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Branched Chain Amino Acids on Swimming Athletes' Muscle Injury after Endurance Exercise

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Abstract: Due to the continuous renewal of the concept of sports training, modern training methods and means continue to emerge, promoting the scientific level of sports training, making the competition of different sports become more intense. Among them, swimming is particularly important for endurance training. Improper training methods can easily lead to muscle injury of athletes. Branched chain amino acids are important substances in the synthesis of human muscle protein, which can effectively improve the synthesis rate of human protein and the efficiency of muscle growth. Therefore, this paper attempts to explore the protective effect of branched chain amino acids on muscle injury of swimmers after endurance exercise. In this paper, 30 swimmers in our province were selected as the experimental objects, and branched chain amino acids (BCAA) were taken as the breakthrough point to explore the protective effect of BCAA on muscle injury of swimmers after endurance exercise. The experimental results show that in a training cycle, Hb will continue to decline under the increasing load, while it will significantly decrease in the heavy load training, but there is no sports anemia, and there is a recovery increase during the adjustment training. Bcca may protect cells by increasing intracellular ATP concentration. Branched chain amino acids can effectively eliminate the excess oxygen free radicals in the body after exercise, so as to reduce the damage and damage of free radicals on the normal cell membrane of the body, and prevent or reduce the lipid peroxidation reaction. BACC has obvious protective effect on muscle injury caused by exercise, and reduces muscle tissue injury.

1. Introduction

In competitive swimming, the development of athletes' competitive ability is not only the scientific selection method of athletes, but also the reasonable training means and methods selected

in each stage and the scientific sports load arrangement in many years' training. The level of endurance ability has a direct impact on the final performance of swimmers. The arrangement and implementation of swimmers' training plan should consider the physiological function changes and state of swimmers, otherwise, it will cause muscle injury of swimmers.

As an important part of swimming training, endurance training has a direct impact on the training level and competitive ability of athletes. Low intensity endurance training can improve hemorheology in sedentary patients with metabolic syndrome, which is mainly due to the decrease of plasma viscosity and the improvement of cardiopulmonary function. Brun investigated whether these findings could be extended to patients with type 2 diabetes [2]. Mursilats conducted a systematic literature review and meta-analysis to assess the chronic effects of simultaneous strength and endurance training sequences on selected important physiological and performance parameters, namely maximum body repetition and maximal aerobic capacity. According to the pre-determined qualification criteria, the chronic effect test was carried out, and the strength endurance and endurance strength training sequence of the same course were compared. The data of effect size, sample size, standard deviation and other related research features were extracted. According to the level of heterogeneity between studies, the fixed or random effects model was used to summarize the effect size, and the reverse variance heterogeneity model was used for further sensitivity analysis to adjust the potential bias caused by heterogeneity[3]. Vesterinen aims to explore the factors that influence the individual's adaptation to high-capacity or high-intensity endurance training. After the first 8-week preparation period, 37 leisure endurance runners were divided into high-capacity training group and high-intensity training group. During the next eight weeks of training, HVT increased the amount of running training and increased the intensity of training. The characteristics of endurance performance, heart rate variability and serum hormone concentration were measured before and after training[4]. Through muscle training, the central nervous system can adjust the firing rate of motor units to maintain strength output and delay fatigue. The aim of Mettler was to study the motor unit discharge rate and pattern of young healthy adults after 4 weeks of muscle endurance training after continuous sub maximal isometric fatigue contraction and activation. Mettler's study showed that although et increased, the average sport unit firing rate did not change significantly with training during fatigue tasks. The shooting mode of general sports units is to slow down first, then increase the shooting speed at the later stage of fatigue, and keep the same before and after training[5].

