Progress on the application of functional dietary supplement in sports science

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Abstract. Functional dietary supplements are now regarded as an important factor to keep physical health, maintain exercise status and improve athletic performance. More and more sports industries are focusing on such supplements, which makes the industry develop rapidly and pay more and more attention to the research and development of different products, functions and the efficacy of health care. In this paper, the functional dietary supplements were classified and summarized, and energy supply supplements were discussed in detail: glucose and Adenosine Triphosphate; Exercise protection supplements: chondroitin sulphate, glucosamine, collagen, vitamin D and calcium; Endurance supplements: strength supplements such as protein, creatine, β -alanine, epicatechin, and taurine. The existing problems of functional dietary supplements were analysed and summarized, and the future development prospects were prospected, hoping to provide references for the development and research of new products of functional dietary supplements.

1 Introduction

Functional dietary supplements are now used by athletes as part of their regular competition. According to the survey, dietary supplement use is common among male and female athletes in all countries. The literature shows that 32-90% of elite athletes are suitable for dietary supplements. [1] For some elite athletes, nutritional dietary supplements can bring great benefits to daily training and competitions, such as improving the adaptability of training, increasing the athletes' recovery ability, so as to make training more lasting and efficient, and finally achieve better competitive results in competitions. [2] When an athlete is diagnosed with a deficiency that cannot be adjusted based on improved diet, necessary dietary supplements can help athletes improve their performance.

Dietary supplements are widely used throughout the world. A dietary supplement is defined in the United States Dietary Supplement Health and Education Act (DSHEA) of 1994 as an absorbable dietary supplement consisting of vitamins, minerals, herbs or plants (including herbs or plant extracts), amino acids, metabolites or any other combination. Creatine, antioxidant vitamins, multivitamins, and amino acids were found to be the most commonly used dietary supplements to motivate elite sports. [3]

There are many factors that influence the prevalence of dietary supplements, such as gender, [3] A study of British junior track and field athletes at the World Youth Championships found that 62% of them used functional dietary supplements, with more women than men; Athletes who are in their formative years (ages 13 to 19) are also more likely than adults to require dietary

supplements at a rate of 22% to 71% [4]; Type of exercise, such as 85% of track and field athletes using dietary supplements [5], Aquatics athletes use creatine, caffeine and buffers [7], The percentage of individuals using supplements appears to be higher than the percentage of groups using them. Athletic performance is also a major factor affecting dietary supplements.

Functional dietary supplements are rarely supported and managed by some reliable studies, which cannot avoid the corresponding disadvantages brought by such functional dietary supplements and may have serious side effects [6]. The excessive intake of such products does not preclude a certain degree of negative impact on athletes, who often do more harm than good when they use them without a full understanding of the dangers of the nutrient. For example, iron supplements are potentially harmful, and prehormones such as androstenedione can have negative health effects while increasing muscle mass or strength. [5,7] Doping has been a hot topic in the sports world for a long time, and the harm caused by long-term use of a single supplement in high doses is unimaginable.

With DSHEA, the U.S. Food and Drug Administration is regulating dietary supplements as a new way to eat. Dietary supplements are divided into three categories: those that are health-related, those that are nutrient-related, and those that have been effectively evaluated in relation to structure/function. Therefore, it is necessary to test and administer supplements for athletes of all sports, races and stages to reduce the harm caused by such supplements.

This paper presents a systematic comprehensive review of the literature, which mainly discusses the functionality, practicability and safety of the functional

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dietary supplement by combining several components of the common dietary supplement with corresponding different groups of athletes.

2 Energy dietary supplement

Fig.1. The chemical structure of triphosphadenine

All forms of exercise provide energy directly in the body with triphosphadenine (ATP), its chemical structure was shown in Figure 1. During exercise, the body obtains and produces ATP by breaking down sugars, fats and proteins. Three food ingredients: sugar, fat and protein, which can through aerobic metabolism and anaerobic metabolism. Therefore, in endurance exercise, direct sugar supplementation can maintain the blood sugar level during exercise and save the glycogen reserve in the body. Sugar is a more efficient fuel for exercise than fat.

