

Review

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Nutraceuticals for Athletes

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ABSTRACT

It is widely known that athletes used to rely on training and good nutrition to provide maximum results. But now to maintain a competitive edge, athletes are switching to nutraceuticals. They are dietary supplements that provide health benefits. Nutraceuticals and dietary supplements are now commonly used to enhance and improve the health and performance of athletes. This has triggered the sale of nutraceuticals in the market and stores and gyms are selling hundreds of different supplements. These nutritional supplements usually claim to improve strength, performance and stamina, help build lean muscle, and help to burn excess fat. There are many health and nutritional supplements available in the market for the athletes. It is a difficult choice to choose the suitable and appropriate nutraceutical for oneself. The present article will introduce the athlete to a variety of different nutritional health supplements available in the market including fat burners, conjugated linoleic acid (CLA), numerous essential fatty acids (EFAs), creatine, whey proteins, glutamine, *Tribulus terrestris*, beta-hydroxy beta-methylbutyrate (HMB), methoxyisoflavone, and *Cordyceps*.

KEYWORDS: Nutraceuticals; Athletes; Nutrition; Health; Whey protein; Creatinine; *Cordyceps*; *Tribulus*.

ABBREVIATIONS: CLA: Conjugated Linoleic Acid; EFAs: Essential Fatty Acids; HMB: Beta-hydroxy beta-methylbutyrate; NHIS: National Health Interview Survey; FDA: Food and Drug Administration; IOC: International Olympic Committee; RDA: Recommended Dietary Allowance; BCAAs: Branched Chain Amino Acids; GMP: Glycomacropeptide; TGF- β : Transforming Growth Factor-Beta; PUFAs: Polyunsaturated fatty acids; CLA: Conjugated Linoleic Acid; DHA: Docosahexaenoic acid; EPA: Eicosapentaenoic acid; ATP: Adenosine triphosphate.

INTRODUCTION

The demand for sports nutraceuticals is increasing day-by-day due to the greater consumer awareness and increasing acceptance of nutraceutical supplements in the market. This increasing consumer demand for supplements geared towards sports nutrition will continue to see strong sales in coming years. According to BCC Research, the global market for sports nutrition products is expected to grow at a rate of 24.1%, and is projected to reach \$91.18 billion this year.¹

The major reasons for explosive growth of such types of athlete performance supplements are due to changing product market focus. Traditionally, sports endurance supplements mainly target towards body-building and other professional athletes. However, sales of sports nutrition products have now been promoted and have been classified into multiple fitness categories. The sports industry has expanded to include the individuals that also participate in recreational workouts and other physical activity. Although athletes performance products have been geared towards male consumers, now-a-days the sports performance nutritional supplements are popular in both the genders. There has also been growth within the youth segment for athletes performance nutritional supplements. A survey performed by the National Health Interview Survey (NHIS) shows that 1.6% of kids, are now users of sports performance formulations. These changing demographics of the typical sports endurance supplement user have

been responsible for the growth of the base market for sports supplements and nutraceuticals.¹

The term nutraceutical is a hybrid of the words 'nutrient' and 'pharmaceutical'. Nutraceuticals are generally dietary supplements derived from food sources with added health benefits. They are defined as any extract (derived from plant or animal origin) that has health-related benefits beyond those obtained by normal nutritional means. Some common examples include elk velvet antler, *Tribulus* while caffeine and androstenedione does not belong to the nutraceutical group. They are not Food and Drug Administration (FDA)-regulated and their therapeutic value has been debated for years, including their potential in the prevention of several chronic diseases like diabetes, slowing the ageing process, mitigate addiction tendencies, relieve anxiety, improve mental acuity and rally antioxidant defenses. As quoted by Greek physician Hippocrates, a proponent of using food as medicine, probably recognizes their potential.

Nutraceuticals can be developed for the benefit of the athletic community. They can be used to influence the athlete's performance either directly or indirectly since nutraceuticals are not drugs; they are natural and healthy and they compromise the health of the athletes. Moreover, nutraceuticals use is also not banned by the International Olympic Committee (IOC) athletes commission. There is no ethical and legal dilemma. So such form of nutritional therapy cannot be denied to the athletes. However, there might be certain problems with the use of nutraceuticals by the athletes. As nutraceuticals can induce positive drug tests, it can result in disqualification.