Branched chain amino acids are composed of leucine, isoleucine and valine. They are named for their prominent branched chains on the carbon skeleton [6]. Plasma BCAA levels continue to increase in obese and type 2 diabetic patients, and can predict T2D. However, the role of BCAA in the pathogenesis of insulin resistance and T2D remains unclear. In order to determine the related pathway of insulin resistance, lerin analyzed the gene expression and metabonomics of skeletal muscle in 41 patients with normal glucose tolerance and 11 patients with T2D[7]. Fasting plasma BCAA levels are associated with insulin resistance, but it is not clear whether there is a causal relationship between them. Mahendran's aim was to unravel causal relationships by using genetic variations associated with circulating branched chain amino acid levels and insulin resistance as instrumental variables through a Mendelian randomized study[8]. Ikeda discussed the effect and feasibility of BCAA (twice a week combined therapy and exercise) on physical function improvement in frail and former frail elderly who need long-term care. I Ikeda compared different doses of BCAA administration sequence, the two groups of patients only in the BCAA, leg pressure has a significant effect. The combination of BCAA intake and exercise therapy can significantly improve lower limb muscle strength and dynamic balance ability [9]. During the development of heart failure, the release of catabolic cytokines leads to the decrease of free fat and fat mass. The combination of resistance exercise and BCAA supplementation can reverse these changes in body

composition. Juan assessed body composition changes in patients with heart failure after resistance training programs and BCAA supplementation[10].

Recently, more and more studies have found that BCAA supplementation can promote skeletal muscle protein synthesis and inhibit protein degradation, suggesting that it may have a protective effect on exercise-induced skeletal muscle injury. Therefore, this paper adopts a placebo-controlled experimental design to explore the role of BCAA in reducing the level of swimming injury and promoting the recovery of injury.

2. Endurance Sports of Swimmers and Branched Chain Amino Acids

2.1. Swimming

Swimming is a special sport. From the special characteristics, the body is in an unstable state during the swimming process. There is no fixed fulcrum. Moreover, it is necessary to fight against the water resistance in the water. Under the condition of keeping the best streamline and reducing the resistance as far as possible, the body can move forward through the power brought by rowing and kicking, Therefore, the training of swimming special strength has its own characteristics. Swimming is a typical sport which combines strength and endurance. Strength and endurance is one of the most important qualities of the athletes. In the process of sports training, the detection, analysis and evaluation of athletes' strength ability is an important part of strength training. Effective strength training needs to be based on scientific diagnosis. One of the main development trends of strength testing is focused on the detection of muscle contraction speed. People no longer regard weight as the only standard to measure athletes' strength level, but comprehensively evaluate athletes' strength level from two aspects of weight and speed.

According to the theory of event group training in sports training, swimming belongs to the category of physical fitness dominated event group. On this basis, according to the distance classification, short-distance swimming belongs to the speed event group dominated by physical fitness, and medium and long-distance swimming belongs to the endurance event group dominated by physical fitness. Physical fitness plays a decisive role in the performance of swimmers. As for the actual level of athletes' physical fitness, it depends on the various forms and functions of the individual body, as well as the various qualities of sports. Body shape refers to the external shape of the body. Body function refers to the function of every organ in the body. Sports quality refers to the various abilities shown in sports when the body is in an active state, which often changes into specific speed and endurance, flexibility and agility. In the short distance swimming, the explosive force, movement speed, speed and anaerobic metabolism ability are usually developed, while in the middle and long distance swimming, the endurance quality of the athletes is especially emphasized. The detection, analysis and evaluation of athletes' strength quality is an important part of strength training. Effective strength training needs to be based on scientific diagnosis. In the process of testing the physical fitness athletes' function, most of the detection indexes are physiological and biochemical indexes, which have different degrees of damage, and require high requirements for testing equipment and storage conditions of reagents[11-12].

2.2. Swimming Endurance Training

Endurance refers to the ability of the body to keep moving. According to the classification of human physiological system, the human endurance quality is divided into muscle endurance and cardiovascular endurance in sports training and sports physiology, and cardiovascular endurance can be divided into aerobic endurance and anaerobic endurance. Anaerobic working capacity refers to the ability of the body to provide energy to the body through anaerobic metabolism in the process

of exercise. It is often supplied by the decomposition of ATP-CP and the anaerobic fermentation of sugar (lactic acid energy) [13]. Compared with aerobic work, the intensity of anaerobic work is increased, but the duration is reduced[14]. The basic component of anaerobic function is atp-cp. the ability of any short-term and efficient exercise, such as sprint and sprint, depends on the functional capacity of atp-cp. however, lactic acid is the material basis of speed and endurance. During the beginning and acceleration of long-term strenuous exercise, anaerobic work also plays a leading role.

