5-HT in the brain through competition binding sites, so it probably has the effect of inhibiting DOMS pain mediating.

To maintain the level of microelement in mitochondria. Dubbed as "the powerhouse of the cell", mitochondria has more than 80% of the energy synthesis in the body and mitochondria of muscle cells cannot work normally without the involvement of K+, Mg2+ and Ca2+. Strenuous exercise may lead to mitochondrial swelling, structure damage and reduction of enzymatic activity and hinder oxidative phosphorylation of muscle cells. As a result, athletic abilities will be influenced. Herein, imbalance of Ca2+ homeostasis is a significant cause resulting in mitochondria damage. The studies of Zhang *et al*. (1999) indicated that supply of BCAA could notably antagonize the accumulation of calcium in cardiac muscle tissue and BCAA may maintain the structure and functions of cardiac muscle cell membrane and mitochondria through cAMO mediating mechanism and thus stabilize mitochondria. According to the studies of Jin *et al*. (2001) and Wang (2002) after the rats' acute movements BCAA could protect bilayer stability of their mitochondria membrane lipids of skeletal muscle, ensure normal biological functions of the mitochondria, reduce the rangeability of three mineral substances (i.e., Ca2+, Mg+ and K+) in the mitochondria and maintain the stability of sodium concentration in cells (Wang, 2002).

To keep the myocardial cells. Bai Youping's study showed that supply of BCAA could remedy disorder of aminogram in the rats' plasma resulting from movements, keep normal level of LDH, GOT, CK,α-HBDH and PK in serum and myocardium, antagonize the increase of calcium in myocardium, inhibit or relieve lipid peroxidation in myocardium and protect the activity of GSH-Px and SOD in serum and myocardium (Bai, 2007). According to Li Ailing's study, supply of BCAA could block chain reactions of free radicals or clear excess free radicals generating at ischemia and protecting ischemic myocardium (Li Ailing, 1998). The studies of Jin *et al*. (2001) indicated that BCAA probably had the effect of regulating rats' myocardium and metabolism of skeletal muscle during their movements.

To maintain blood-testis level in weight-loss body. Studies showed that substantial supply of BCAA could help weight-loss white rats fight fatigue; and supply of BCAA could assist humans in lose-weight period to maintain current weight (Lai *et al*., 1994). That was proved by the Bai Hong's test on athletes in antagonistic program and Liu Jianhong's test on professional male rowers (Liu *et al*., 2003).

Promotion effect: To promote the energy supply in endurance exercises. As a special amino acid involved in energy supply, BCAA is an important amino acid participating in energy supply in long-time and continuous exercises. According to some studies, muscles would release 50-60% glutamine and alanine after being damaged whereas BCAA only release 6%; while, among those patients suffering from liver cirrhosis energy proportion of BCAA reached up to 30%, which was related to high efficiency of BCAA used in energy metabolism. According to Huang (2003) studies on 20 rowers, supply of BCAA could promote glycometabolism and gluconeogenesis, provide energy, delay fatigue and help rowers' recover from exhaustion after exhaustion exercises or in convalescent period, but further exploration needed to be made on the mechanism (Xu and Fang, 2008). Other scholars' studies manifested that increasing the intake of BCAA could promote secretion of HGH in exercise, increase oxidation of athletes with lots of fat, improve catabolism rate of fatty acid, facilitate functions and enhance endurance (Wang *et al*., 2013). Lu (2005) held that drinking 7.5-12g BCAA beverage could alleviate accumulation of lactic acid in muscles and change in pH and the relatively strong buffer ability could enhance kinetism in anaerobic metabolism.

To improve athletes' strength. According to the studies of Liu and Shi (1992), sports nutrition preparation with BCAA as the principal component could remarkably improve cardio-pulmonary functions, reduce accumulation of lactic acid, quicken lactate metabolism, maintain metabolic balance of amino acid in plasma, increase muscular strength and enhance muscle work ability. Lai *et al*. (1994) conducted tests on athletes in antagonistic program and found that appropriate BCAA supply for athletes could better maintain their strength of thigh muscles.