Gurley et al² reported in a study that 11 out of 20 ephedra supplements that claimed to contain the particular amount of ingredient (active phytochemical) as labeled on their container, they either failed the quality test or had more than 20% difference from the actual amount. It was also reported in another meet that *Tribulus* is often contaminated with testosterone, nor-testosterone and sometimes androstenedione also; around 25% of *Ginkgo biloba* preparations failed to qualify the quality tests. Thus to make nutraceuticals acceptable for the athletes, the issue should be addressed with valid scientific investigations.

The scientific issues can be resolved by scientific validation of the nutraceuticals with respect to quality controls. Controlled clinical trials should be conducted in order to determine if nutraceuticals can influence athletic performance or drug tests. In the present paper, the role and functions of nutraceuticals in enhancing athletic performance is studied.

NUTRACEUTICAL TYPES FOR ATHLETES

Organic Fat burners

These are one of the largest sold supplements to athletes. Fat burners serve a variety of functions that includes enhancing basal metabolic rate and energy levels of the body, suppresses

appetite, and reduces excess water levels. Athletes typically use fat burners to improve their energy levels to enhance their training and performance. There are numerous ingredients and their combinations present in fat burners. Some of the common and popular ingredients present in organic fat burners are guarana and/or kola nut (natural sourced caffeine), *Citrus aurantium* (bitter orange), and cayenne pepper. These are majorly used to increase metabolism and energy. Chromium and *Garciniacambogia* are amongst some most frequently used appetite suppressants, while Dandelion root is a common diuretic.¹

Fat burners, while providing benefit for many people, are also the most abused supplements in the market. Exceeding the recommended dosage is a common practice by many people in the hope of obtaining quicker and more profound results. This practice poses a danger to many people and they can have serious consequences on their health. The recent ban of the herb Ephedra by Health Canada is a prime example. Ephedra was commonly used by athletes as a fat burner for many years. The abuse of this supplement in recent years has caused serious side effects in many people, which prompted Health Canada to ban this product from the market. Fat burners that are used correctly can be an excellent addition to a work out regime.¹

The natural fat burners most commonly used are *Garciniacambogia*, green coffee bean and raspberry ketone. Raspberry ketone is a primary aroma compound present in red raspberries. It regulates the release of a protein called adiponectin (used by body to regulate the metabolism). The raspberry ketone compound causes the breakdown of fat cells more effectively, which in turn helps to burn the fats in the body. The raspberry ketone is very effective when combined with regular work out along with a nutritious diet. The recommended intake is 100 mg per day.¹

Another natural fat burner is a plant *Garciniacambogia* whose fruits are utilized in making weight loss products. This small pumpkin shaped fruit prevents the storage of fat while controlling the appetite. Unlike other supplements, garcinia does not require any special diet but in order to have better results, a sensible balanced diet along with regular exercise is preferred.

Green coffee beans are another group of natural fat burners. These include the coffee beans before they are roasted. This is because the amount of active phytochemical called chlorogenic acid gets reduced after roasting. Chlorogenic acid has various health benefits like it aids in weight loss, reduces heart disease risk, diabetes and boosts the immune system. The green coffee beans regulate blood sugar and metabolism that helps in weight reduction.¹

Thus, organic fat burners are more preferable than the artificial fat burners as they are natural and have no side effects. This should be accompanied with balanced diet and regular exercise. Just to cite an example, one of the commercially available fat burners is T5 fat burner marketed by Biogen. This nutraceuti-

cal in addition to promoting healthy fat burning capabilities, it also increases the body's natural production of metabolic hormones T4 (thyroxine) and T3 (tri-iodothyronine). Both these hormones are produced by thyroid gland and are primarily responsible for the regulation of metabolic rate and increase the levels of focus and mental alertness. It contains more thermogenic ingredients that aids in increased fat cell lipolysis, supercharged metabolism, extreme fat loss, enhanced energy levels, greater concentration and maximum thermogenesis.¹

Muscle Building Supplements

These supplements are the important component of an athlete's diet. There are many essential nutrients that are required to stimulate growth hormone, testosterone and maintain metabolic rate. Some of the important muscle building supplements are:

Whey proteins (WP): As per recommended dietary allowance (RDA), the daily protein intake of a normal person should be 1-1.5 g of protein per kg body weight.¹ This amount cannot be recovered from the diets alone. Protein is essential for athletes to build and repair muscle that is broken down during exercise. Protein supplements in the form of whey proteins are widely recommended. Whey proteins are considered to have the highest nutritional values of all food proteins as they contain all the essential and important amino acids required by humans, in the right proportions. Whey proteins are rich in branched chain amino acids (BCAAs), a major component that provide energy for people undergoing intense or prolonged periods of exercise and help prevent loss of body mass and muscle. They are also readily digestible and completely bio-available. Whey proteins supply additional nutritional benefits, for example, α -lactalbumin, the second most abundant whey protein, has a high content of the amino acid tryptophan, a precursor of the vitamin niacin.³

Whey protein is a complete protein containing all the essential amino acids with a high biological value. Biological value is actually a measure of protein quality, measuring the amount of protein that is retained from the absorbed protein in the body for maintenance and growth. This means that the absorbed whey protein is retained in the body and not quickly excreted. This will help the athlete by allowing them to use the components of whey protein to aid muscle recovery after a workout and would also promote their skeletal muscle growth. Whey protein is an excellent choice to promote muscle growth and used as a high protein meal replacement. It enhances the workout of athletes and also improves the effectiveness of many other supplements, like creatine.¹

Several researches have also focused on soy and whey protein in athletes diets. For example, Kalman et al⁴ studied the effects of soy- and milk-based proteins on circulating androgens and changes associated with exercise-induced body composition. For 12 weeks, 20 subjects took 50 g of one of four protein sources (soy isolate; soy concentrate; soy isolate and whey blend; or whey blend only)/day during their participation in a

resistance training program.⁴ Protein supplementation resulted in a significant increase in lean body mass independent of the protein source.⁴

There are several categories of whey protein ingredients that are commonly used in food and nutrition products, including whey powder, whey protein concentrate and whey protein isolate.³ The variation in their composition is due to the difference in extent and method of processing.

Whey powder is prepared from whey, a by-product of cheese manufacture. Whey is then clarified, pasteurized and dried to provide a fine white powder known as whey powder.

Whey concentrate typically uses ultra-filtration membrane technology to filter or concentrate various whey components on the basis of the membrane pore size and/or molecular wt. The fluid whey is allowed to pass through a semi-permeable membrane thereby removing lactose and ash and concentrating the protein content.³

Whey protein isolate have a protein content of 90% or more and is produced through a variety of processes like micro-filtration and ion exchange. Microfiltration removes additional lactose and fat to increase protein concentration up to 90% or higher. The advantage of this process is that it maintains the various important naturally occurring bioactive components in whey. Advanced chromatography technology can be used to further separate the individual protein components such as lactoferrin and lactoperoxidase from the main whey proteins (α -lactalbumin, β -lactoglobulin and bovine serum albumin). Advanced membrane technology is used for the enrichment of whey concentrate with whey bioactive components such as sphingolipids, lactoferrin, immunoglobulins, glycomacropptide (GMP) and transforming growth factor-beta (TGF- β).⁵ The whey solids are used as concentrated whey for human and animal food, as rich source of proteins.³

BRANCHED CHAIN AMINO ACIDS (BCAA)

Branched chain amino acids (BCAAs) account for 14-18% of amino acids in skeletal muscle proteins and are the most widely used supplements among natural bodybuilders.⁶ It helps to stimulate protein synthesis and promote muscle building and a faster recovery from exercise. The examples of BCAAs are amino acids such as leucine, isoleucine and valine but out of all BCAAs, leucine is of particular interest because it stimulates protein synthesis to an equal extent as a mixture of all amino acids. However, it has been observed that ingestion of leucine only can decrease the level of plasma valine and isoleucine; therefore, all 3 amino acids need to be consumed to prevent plasma depletion of any 1 of the BCAAs.⁷ The presence of leucine in the muscles has a direct effect on protein synthesis pathway. Studies have shown that BCAAs are metabolized in the muscle to manufacture glutamine, a precursor to GSH and another important component of the immune system.⁸

The safe upper limit of leucine is 550 mg/kg body-weight/day in adult men; however, future studies are needed to determine the safe upper limit for other populations.⁹ Intake of BCAAs before and after the workout reduces the amount of muscle damage and muscle soreness post-workout. It has been suggested a daily intake of 10-15 g of 2:1:1 ratio of BCAAs before and after the workouts for best results.¹⁰

ESSENTIAL FATS

The body can synthesize most of the required fats from the diet. However, the 2 essential fatty acids, linolenic and linoleic acid as they cannot be synthesized in the body, must be obtained from food. These basic fats, found in plant foods, are used to produce specialized fats in the body called omega-3 and omega-6 fatty acids.