Exercise, especially long-term endurance exercise, increases the oxidation of amino acids in muscle and participates in energy supply. The changes of plasma branched chain amino acids varied with exercise time. BCAA showed a significant increase under long-term negative intensity; BCAA showed a downward trend only under ultra-long-term load. The catabolism of BCAA increased during the long-term exercise, which was supposed to be related to the increase of energy supply ratio.

All the chemical reactions that nutrients undergo in an organism are called metabolism, and these reactions are continuous chemical reactions catalyzed by enzymes. In the process of metabolism, the catalytic product of the former enzyme is also the substrate of the latter enzyme, so the continuously changing enzymatic product is called metabolic intermediate product. The metabolism of organism mainly includes two aspects: anabolism and catabolism. The process that organisms use small molecules to generate their own macromolecules is anabolism, while the process of transforming their own macromolecules or macromolecules obtained from the outside into simple small molecules is catabolism. Branched chain amino acids (BCAA) are produced by the body from protein molecules, on the other hand, they participate in their own catabolism in the body. The metabolism of branched chain amino acids in the body mainly refers to their catabolism. Through a series of enzymatic reactions, a variety of metabolic intermediates can be produced, and finally decomposed into smaller units of molecules which can be used or discharged from the body.

2.3. Branched Chain Amino Acids

Valine, leucine and isoleucine are essential amino acids, which are mainly derived from diet or hydrolyzed by the body's own old proteins, and then dehydrated and condensed with other amino acids on ribosomes to produce new proteins. These three amino acids belong to hydrophobic amino acids in physical and chemical properties, which largely determines their role in protein structure. In globular proteins, they are usually located inside and provide a hydrophobic active center. Membrane proteins need hydrophobic amino acid groups to form the transmembrane region. Studies have shown that the content of BCAA in some transmembrane proteins is high. During the catabolism of branched chain amino acids, many intermediates containing carbon skeleton are produced. These intermediates can also participate in other metabolic pathways in the cell to generate ketones, glucose and glycogen. Branched chain amino acids, as small molecules with regulatory function, play other important biological functions in organisms. Branched chain amino acids participate in energy supply and play an important role in the energy supply process of long-term sports. The decomposition of BCAAs in muscle is very active, which can complete the process of ammonia conversion and oxidation quickly. The efficiency of ATP production by BCAAs oxidation is much higher than that of other amino acids. When the body is at rest, this process can even provide some energy for skeletal muscles. When the body is in the state of exercise, the catabolism of BCAAs can be further strengthened. The mechanism may be that the hormone secretion promoting catabolism increases during exercise, which improves the enzyme activity of oxidative decomposition of BCAAs and the energy utilization efficiency of skeletal muscle, which makes BCAAs an important energy source in exercise. The increase of plasma free BCAAs content

can improve the absorption and utilization efficiency of muscle. Timely supplement before or during long-term exercise can provide timely energy supply for the body. It can not only avoid the absorption of liver but also be quickly used by skeletal muscle. Moreover, BCAAs can also generate glucose or store in the form of glycogen during gluconeogenesis in the liver, Thus, the consumption of sugar and glycogen can be reduced in two ways. The catabolism of BCAA in muscle is very active. Compared with most other amino acids, BCAA can convert to amino group and completely oxidize at a fairly fast rate, and provide amino groups for alanine and glutamine. The decomposition products of BCAA, such as acetyl coenzyme A and succinate monoacyl coenzyme A, enter the tricarboxylic acid cycle and release a lot of energy. Moreover, the efficiency of BCAA oxidation to produce ATP is higher than that of other amino acids. Amino acids do not participate in oxidative energy supply during quiet state and general exercise, but BCAA is an important energy source in some special physiological states. Fasting can increase BCAA oxidation rate several times and decrease protein synthesis; muscle oxidation of BCAA trans amino product α - keto acid can be increased several times during fasting; BCAA transaminase activity and Leu oxidation rate in mammary gland of lactating rats are increased.

Because athletes have been trained for a long time and adapted to a large amount of training, their muscles are no longer sore, but there is often a phenomenon of brain fatigue, which is caused by the secretion and regulation of neurotransmitter "5-hydroxytryptamine". The secretion of 5-hydroxytryptamine can stimulate the motor nerve to keep excited, but with the increase of secretion, people will be in a relaxed state. When the secretion is excessive, the human body will feel a kind of drowsiness and fatigue. Tryptophan in branched chain amino acids is an important substance in the synthesis of 5-hydroxytryptamine, which can effectively control the synthesis of 5-hydroxytryptamine, and then inhibit the generation of central fatigue.