Among sugars, professional athletes often choose glucose, a simple sugar, as a quick energy supplement because it is well absorbed in the blood. Glucose, defined as the smallest molecular weight sugar, is the basic form found in the body. People usually convert carbohydrates from food into glucose in the body and then directly provide energy. The excess glucose is stored in muscle tissue and liver tissue in the form of glycogen. At rest, sugar is used at a relatively low rate and is stored in muscle glycogen. With the increase of exercise intensity, the utilization of sugar also increases gradually. As intensity of exercise closed to VO₂ Max, almost all of the energy needed for muscle contraction is supplied by sugar.

Exercise is generally divided into aerobic exercise, such as cycling, dancing, jumping rope, rowing, etc., and resistance exercise, such as some upper body, lower body and abdominal weight training forms. [8] Either form of exercise is associated with regulation of glucose homeostasis, glucose transport and metabolism in skeletal muscle. Skeletal muscle plays an important role in maintaining blood sugar and glucose metabolism. First, skeletal muscle absorbs glucose on the surface through a transporter protein from the extracellular fluid and into the cell. There are many subtypes of glucose transporters in skeletal muscle, among which GLUT1 is the most important subtype in basic glucose transport.[9] When glucose enters skeletal muscle, it is phosphorylated by hexokinase to form glucose-6-phosphate, which is stored in cells and transported to muscles according to different metabolic pathways.

The storage of endogenous glycogen and the circulation of glucose in plasma become the key to timely energy supply. Timely carbohydrate supply was chosen by athletes as the most common way. Studies have shown that ingestion of carbohydrate (CHO) can improve performance and prolong exercise time. [10] Early studies showed that ingestion of CHO could maintain blood glucose concentration and oxidation rate of CHO, and experimental data showed a significant increase in exercise ability by 33%. [11] CHO appears in the form of CHO- electrolyte beverage during exercise, which has significant effects in terms of improving time and exercise intensity. Although the timely supply of CHO does improve the ability of movement, the underlying mechanism is still being studied. Some scientists believe that CHO supplementation in endurance athletes may have a negative effect on blood lipid and insulin sensitivity. [12]

3 Protective dietary supplements

Professional athletes are exposed to high-intensity exercise environments, aerobic and anaerobic, with training patterns of running, jumping, dribbling, throwing, or competing with opponents. [13] This series of exercises gradually increases the risk of skeletal injuries, which are usually reported in the upper and lower limb joints and have a high probability of recurrence. [14]

Osteoarthritis often occurs in athletes. It has been recently documented that 80% of middle and former professional football players have osteoarthritis of the knee and ankle joints, while more than 90% of former professional football players have moderate or severe joint disease. [15] OA is a joint type disease caused by the overuse of articular cartilage, which will lead to a series of irreversible pathological changes of joints, accompanied by pain, stiffness, motor dysfunction, functional instability and other discomfort, resulting in limited motor performance. The most common treatment regimen for OA is the use of non-steroidal anti-inflammatory drugs (NSAIDs), cartilage protection drugs, and some nutrients. Cartilage protection drugs can delay the degeneration of cartilage and even improve the regeneration of cartilage structure on the basis of disease treatment. Glucosamine, hyaluronic acid and chondroitin sulfate are important building blocks found in cartilage and synovial fluid that can be synthesized automatically by the body and obtained from food. [16] In this report, chondroitin sulfate was emphasized.