Research has shown that essential fats helps in speedy recovery, support the immune system, promote the production of testosterone, improve muscle function and helps to maintain lean muscle mass. Another example of essential fats is fish liver oil. Fish oil is high in omega-3 polyunsaturated fatty acids (PUFAs). Omega-3 fatty acids are popular amongst athletes and non-athletes alike for their ability to improve blood vessel (endothelial) function, anti-inflammatory, and increase provision of energy from fat. Fish oil supplementation decreases the oxidative stress in response to strenuous exercise. This is positive in that it reduces exercise-induced inflammation, reduces the risk for infection due to immuno-deficiency, decreases delayed-onset muscle soreness, and increases the rate of recovery. Fish oil can reduce heart rate during rest and exercise implying a more efficient heart. This effect is due to direct effect on electrophysiological function of the heart.¹

Approximately consumption of 1-2 g of fish oil in a ratio of 2:1 eicosapentaenoic acid: docosahexaenoic acid or EPA:DHA per day improves cardiovascular function and exercise performance.¹ Most studies have shown that this regimen reduces exercise-induced muscle soreness and many have shown a lowering of blood pressure and improved blood flow during exercise.¹⁰

VITAMINS AND MINERALS

Micronutrients play a vital role in energy production, hemoglobin synthesis, and maintenance of bone health, adequate immune function, and protect body against oxidative damage. They also assist in synthesis and repair of muscle-tissues during recovery from exercise and injury. During exercise, body is stressed and requires various micronutrients in their metabolic pathways, and training during exercise may result in muscle biochemical adaptations that increase micronutrient needs. The routine exercise may also increase the turnover and loss of these micronutrients from the body. As a result, greater intakes of micronutrients may be required to cover increased needs for building, repair, and maintenance of lean body mass in athletes.¹¹

Most athletes are deficient in essential micronutrients. Training alone can deplete minerals and vitamins, due to sweating and fuels muscle contraction. Thus it is essential to fortify the food with vital micronutrients to unleash the energy from the food consumed.¹²

The most common vitamins and minerals found to be of concern in athletes diets are calcium and vitamin D, the B vitamins, iron, zinc, magnesium, as well as some antioxidants such as vitamins C and E, β -carotene, and selenium.¹¹⁻¹³ Iron is critical for athletes because it helps the body use and carries oxygen to active muscles. Iron from plant sources such as beans, lentils, seeds, soy, whole grain or fortified cereals, breads and pastas is not well absorbed, so a source of vitamin C like citrus fruit and juices, strawberries, bell peppers or broccoli should be included in the diet to help absorb the iron.

B vitamins are needed for releasing energy in the body, building and repairing tissues and for healthy red blood cells. There is scientific evidence that athletes may need higher amounts of B-complex vitamins, alternatively, eating foods from all 4 food groups and taking enough calories will ensure to meet these needs.

Besides, there are a variety of antioxidants that help protect the body's cells from damage. The antioxidants from nutrient-rich foods, especially plant foods like vegetables, fruit, nuts, whole grains and legumes. The antioxidant rich nutrients are beta-carotene, found in brightly coloured vegetables and fruit like sweet potatoes, carrots, pumpkin and apricots; vitamin E is present in vegetable oils, avocado, wheat germ, nuts and seeds; vitamin C is found in many vegetables and fruits such as citrus, strawberries, bell peppers, tomatoes and broccoli. Selenium is found in meat, fish and poultry, milk and milk alternatives such as cheese and yogurt, whole grains, mushrooms, nuts, seeds and legumes.^{12,13}

Therefore, reviewer suggest that athletes should not take supplements to get antioxidants but they should be essentially obtained from the diet.

SPECIFIC NUTRACEUTICALS SUPPLEMENTS FOR ATHLETES

Conjugated Linoleic Acid (CLA)