In the process of long-term endurance exercise, BCAAs can inhibit ubiquitin protease system and autophagy lysosome system, reduce muscle protein catabolism through self-oxidation, and may also have an active effect on protein synthesis through mammalian rapamycin target protein complex. The effect of BCAAs on protein metabolism is mainly caused by leucine, which may be because Leu intake can increase the expression level of leutrna, thus promoting protein synthesis by stimulating the synthesis of polypeptide chain. This effect of Leu may be related to the tran Scepter function of latl, that is, Leu acts as a receptor while transporting Leu into the cell. It upregulates the expression of mTOR protein through unknown pathways, and induces downstream proteins such as P70S6K and 4E BPL to produce cascade effects. 1. As a substrate for glutamine synthesis, β - hydroxy - β - methylbutyric acid is also a regulator of protein synthesis. HMB may also reduce muscle injury and protein decomposition, and induce positive nitrogen balance. As far as glutamine itself is concerned, it can not only transport nitrogen, but also be used to synthesize protein to promote muscle growth.

3. Experiments Materials and Methods

3.1. Subjects

In recent half a year, the healthy and healthy male athletes will be selected. In the first half month, they did not take traditional Chinese medicine and Western medicine with the main purpose of enhancing sports ability and anti-fatigue. A total of 30 swimmers were randomly divided into experimental group and control group, 15 in each group.

3.2. Experimental Methods

All the athletes in the study stopped using any sports health products half a month before the

experiment. After the experiment was officially started, the athletes in the experimental group and the control group were given normal diet. The athletes in the experimental group took four capsules of extreme BCAA capsules three times a day for four weeks. The control group was given placebo, which was a capsule containing starch, similar in appearance to BCAA capsule. During the observation, all subjects were trained according to the original training plan.

After four weeks of BCAA supplement, the athletes were tested on the dynamometer. After the preparatory activities on the swimming dynamometer, the athletes completed the distance of 500 m and & 1000 m respectively with their maximum ability, and the group took a half hour rest. Before the test, immediately after the test and half an hour after the completion of the test, blood samples were collected, and serum creatine kinase, lactate dehydrogenase, alanine aminotransferase and other indicators were analyzed and determined. SPSS 10.0 software was used for statistical analysis, and paired bilateral t test was used. When the significance level was $p < 0.05$, the difference between the two groups was significant. The formula of mean and standard deviation is as follows:

$$\mu = A_n = \frac{a_1 + a_2 + a_3 + ... + a_n}{n} \tag{1}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \tag{2}$$

4. Analysis on the Protective Effect of Branched Chain Amino Acids on Swimming Athletes' Muscle Injury

4.1. Changes of sTfR and Hb in Endurance Training Cycle

After the first three weeks of incremental exercise, sTfR showed a trend of gradual decrease, and then gradually increased in the process of adjustment. Statistical analysis shows that: in the whole process, the sTfR decrease after a week of heavy load training is significantly different from that before training, and there is no significant difference in other time pairwise comparison. The changes of sTfR and Hb in endurance training cycle are shown in Figure 1.