3.1 Chondroitin sulfate

Chondroitin sulfate (CS), a natural glycosamine composed of alternating glucuronic acid and N-acetyl-d-galactosamine, is an important component of the extracellular matrix. In cartilage, it's primarily responsible for keeping the cartilage hydrated and resisting pressure. It can be extracted from cartilage in animals. CS is highly rated by the European Rheumatic League (EULAR) in its recommendations for intake of

osteoarthritis of the knee. CS has been shown to have a considerable positive effect on anti-symptoms such as OA pain and inflammation. According to the experimental study of CS, CS affects the pain of osteoarthritis, [17], and has knee joint space [18], and has a positive improvement in joint structure and symptoms [19]. CS leads to the synthesis of collagen and proteoglycans. After long-term research and experimental conclusion analysis, CS supplement is an excellent choice for joint diseases, and long-term use will not cause a series of safety problems.

3.2 Glucosamine

Glucosamine play an important role in the synthesis of proteoglycan in cartilage matrix, and the water binding in the body acts as buffer to lubricate and protect the transparent cartilages. Glucosamine can be supplemented in the form of a diet. In the early stage of joint degeneration, the biosynthesis of aggregated glucosaccharide would increase gradually. In the later stages of the disease, they gradually decrease. These symptoms affect cartilage elasticity, so supplementation with amino monosaccharides is needed to stimulate chondrocytes to produce normal glycoproteins and inhibit enzymes that have a negative effect on articular cartilage. Although most studies have shown that glucosamine has a positive effect in treating and improving the symptoms of osteoarthritis, reducing pain, improving joint function and inhibiting the course of osteoarthritis, the effectiveness of glucosamine remains to be evaluated.

3.3 Collagen

Collagen is an important component of skin, bone and connective tissue. Collagen can be roughly divided into types 1, 2 and 3. Gelatin and collagen have long been used as dietary supplements to improve bone and joint health. Collagen peptide accumulation in collagen plays a protective role in articular cartilage and has a positive effect on the regenerative function of hyaline cartilage [20]. In Oesser and Seifert's study, it was found that adding collagen peptide directly stimulated type II collagen and proteoglycan to alleviate joint pain during exercise. [21] Collagen also has anti-inflammatory properties. The hydrolyzed collagen is composed of unique amino acids rich in glycine, proline, and hydroxyproline. The results showed that oral collagen had positive effects on the protection and improvement of bone collagen. [22]

3.4 Vitamin D and Calcium

In sports training, due to the long-term jumping and endurance training, the injury of athletes' bones and muscles is inevitable. Studies have shown that the appropriate supplementation of vitamin D and calcium can reduce the incidence of fractures, but vitamin D alone does not improve the outcome significantly.

Vitamin D is a fat-soluble vitamin that can effectively promote the absorption of calcium and phosphorus by small intestinal mucosa and the reabsorption of calcium and phosphorus by renal tubular cells. By supplying calcium to the muscles through blood transport, the bones facilitate bone formation and calcification. Studies have shown that vitamin D can also improve muscle function, but the results have been modest due to differences in the amount of vitamin D. [23] Currently, the Institute of Medicine advise adults should take 450 IU/D of vitamins D per day to meet their basic needs.

Sources of vitamin D can be obtained through natural pathways of direct sunlight and dietary supplements. [24] A number of studies have found that athletes are deficient in vitamin D mainly because of insufficient sun exposure and lack of vitamin D supplements in the diet.

The researchers speculate that the function of vitamin D and calcium is closely related, because vitamin D promotes the absorption of calcium in the gut and thus reduces excretion by the kidneys. The importance of calcium to bones and muscles can be seen in the fact that 99% of calcium is found in bones. Vitamin D supplements alone do not relieve calcium deficiency in osteoporosis. It is recommended to choose a combination of calcium supplements and vitamin D to avoid bone disease and maximize its function.