Conjugated Linoleic Acid (CLA) is another supplement often labeled as a fat burner and is a potent antioxidant. It is a mixture of different types of isomers of linoleic acid, primarily position and geometric isomers, which is found preferentially in dairy products and meat.¹⁴ Current research findings suggest that CLA has many advantages both for bodybuilders and any type of athlete. CLA is also unique because it is present in foods obtained from both animal and dairy sources, besides it also possess anti-cancer activity and is expressed at concentrations close to human consumption levels. CLA appears to reduce the body's ability to store fat and increase the body's use of fat for energy. Another

advantage of CLA is that once it is soaked into muscle cells, it can trigger an increase in muscle mass. It is also a potent anti-oxidant, anti-carcinogen, and anti-catabolite, as well as a powerful immune system enhancer.¹⁴ Some of the common accolades of CLA are assistance in fat burning, building and retention of lean muscle, and is anti-cancer. Some of the most common benefits of CLA supplementation are that it increases metabolic rate, lowers cholesterol and triglyceride level, enhances muscle growth, lowers insulin resistance, reduces food-induced allergic reactions, and enhances immune system. This would obviously be a positive benefit for any type of athlete that is trying to lose weight and improve body composition. CLA supplementation was also shown to improve the lean mass to body fat ratio, decreases fat deposition, especially on the abdomen, and enhances muscle growth. CLA achieves this reaction by reducing body fat and by enhancing insulin sensitivity so that fatty acids and glucose can pass through muscle cell membranes and away from fat tissue.¹⁵ This results in an improved muscle to fat ratio. Compelling evidence also indicates that CLA also promotes youthful metabolic function and reduces body fat. The unique mechanism by which this fatty acid protects against disease makes it an important addition to any supplement program (Table 1).¹⁶

Food source	CLA (mg/gram) of total fat
Lamb	5.6
Homogenized cow's milk	5.5
Homogenized cow's milk	4.8
Butter	4.7
Cottage cheese	4.5
Fresh ground beef	4.3
Sharp cheddar cheese	3.6
Chicken	0.9
Pork	--

Table 1: Common food sources and the amount present of CLA.¹⁷

Essential Fatty Acids (EFAs)

Omega-3's are the essential fatty acids, because they are necessary for health and must be included in diet (because the human body cannot manufacture them on its own). There are mainly 3 types of fatty acids that are collectively referred to as omega-3: alpha-linolenic acid (ALA), eicosapentaenoic (EPA), and docosahexaenoic acid (DHA).¹⁸

ALA is found in foods of plant origin. The richest source of ALA is flaxseed, but it is also found in hempseed, canola oil, soybeans, soybean oil, pumpkin seeds, pumpkin seed oil, linseeds, walnuts, and walnut oil.

Docosahexaenoic acid (DHA) is found in seafood, algae, and cold water fish such as salmon, sardines and albacore tuna.

Eicosapentaenoic (EPA) is found in many of the same foods as DHA, including cold-water fish such as salmon, and sardines, including cod liver, anchovies, halibut, herring and

mackerel.

EFAs include both omega 3 and 6, which play an important role in the functioning of the human body. A balanced intake of these 2 EFAs is essential for healthy cellular function and optimal athletic performance.¹⁹ Studies have proved that EFAs can improve stamina and endurance, decrease recovery time and inflammation after exercise, and improves amino acid utilization to help build and maintain lean muscle mass. Many athletes include EFAs as a staple in their diet to receive these benefits.²⁰

Creatine

Creatine is another supplement that is extremely popular with athletes. It is naturally synthesized in the human body from amino acids primarily in the kidney and liver and transported in the blood for use by muscles. Approximately 95% of the body's total creatine content is located and concentrated in skeletal muscle. It is required for the production of adenosine triphosphate (ATP), the cellular fuel that runs the body. ATP that is stored in the muscle is the only fuel available for energy and the only fuel source capable of generating 100% muscle contraction. Muscle contraction by stored ATP is most effective for building strength and once it has been depleted, the other fuel sources will dominate and muscle contraction will decline. Vigorous exercise will deplete muscles from their routine creatine supply. Creatine supplementation re-energizes tired muscles, allowing the athlete to work out harder for a longer duration, and also increases muscle and strength. Taking 30 to 40 grams of mixed sugars with each dose will aid and enhance in muscle uptake of creatine.¹ The sugars stimulate insulin, which is essential to push creatine through the cell membranes. Creatine should be cycled and not taken on a continuous basis. It has maintained a consistent popularity amongst body builders and also remains a top choice for athletes looking to build lean muscle.¹

The benefits of creatine include an increased strength, enhanced performance, increased testosterone levels, improved brain activity, and also helps in regeneration of muscle cells. Washington State University (WSU) study concluded that creatine supplements can increase muscle mass and strength to the participants and also provides an opportunity to power through intense workouts. Another study conducted by Australian researchers determined that intake of 5 g of creatine daily over a period of 6 weeks, the neurological performance of the participants improved significantly including the speed in which information was processed as well as it also increased the memory. However, creatine may not benefit to those participating in lower-intensity exercises, such as aerobics. So supplement distributors should focus on other formulations and ingredients to target average consumers.¹