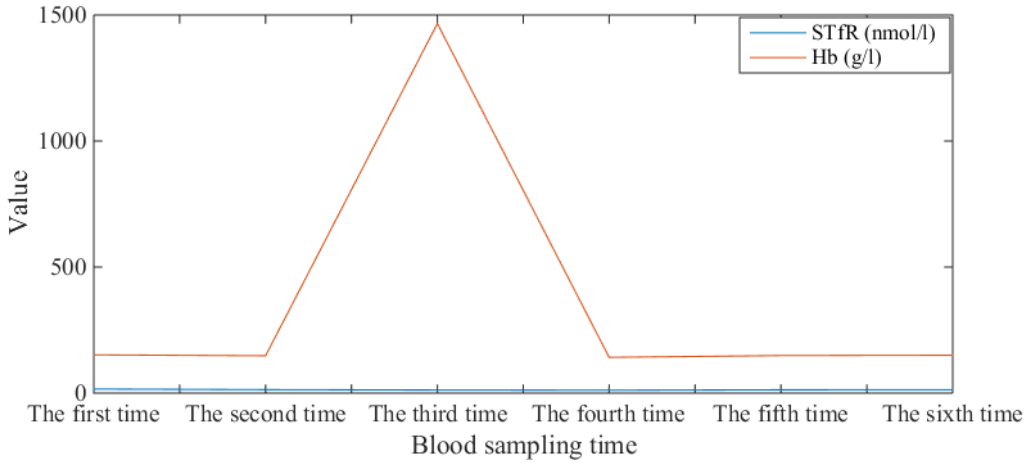

Figure 1. The changes of sTfR and Hb in the endurance training cycle

In this training cycle, with the increase of training load, Hb of athletes shows a gradual downward trend. After one week and two weeks of training adjustment, Hb gradually increases. In the whole process, only after the third week of heavy load, there was a significant difference

between the results and the quiet value, and there was no significant difference in other times. It is suggested that the adjustment period of two weeks may be shorter, or the load in the adjustment period should be reduced again. With the increase of load, Hb gradually decreased, and finally recovered in the process of adjustment, which was in line with the change law of endurance events. Statistical analysis showed that the change was statistically significant during heavy load exercise, indicating that the periodic changes of Hb of endurance athletes were consistent. Although HB has a significant decline, but the whole process did not appear sports anemia phenomenon, in the training cycle of small and medium load stage, Hb decline is not significant, which may be related to the specific training plan of small and medium load during exercise, and may also be related to the characteristics of swimming: swimming is different from the track and field events of middle and long distance running, because there is no impact on joints and soles of feet, The injury of water sports on Athletes' body is lighter, and the hemolysis of red blood cells caused by mechanical factors is also lighter. In a training cycle, Hb will continue to decline under increasing load, while it will significantly decrease in heavy load training, but there is no athletic anemia, and there will be a recovery increase during adjustment training.

4.2. Analysis of the Effect of BCAA Deletion on Induced Cell Damage

In this paper, a cell culture medium lacking branched-chain amino acids is used to starve cells with branched-chain amino acids. Firstly, the primary cardiomyocytes were starved with BCAA for 1 hour, and then the cells were stimulated with H2O2. The analysis of the effect of BCAA deletion on induced cell damage is shown in Figure 2.

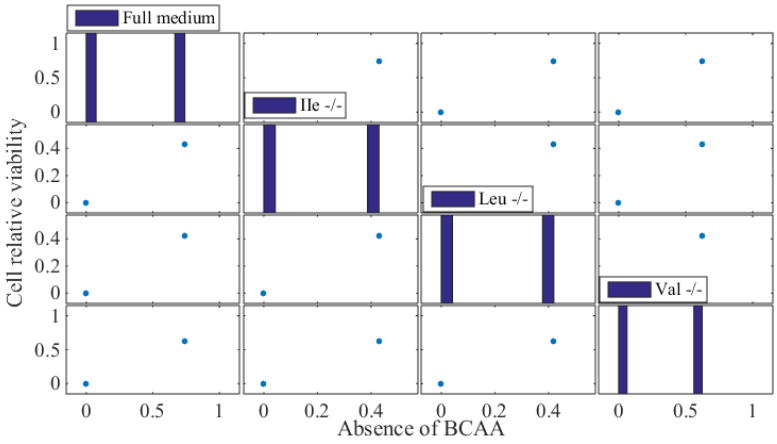

Figure 2. Effect of BCAA deletion on cell injury induced by BCAA

From the cell morphology, we can see that after H2O2 stimulation, the cells in the complete culture medium and BCAA deletion medium culture conditions have cell death, and BCAA deficient culture of cardiomyocytes die more. In the same way, immortalized embryonic fibroblasts were cultured in the medium of isoleucine, leucine and valine respectively for 3 hours, and then stimulated with H2O2. The results of MTT assay showed that under the conditions of three kinds of branched chain amino acid deficiency, the cells died more after H2O2 stimulation. When the cells were cultured in complete medium and treated with H2O2 and supplemented with BCAA or BCKA, the cell death rate was significantly reduced. The results showed that the ATP level decreased gradually after H2O2 was added, but the ATP level recovered to a certain extent when H2O2 and bcca were treated at the same time. It is suggested that bcca may protect cells by increasing intracellular ATP concentration.