To enhance the body's immunity. BCAA is closely related to the body's immune function in exercise. Studies showed that lack of BCAA could lead to the body's change in immune organs, atrophy of thymus and spleen and damage of lymphoid tissue. In particular, lack of valine could apparently impede the growth of thymus and peripheral lymphoid tissue and inhibit the hyperplasia of neutrophil and eosinophiler leukozyt. According to the studies of Gatnau *et al*. (1995), BCAA could be rapidly changed into glutamine and alaine and then they would be transported to liver, kidney and intestinal cell for use. After that, leucocyte would be generated and antibody synthesized to combine with antigen and more acute phase proteins would be produced. While, as a significant energy substance for lymphocyte and neutrophile granulocyte, glutamine can improve the multiplication capacity of leukocyte and lymphocyte. Cui and Yang (2007) studied the

concentration of glutamine in plasma of athletes participating in triathlon and found that supply of BCAA would change the generative capacity of leukocyte after exercise and boost the body's immunity. Views vary in this regard; for example, Chinese scholars (Shi and Yuan, 2003) found that supply of BCAA in long-time and high-intensity exercises would evidently relive the rats' fatigue but there was no influence on proliferation of leukocyte, according to their studies.

DIFFICULTIES OF BCAA'S APPLICATION IN COMPETITIVE SPORTS

Difficulties in actual operation: People usually take capsule orally or take BCAA powder to supplement nutriments; while, injection method is frequently used in clinical treatment. Currently, BCAA injection used in clinic treatment has 1.35 g isoleucine, 1.65 g leucine and 1.26 g valine per 100 mL. In terms of leucine and the proportion of three amino acids in BCAA, Nachbaue *et al*. (year) used BCAA solutions with 5 different mmol proportions of leucine, isoleucine and valine to inject guinea pig with sepsis and drew the conclusion that protein degradation in BCAA solution group with high content of leucine was notably lower than that in BCAA solution group with high content of valine and in general amino acid solution group. Generally, the ratio (mmol ratio) amongst leucine, isoleucine and valine shall be 1: 0.5: 0.56. Therefore, the specification of amino acid capsule in clinical treatment is usually 5g (2.5g leucine, 1.25g isoleucine and 1.25g valine) (Jiang *et al*., 2011). However, there are still some difficulties in actual operation for BCAA's application in competitive sports as nutritional supplement. For example, there is still no definite standard and a few studies on BCAA' supplement method, dosage, time, duration and concentration, proportion of three amino acids and notes for different athletes participating in various sport events in competitive sports.

Toxicity: Since ammonia is false neurotransmitter which can interfere with the functions of normal neurotransmitter in the brain, rise of blood ammonia will trigger central fatigue and even lead to ammonia toxicity. Theoretically, increasing supply of BCAA will result in more generation of blood ammonia, but up to now no toxicological tests have achieved the expected results. For example, Okazaki adopted BCAA complexing agent with single dose of 10 g/kg to inject rats and mice in acute toxicity test and found they were still alive. No toxic signs had been found when Okazaki injected the animals with the single dose of 2.5 g/kg per day for 3 months or with the dose of 1.25 g/kg per day for 1 year. Chinse scholar Xia Zhi conducted a 2-week BCAA solution (the proportion amongst leucine, isoleucine and valine was 1:1:1) gavage test on mice by adopting the gavage dose of 420 gm/kgWB and 1260 mg/kgWB and found that the mice's blood ammonia remarkably increased when the dosage amounted to 1260 mg/kg but toxic signs did not take place (Xia *et al*., 2006).

The said studies indicate that increasing supply of BCAA will lead to rise of blood ammonia in theory but there were no toxic signs in practical condition. That can be probably attributed to supply of BCAA has not reached the upper limit or BCAA's ability in generating ammonia from metabolism in exercise is not strong enough as compared with its ability in inhabiting synthesis of 5-HT. In the future, sport and exercise nutrition will focus on whether supply of BCAA can reduce or repair muscle damage in long-term training, whether there is difference on different genders and whether excessive intake of BCAA will exert negative influence on the brain the muscle and thus lead to disorder of gastrointestinal functions.

Non-effective views: Aside from that, some scholars reported that supply of BCAA had no promotion effect on athletic abilities; for example, Dutch scholars found in their studies that supply of BCAA reduced the absorption (reduction of 8-12%) of tryptophan in the brain but there was no difference between supplement group and control group in sport performance. Scholars put this conclusion down to the selection of test objects and methods, or supplement amount.

CONCLUSION

Amino acid metabolism is one of the focuses in life science research field. As the essential amino acid for the body, BCAA can get involved in energy supply in exercises, especially in long-time endurance exercises. And it also has special effect on fatigue resistance and reduction of glycogen consumption. For this reason, BCAA is currently utilized as a sport nutrition supplement. Due to the complexity of sports test, dosage of supplement BCAA has not been given a specific value and more studies need to be conducted on how to supply BCAA reasonably. Also, the mechanism of BCAA's involvement in glycometabolism has not been made clear. In addition, for a long time a great many scholars are committed to studying the effects of supply of sugar and BCAA in exercises on endurance exercise but there is still no final conclusion. Despite this, we have faith that a conclusion will be made with the application of such technologies as micro dialysis.

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