Glutamine

It is the most abundant free amino acid found in the muscles of the body and is readily available for the synthesis of skeletal

muscle proteins. This amino acid helps to build and maintain muscle, and therefore nutritional supplements containing glutamine is useful for athletes. L-glutamine is the natural form of the amino acid glutamine and it is therefore one of the top sports supplements sold on the market. L-glutamine can naturally boost the level of human growth hormone and has gained a lot of recognition as a supplement used to enhance muscle recovery.²¹ Major dietary sources of glutamine are plant and majority animal proteins such as beef, pork and poultry, milk, yogurt, ricotta cheese, cottage cheese, raw spinach, parsley and cabbage. Glutamine is found in many foods high in protein, such as beans, fish, meat and dairy products. Free L-glutamine is also present in vegetable juices and fermented foods such as yogurt.

Glutamine is a non-essential amino acid and the major part of the de novo synthesis in the human body. However, during strenuous physical exercise, critical illness, injury or heavy stress loads, the need for glutamine can increase beyond the body's known ability to synthesize it, and therefore it becomes 'conditionally essential'.

The other key benefits of glutamine are²²:

- Increasing glutamine in muscle tissue to produce an anabolic effect for body builders and other athletes.
- Glutamine prevents muscle wasting in post-surgical patients and for those with trauma and with conditions causing muscle catabolism.
- Glutamine stimulates and supports the immune system.
- It increases mental alertness and supports neurological health.
- It helps to promote proper glucogenic function necessary for balancing low blood sugar levels.
- It also affects the appetite center to help reduce cravings for sugar and alcohol.
- It also supports the proper intestine function.

Athletes who undergo intense, prolonged exercise have an increased risk of infections, apparently as a result of immunosuppression. Glutamine plays an important role in immune function, and plasma glutamine levels decline after intense, prolonged exercise.²³

In a double-blind trial, supplementation with 10 g of glutamine after a marathon or ultra-marathon run significantly decreased the incidence of infections over the next 7 days. In a double-blind fashion study, 151 marathon and ultra-marathon runners received 5 g of glutamine or placebo in 330 ml of water immediately after completing the run and again 2 hours later (total glutamine dose, 10 g). In the 7 days following the event, infections occurred in significantly fewer individuals in the glutamine group than in the placebo group (19.2% vs. 51.2%; $p < 0.001$).²⁴

Arginine

L-Arginine is a semi-essential amino acid that is though body has the ability to manufacture this amino acid, sometimes additional supplementation may be necessary. This is to increase the natural benefits of this amino acid. L-Arginine is a precursor to nitric oxide and necessary for the synthesis of creatine.¹

"NO supplements" containing arginine are widely known as a vasodilator and are consumed by bodybuilders to increase blood flow to the muscle during exercise, increase protein synthesis, and improve exercise performance. These supplements are very popular among professional athletes and the body building sports persons as it increases the blood flow and oxygen throughout the entire body.

However, there is little scientific studies to support these claims. In a research, healthy young men were supplemented with 7 g arginine or a placebo prior to exercise and were observed with no significant change in blood flow following exercise.²⁵

However, the effects of arginine supplementation on performance are still controversial. Approximately one-half of acute and chronic studies on arginine and exercise performance have found significant benefits with arginine supplementation, while the other one-half has found no significant benefits.²⁶

In another study, it was found that arginine supplementation significantly reduced muscular endurance by 2-4 repetitions on chin up and pushes up endurance tests.²⁷ Based on these results, the authors of a review concluded that arginine supplementation had little impact on exercise performance in healthy individuals.²⁸

Tribulus Terrestris (Puncture Vine)

Tribulus Terrestris is a nutritional supplement that has been growing in popularity over the last few years. Traditionally, it was used by men to improve libido but recently has gained recognition as a muscle builder. *Tribulus Terrestris* functions by enhancing testosterone levels by increasing luteinizing hormone levels. Increasing testosterone levels also promote protein synthesis and positive nitrogen balance. The benefits for the athlete are muscle cell growth, increase in body strength, and faster recovery from injury. *Tribulus Terrestris* is an extremely powerful medicinal plant with a strong effect on testosterone along with muscle building, restorative sleep, protection of cardiovascular system and pain reduction. It is famous amongst athletes because it significantly increases endurance and is anabolic. The plant fruit has been well documented and used in both traditional Chinese Medicine and in Indian Ayurvedic medicine for more than 3000 years.