4.3. Analysis of the Effect on Liver Glycogen and Muscle Glycogen

The contents of liver glycogen and muscle glycogen in high-dose group and low-dose group after exercise were significantly higher than those in control group. The content of liver glycogen in high-dose group was significantly higher than that in control group, indicating that high-dose group can effectively increase hepatic glycogen reserve. The effects of different components on liver glycogen and muscle glycogen after exercise are shown in Table 1.

Table 1. Effects of different components on liver glycogen and muscle glycogen after exercise

Group	Liver glycogen (mg/g)	Muscle glycogen (mg/g)
High dose group	39.54±4.32	3.92±0.69
Low dose group	37.03±2.63	3.95±0.64
Normal control group	32.95±4.93	3.23±0.71

The contents of liver glycogen and muscle glycogen in the low-dose group were also significantly higher than those in the control group. The increase of liver glycogen and muscle glycogen is helpful to reduce the catabolism of protein and nitrogen compounds, inhibit hypoglycemia in the later stage of exercise, alleviate the decline trend of ATP synthesis speed, improve exercise ability and endurance, maintain the stability of blood glucose concentration, thus playing an anti-fatigue effect. The experimental results show that the effect of high dose group is better than that of low dose group. The influence of T-SOD and GSH PX activities in different groups is shown in Figure 3.

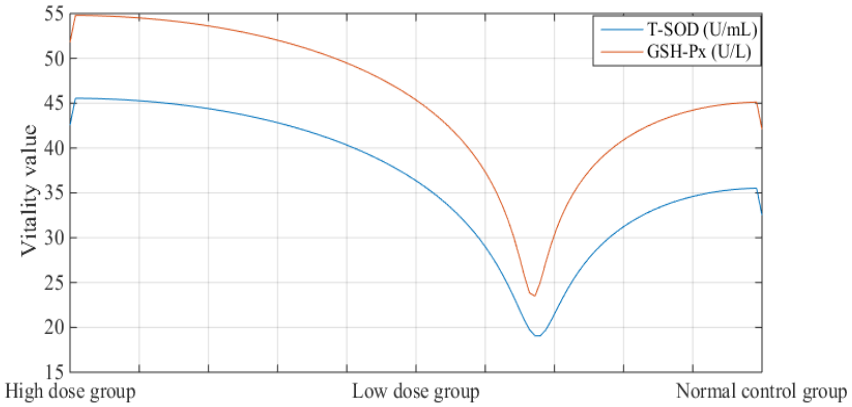

Figure 3. Effect of T-SOD and GSH PX activities in serum of different groups

Compared with the control group, the activity of T-SOD in the high-dose group and the low-dose group was increased to a certain extent. The results show that branched chain amino acids can improve the activity of SOD in serum to a certain extent, so as to eliminate the superoxide anion produced in the process of exercise, so as to prevent or reduce the lipid peroxidation reaction, and play a certain role in delaying fatigue. The activity of GSH PX in serum of swimmers in high-dose group and low-dose group was higher than that in control group. These results indicate that branched chain amino acids can increase the activity of GSH PX and improve the efficiency of scavenging hydrogen peroxide. Moreover, the effect of high dose group was lower than that of low dose group. Branched chain amino acids can effectively eliminate the excess oxygen free radicals in the body after exercise, so as to reduce the damage and damage of free radicals on the normal cell membrane of the body, and prevent or reduce the lipid peroxidation reaction. This is also a protective effect on the motor central nerve, reducing the damage of central nerve cells.

4.4. Changes of Serum CK, LDH and ALT Activities in Two Groups of Athletes before and after Simulated special Endurance Test

After specific endurance exercise, the serum ALT activity of the control group had no significant change immediately after exercise and half an hour after exercise. The changes of serum CK, LDH and ALT activities of the two groups of athletes before and after the simulated special endurance test are shown in Table 2.