4 Strength-enhancing supplements

4.1 Protein supplements

Proteins are the material basis of body and participate in all the activities of the life. The basic building blocks of proteins are amino acids. Protein plays an essential role in exercise and is the main substance needed for muscle growth. Long-term intake of protein during exercise can improve the basal metabolic rate and increase the synthesis rate of muscle protein, help the body burn fat, improve exercise level, make quick repair of muscle, relieve muscle fatigue and other benefits. [25]

At present, whey protein and soy protein are mostly selected as sports nutritional supplements in the sports market. Both proteins contain essential amino acids.

Soy protein in plant protein when the complete protein, nutritional value can be compared with animal protein, when the most nutritional value of plant protein, its advantage is that soy protein does not contain cholesterol.

Whey protein is one of the high-quality protein supplements for human body. Among all kinds of proteins, the animal protein with the highest nutritional value contains 8 kinds of amino acids necessary for human body, rich in leucine, functional peptides, antioxidants and immunoglobulin. The amount is more in proportion to the human body's needs. Whey protein can greatly improve the antioxidant capacity of iron, immunity and repair of muscle damage during exercise [26] Whey protein is more beneficial to muscle growth than soy protein. Studies have shown that taking whey protein during exercise can prevent the imbalance of

cellular immune function caused by exercise training, increase the serum protein in the body reserve, reduce the immune stress response after strenuous exercise, so that athletes can reach the best state during exercise. West et al. took whey protein or energy-matching placebo for 12 athletes during recovery and found that the whey protein supplement could enhance the body's anabolic metabolism. [27]

As more and more people exercise, the product of this kind of protein has become the hot spot of exercise diet nutrition. Whey protein hydrolysate polypeptides have been found to be more easily digested and absorbed by the human body when taken after exercise, which can promote the oxidative energy supply of glucose and the synthesis of muscle glycogen [28], which can accelerate the absorption and utilization of polypeptides and amino acids in the body, especially in the elimination of fatigue and repair of tissues and organs. [29] However, such products can only play their role in a long period of time if they cooperate with the movement.

4.2 Creatine

Sports are generally a wide range of ambient endurance training and strength training. It requires athletes to complete a series of strength training under the condition that the muscles are not injured. Creatine is divided into endogenous and exogenous creatine, which can be synthesized from arginine, methionine and glycine in the liver and kidneys. Exogenous creatine is a kind of supplement commonly used by athletes to provide energy for muscles during explosive movement. Creatine is essential for the synthesis of adenosine triphosphate, stored in muscles in the form of phosphocreatine.

Exogenous creatine is obtained from meat, which also could explain the fact that why athletes need to eat a lot of high-quality meat to provide energy during training. Creatine can increase the ability to explode during exercise. This is because creatine can increase the storage and resynthesize of phosphocreatine in skeletal muscles and has a protective effect on muscles, reducing the consumption of lactic acid by muscles to obtain ATP. [30] Timely supplementation of creatine phosphate during high-intensity exercise can increase the storage of creatine phosphate, form ATP, maintain the ATP level during exercise and promote the intermittent resynthesize of creatine phosphate during continuous exercise. In summary, the supplementation of creatine has a positive effect on intermittent, short duration and high intensity exercise. [31] In addition, long-term creatine supplementation can also improve the ability of strength exercise and sprint exercise. With a normal diet, 5.0 g of creatine per day combined with strength exercises is beneficial. [32]

4.3 β -alanine

β -alanine is a naturally occurring non-essential amino acid. The amino acid is thought to be part of muscle building and repair and a substance involved in the body's motor metabolism. When the human skeletal

muscle body moves, the acid product in the bone increases gradually, the pH value drops, the energy liquid that the muscle consumes increases gradually. The peptide muscle composed of β -alanine and L-histidine has a positive contribution to exercise ability. Scientific studies have shown that a daily intake of 1.2 g β -alanine increases muscle carnosine levels, which return to normal after 6-20 weeks of cessation. [33] But the intake of too much β -alanine can have side effects, such as abnormal muscle soreness and tingling skin. [34] Studies have found that muscle symptoms begin when humans consume 4.8 g of β -alanine. Long-term quantitative supplementation of β -alanine to the muscles can significantly improve the performance of the body. In addition, several studies also have found that the intake of β -alanine along with the sodium bicarbonate is beneficial to improve the persistence of athletics in high-intensity exercise.