Tribulus Terrestris is composed of large number of active elements including steroidal saponins such as dioscin, di-

osgenin and protodioscin. These elements are the active phytochemicals responsible for the fitness and building of muscle mass (natural anabolic). *Tribulus* also contains phytosterols especially beta-sitosterols that act on the different problems associated with the prostate, urinary and cardiovascular systems. It is a very powerful plant and does not have side-effects within the recommended dosage. It is a safe plant, but is not recommended to exceed a maximum of 1200 mg/day.¹ In strong doses, *Tribulus* can damage liver, eye and its retina.¹

Beta-hydroxy Beta-methylbutyrate (HMB)

The leucine metabolite beta-hydroxy-beta-methylbutyrate (HMB) has been extensively used as an ergogenic aid; particularly among bodybuilders and strength/power athletes to promote exercise performance and skeletal muscle hypertrophy. It decreases muscle protein catabolism and increase muscle protein synthesis.^{29,30} HMB may also decrease blood pressure, total and low density lipoprotein (LDL) cholesterol, especially in hypercholesterolemic individuals. HMB is particularly effective in catabolic populations such as the elderly and patients with chronic disease.³¹ While numerous studies have supported the efficacy of HMB in exercise and clinical conditions, there have been a number of conflicting results.³²

In a recent study, the effect of 12 weeks of HMB supplementation on skeletal muscle hypertrophy, body composition, strength, and power in trained individuals were studied. The effect of hydroxyl methyl butyrate (HMB) on muscle damage and performance during an overreaching cycle were also determined and it was concluded that HMB enhances hypertrophy, strength, and power following chronic resistance training, and prevents decrements in performance following overreaching.³³

β -hydroxy β -methylbutyrate (HMB) is a supplement that was once quite popular with athletes but has now faded into obscurity. HMB is a metabolite of the normal breakdown product of the amino acid leucine and enhances the effects of vigorous exercise by building muscle and reducing body fat. Studies have shown a pronounced effect of HMB on decreasing protein breakdown while increasing nitrogen retention by the body. This results in an increase in lean muscle mass and strength. However, its results are visible along with regular exercise.

In case an athlete is not on a regular routine of strenuous exercise, it is unlikely that there would have been not many noticeable results. However, the safety of HMB supplementation has also been studied with no adverse effects on liver enzymes, kidney function, cholesterol, white blood cells, hemoglobin, or blood glucose have been observed.³⁴ In another study, 2 meta-analysis on HMB supplementation have concluded that HMB is safe and does not result in any major side effects.³⁴ HMB is actually advantageous by decreasing blood pressure, total and LDL cholesterol, especially in hyper-cholesterolemic individuals.

Research has shown that HMB is particularly effective

in catabolic populations such as the elderly and patients with chronic disease.³¹ However, studies on the effectiveness of HMB in trained, non-calorically restricted populations have been mixed.

The reasons for discrepancies in the results of HMB supplementation studies in healthy populations may be due to many factors including clustering of data in this meta-analysis to include many studies from similar groups, poorly designed, non-periodized training protocols, small sample sizes, and lack of specificity between training and testing conditions.³²

However, overall HMB appears to be effective in a majority of studies with longer-duration, more intense training protocols and may be beneficial to bodybuilders, particularly during planned over-reaching phases of training.³⁵

Methoxy Isoflavone

Methoxy-isoflavone (M), another supplement, is a non-hormonal member of the isoflavone family. It is highly anabolic (increases protein synthesis) with no androgenic effects. Methoxy-isoflavone partially suppresses the catabolic hormone, cortisone, while improving nitrogen retention by the body. Thus, it is suitable for athletes looking to gain more lean muscle. The long term effects of its higher dosing are unknown, with no short-term effects.

In a study, the effect of M, along with other supplements such as 20-hydroxyecdysone (E), and sulfo-polysaccharide (CSP3) were analyzed on the athletes as dietary supplements that improve strength and muscle mass during resistance training. However, little is known about their potential ergogenic value. The purpose of this study was to determine whether these supplements affect training adaptations and/or markers of muscle anabolism/catabolism in resistance-trained athletes. The results indicated that M, E, and CSP3 supplementation do not affect body composition or training adaptations nor do they influence the anabolic/catabolic hormone status or general markers of catabolism in resistance-trained males.³⁶

Smilax Officinalis

Smilax officinalis (SO) is a plant that contains plant sterols purported to enhance immunity as well as provide an androgenic effect on muscle growth.³⁷ Some data supports the potential immune enhancing effects of SO. However, there is no data available to show that SO supplementation increases muscle mass during training.