Table 2. Changes of serum CK, LDH and ALT activities before and after the simulated special endurance test of the two groups of athletes

Group		BACC group	Control group
When quiet	CK	3.87±1.21	3.87±0.85
	LDH	4.43±1.53	5.46±2.25
	ALT	4.67±2.07	5.84±1.84
Immediately after exercise	CK	3.75±0.71	3.82±1.23
	LDH	4.03±0.69	4.72±0.92
	ALT	4.56±1.42	4.82±2.36
Half an hour after exercise	CK	0.62±0.15	0.64±0.19
	LDH	0.64±0.16	0.57±0.24
	ALT	0.56±0.18	0.56±0.27

Serum CK and LDH activities increased immediately after exercise and half an hour after exercise compared with those before exercise. The serum CK and LDH activities in BCAA group increased immediately after exercise compared with those before exercise, but there was no significant difference, and they were significantly lower than those of the control group immediately after exercise. Half an hour after exercise, the activity of CK was significantly increased compared with that before exercise, and the activity of CK was also significantly lower than that of the control group at half an hour after exercise. The changes of serum CK, LDH and ALT activities of the two groups of athletes before and after the simulated special endurance test are shown in Figure 4.

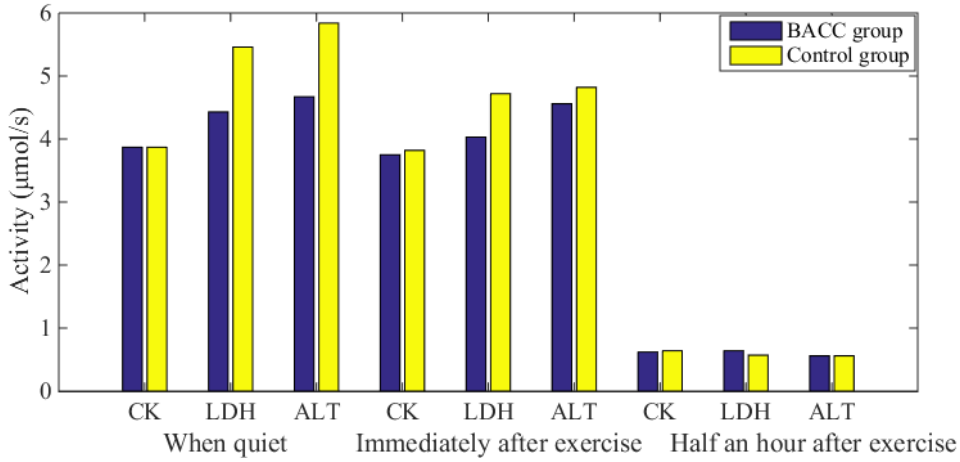

Figure 4. Analysis of the changes of serum CK, LDH and ALT activities before and after the simulated special endurance test of the two groups of athletes

The activity of CK and LDH in the control group was significantly higher than that in the pre exercise and post exercise period, which indicated that the intensity of exercise load was one of the

main reasons for the increase of serum enzyme activity. The activity of CK and LDH in BACC group increased significantly in the recovery period after exercise, and the value was significantly lower than that in the control group immediately after exercise; the activity of ALT did not change significantly in both groups, indicating that BACC has obvious protective effect on muscle injury caused by exercise and reduces the injury of muscle tissue.

5. Conclusion

Excessive exercise will bring fatigue to muscles, nerves and other tissues. Taking branched chain amino acids can effectively increase the secretion of 5-hydroxytryptamine, thus stimulating Swimming Athletes' motor nerves to maintain a certain degree of excitement. Tryptophan in branched chain amino acids is an important substance in the synthesis of 5-hydroxytryptamine, which can effectively increase the synthesis of 5-hydroxytryptamine, and then inhibit the generation of central fatigue, and restore the content of liver glycogen and muscle glycogen of swimmers at normal level. Therefore, supplement of amino acids and other nutrients has a good effect on sports central fatigue.

BCAA can effectively reduce muscle soreness after strenuous endurance exercise and promote muscle recovery. This effect may be related to the fact that BCAA can be used as a substrate to synthesize protein to promote injury repair; BACC may promote skeletal muscle protein synthesis through other unknown molecular mechanisms. The mechanism remains to be further explored.

We found that BCAA may be involved in the regulation of certain cell death pathway, and this pathway has no obvious correlation with the known death pathway. This discovery greatly enriched the research on the relationship between nutritional stress and cell death, and the relationship between branched chain amino acids and cell death also enriched the research field of amino acids regulating cell death. Unfortunately, the current work cannot confirm what kind of cell pathway bcca is involved in; this will be the focus of future work.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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