5 Endurance supplements

5.1 Epicatechin

Epicatechin is a naturally occurring white crystalline flavanol compound that dissolves easily in water. It exists in tea and dark chocolate in daily life. Epicatechin is one of the active ingredients in dark chocolate, which has many health benefits.

Studies have shown that epicatechin plays an important role in enhancing human endurance during exercise. In animal exercise experimental models, feeding mice for 15 consecutive days was found to increase the resistance to skeletal muscle fatigue, the number of mitochondria, and the formation of blood vessels. [35]. Epicatechin had no significant effect on skeletal muscle growth but had a positive response to increased endurance. There is a corresponding synergistic effect between epicatechin supplementation and exercise training, meaning that only when epicatechin supplementation is combined with exercise training, it has the effect of increasing endurance.

Epicatechin also has the important influences in lipid metabolism and glucose metabolism of the body. According to the study of adults after eating fat and observation data of the glucose metabolism, supplementary epicatechin (calculated by body weight 50.0 kg, adult athletes need 50.0 mg epicatechin), athletes showed a lower content of rough endoplasmic reticulum, lipid oxidation on the increase. In addition, the blood glucose concentration after epicatechin supplementation was also lower than that without epicatechin supplementation. [36]

Based on the above studies, epicatechin has a good effect in promoting mitochondrial biosynthesis and acting as an auxiliary agent for lipid oxidation, and epicatechin has a good application prospect as a new type of exercise dietary supplement.

5.2 Taurine

Taurine is a thionine derived from animals. It was originally isolated from the bile of cattle, thionine was given the name taurine, and it was later found not only in cattle, but also in other animals and humans. Taurine can be derived not only from the liver for biosynthetic purposes, but also from food intake.

Taurine is produced in vivo by methionine and cysteine metabolism of the intermediate products of cysteine in the role of decarboxylase of cysteine sulfonic acid decarboxylase under the action of decarboxylase to produce subtaurine, taurine through oxidation and finally taurine.

Recent studies have shown that taurine can maintain and protect the motor function of skeletal muscles. During exercise, calcium can be promoted to participate in excitation-contraction process, which can help cells resist oxidative stress response. The study found that 10 athletes completed 60 eccentric biceps contractions with maximum effort. After that, athletes took taurine supplement twice a day (0.1 g/kg according to human body weight) and took it for 3 days, which greatly improved the functional recovery of biceps. [37] In addition, taurine also has a positive effect on human endurance. By oral administration of different doses of taurine, generally 1.0 – 6.0g can significantly improve human endurance and enhance the body's resistance to fatigue [38].

6 Conclusion

With the progress of society and the improvement of residents' living standard, people pay more and more attention to healthy physical exercise. In physical exercise, functional dietary supplements become one of the essential foods for athletes and bodybuilders. This essay focuses on summarizing functional dietary supplements such as energy supply, exercise protection, strength enhancement and endurance improvement, and obtains knowledge of experimental effect evaluation from the aspects of efficacy components, mechanism of action and animal model or human intake.

However, according to the summary report of this paper, it is found that the current development status of functional dietary supplements has some problems as well as great market potential, such as the uneven quality of products on the market. The efficacy of products is exaggerated through new media or propaganda, which leads to the mistake of public cognition and makes it impossible to treat such products scientifically. There is a big gap in the regulatory measures, lack of professional, standard evaluation.

Future development may need to improve the nutrition, efficacy and safety of products, classify products according to different functions of products, and form a benign industry; Secondly, the formula of the product is optimized by using known functional ingredients. Finally, the platform of sports nutrition and health service system should be improved to standardize the related work of functional dietary supplements.

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