Growth Hormone Releasing Peptides (GHRP) and Secretagogues

Research has indicated that growth hormone releasing peptides (GHRP) and other non-peptide compounds (secretagogues) help to regulate growth hormone (GH) release. These observations

have served as the basis for development of nutritionally-based GH stimulators (amino acids, pituitary peptides, pituitary substances, *Mucunapruriens*, broad bean, alpha-GPC). Although there is clinical evidence that pharmaceutical grade GHRP's and some non-peptide secretagogues can increase GH and IGF-1 levels at rest and in response to exercise, it has not been demonstrated that such increases lead to an increase in skeletal muscle mass.³⁸

***Cordyceps Sinensis* (Caterpillar Fungus)**

The caterpillar fungus is a traditional medicine that was widely used as a tonic and/or medicine by the Chinese for hundreds of years. *Cordyceps* was traditionally used to combat fatigue and promote vitality. It improves athletic performance by opening up the breathing passages, thereby allowing more oxygen flow into the body. Oxygen is essential for energy production, thereby enhancing the athlete's training and performance.

The use of this fungus was relatively unknown in this country until it was known and credited for the success of a Chinese women athlete at the National Games in Beijing, in 1993. Three Chinese track runners set new world records during that Games at 3 different distances, 10,000 m, 15,000 m and 30,000 m. Their coach, Mr. Ma Zunren, attributed the athlete's success to intensive training as well as a stress-relieving tonic prepared from the caterpillar fungus. Since then *Cordyceps* on an upward trend and as athletes see more positive results; it will become a mainstream supplement.

The various mode of action of *Cordyceps* are firstly it increases ATP level as one of the active ingredient of cordyceps is adenosine, a nucleic acid that is a crucial component of ATP; secondly it boosts testosterone levels thereby increasing the ability to add muscle mass; thirdly it improves oxygen utilization by up to 50% and finally cordyceps also boosts perceived energy levels.

A number of studies have also shown that supplementing cordyceps can lower the heart-rate, which explains why people report being able to train harder for longer duration of time when using this supplement. Another study published in 1999 also pointed to long-term cardiovascular health benefits from cordyceps, indicating that it can lower total cholesterol by 10-20% and increase HDL by a quarter.³⁷

Cordyceps creates the effect similar to caffeine, but without the side effects of jitters or an inability to sleep several hours later. This is because cordyceps attaches to the same receptors as caffeine, providing a noticeable feeling of enhanced energy and thus it is used as a popular anti-aging supplement in China.³⁷

Ornithine- α -ketoglutarate (OKG)

OKG is commonly administered through enteral feeding and has

been shown to significantly shorten wound healing time and improve nitrogen balance in severe burn patients.³⁹ OKG has the ability to improve nitrogen balance, thus it is helpful for athletes engaged in intense training.

A scientific study reported that OKG supplementation (10 g/day) during 6-weeks of resistance training promoted greater gains in bench press. However, no significant differences were observed in squat strength, training volume, gains in muscle mass, or fasting insulin and growth hormone. Therefore, additional research is needed before conclusions can be drawn.⁴⁰

CONCLUSION

Thus, from the above discussion it can be safely concluded that the contribution of nutraceuticals towards athlete's health is appreciable. Nutraceutical market is therefore consistently growing and has turned into a billion dollar industry. But it is advisable that an athlete should research a supplement before using to ensure the most appropriate effect on their training and performance. However, the banned nutritional supplements should be avoided by the athletes. The athlete should always choose the product based on its quality and effectiveness, not necessarily on what an advertisement states. The use of nutraceuticals/dietary/functional supplements to improve athletic performance will likely to remain in the forefront of the nutritional and dietary supplement industry in the coming years.

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DECLARATION BY THE AUTHORS

This article is intended for general reading only and is based on the data available from the scientific literature and as reported in blogs, posts and some unofficial sources. The authors do not claim any efficacy of the above cited products. In addition, the authors do not promote or advertise any commercial products/supplements mentioned in the article.

ETHICAL ISSUES

There is none to be declared.

CONFLICTS OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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