



Nutraceutical Innovations for High-Altitude Performance: Enhancing Sports Endurance

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Abstract

Nutraceuticals are gaining recognition for their preventive and therapeutic roles in complex diseases. This review explores the potential of nutraceuticals in various health conditions, with a particular focus on their relevance in high-altitude environments. The review explores specific nutraceutical sources like *Ophiocordyceps sinensis* and *Spirogyra portcallis*, highlighting their rich bioactive compound profiles and potential health benefits. The review also examines the significance of wild edible fruit plants of the Indian Himalayan region as a source of essential nutrients and antioxidants. Furthermore, it explores the application of nutraceuticals in sports, emphasizing their role in enhancing performance, recovery, and overall health. It details various categories of sports nutraceuticals, including organic fat burners, muscle building supplements, and substances that aid in mitigating gastrointestinal issues. Finally, the review discusses the potential of nutraceuticals like Berberine, Curcumin, Green tea, etc in promoting gut health and modulating gut microbiota. Overall, the review underscores the promising potential of nutraceuticals as a valuable addition to conventional healthcare approaches.

Keywords: Nutraceuticals, High-Altitude Environment, Curcumin, Antioxidants, Spirogyra Portcallis

Introduction

Nutraceutical is a recent term for food or food parts that supposedly offer health benefits beyond basic nutrition. Coined in 1989 by Dr. Stephen DeFelice, it combines “nutrition” and “pharmaceutical” and differs slightly from regular food supplements [1]. They are designed to address specific dietary needs and potentially prevent or treat diseases. Nutraceuticals target specific health conditions and have stronger scientific backing for their effectiveness. This area is attracting a lot of attention due to perceived safety and potential health advantages [2]. Despite the growing demand, there remains a lack of universally accepted definition for nutraceuticals, often described as ‘pharma food’-sitting between diet and

pharmaceuticals. These products encompass various formulations containing macronutrients (e.g., omega-3 fatty acids, magnesium, potassium, calcium), micronutrients (e.g., vitamins, minerals), and phytochemicals sourced from food. Nutraceuticals include a broad range of products from herbal supplements to isolated nutrients and genetically modified foods. From big pharma to small vitamin companies, many are creating new products for health-conscious consumers [3]. These nutraceuticals have the potential to prevent and treat various conditions, but research on their effectiveness is still ongoing [4]. The global nutraceutical market is rapidly expanding, driven by increasing awareness of nutritional benefits and a growing demand for health products, particularly in emerging

economies like India [5]. The market is projected to reach substantial figures, with significant growth expected in Asia Pacific. This growth trend underscores the evolving landscape of nutraceuticals and highlights the need for responsible regulation amid their increasing popularity and market reach [3].

Nutraceuticals, which encompass a range of natural compounds with potential health benefits, are increasingly recognized for their preventive and therapeutic roles in complex diseases. However, their administration and prescription require strict regulation to avoid misuse and adverse effects [6]. Research into drug compound-based nutraceuticals aims to enhance their efficacy and bioavailability. Recent studies have shown promising results for these compounds in various pathological conditions, including diabetes, atherosclerosis, cardiovascular diseases (CVDs), cancer, and neurological disorders. These conditions often involve alterations in the body's redox state [7]. Fortunately, many nutraceuticals exhibit antioxidant activity, which may help counteract this imbalance and contribute to improved health outcomes. Notably, certain nutraceuticals like statins have shown promise in preventing cardiovascular diseases, even in pregnant women. Calcium, omega-3 fatty acids, vitamin D, and others have emerged as potential candidates for preventing conditions like diabetes and hypertension, either independently or in combination with standard medications. Novel blends, such as a nutraceutical with non-steroidal anti-inflammatory drugs (NSAIDs) for osteoarthritis, are demonstrating improved efficacy and safety [3].

Over recent years, there has been a significant shift towards scientifically verifying the effects of food compositions on health and disease prevention, reflecting growing public awareness of the link between nutrition and wellness. Research and development efforts are intensifying to explore the potential of nutraceuticals in healthcare, emphasizing the need for standardized constituents, robust protocols, and clinical studies to underpin consumer health and industry impact. This surge in awareness has led to nutraceutical medicine being recognized as a part of Complementary and Alternative Medicine (CAM), forming a distinct branch within this field. Nutraceuticals, known for their combined nutritional and medicinal properties, are increasingly preferred by both the general public and healthcare providers over traditional medicines [8].

The shift towards nutraceuticals is driven by several factors:

1. A growing number of consumers are increasingly concerned about rising healthcare costs.
2. Individuals dissatisfied with pharmaceuticals for health promotion are turning towards nutraceuticals to enhance health and prevent chronic diseases.
3. Healthcare providers recognize that our heavily processed food supply, derived from crops treated with chemical fertilizers, pesticides, herbicides, and often genetically modified seeds, lacks sufficient nutrients essential for optimal health.
4. There is a rising belief in prioritizing prevention over cure among the populace.

5. Individuals with chronic diseases who have not found solutions with conventional allopathic medicines are seeking alternatives like nutraceuticals.
6. Economically disadvantaged patients are also exploring nutraceutical options [9].

Nutraceuticals In High Altitude Regions

Ophiocordyceps sinensis (Berk.)

Ophiocordyceps sinensis (Berk.) (*O. sinensis*) is a fungus that parasitizes certain caterpillars in high-altitude regions, particularly in the Himalayan tracts of India, Tibet, and China, at elevations ranging from 3500 to 5000 meters. It's known for its dynamic life cycle during different seasons. This fungus has been used in traditional Chinese medicine for over 300 years to treat various conditions such as kidney failure, respiratory diseases, heart disease, and more. Modern scientific studies have validated its medicinal properties, including its ability to modulate various physiological systems (immune, cardiovascular, respiratory), exhibit immunomodulatory effects, and potentially act as an anticancer agent. *O. sinensis* has been utilized in the development of medicinal products worldwide, including formulations for targeted drug delivery systems, such as nanoparticles and microspheres for conditions like osteoarthritis.

O. sinensis contains a rich array of pharmacologically active compounds. Notably, nucleotides and nucleosides are key components, including six nucleobases (cytosine, thymine, adenine, guanine, uracil, and hypoxanthine) and derivatives, with higher content observed in cultured *O. sinensis*. Important nucleotides such as uridine-5-monophosphate (UMP), adenosine-5-monophosphate (AMP), and guanosine-5-monophosphate (GMP) exhibit various pharmacological properties, including immune enhancement, metabolic regulation, and anti-inflammatory effects. Polysaccharides from *O. sinensis*, known for their antitumor, immune-enhancing, and antioxidant effects, are extensively studied and characterized. Specific polysaccharides like cordysinocan and SCP-1 demonstrate unique bioactivities. Proteins identified in *O. sinensis*, such as OS DNase and OSP (*O. sinensis* Serine Protease), have notable enzymatic functions and potential therapeutic roles, including cardiovascular disease treatment. Amino acids and polypeptides in *O. sinensis* contribute to clinical management of hypertension, with tryptophan being particularly significant for its physiological effects. Additionally, specific compounds like cordymin and cordyceamides A and B show promising therapeutic potential, including effects on diabetic osteopenia and cytotoxic activities. Steroids and other bioactive molecules found in *O. sinensis*, such as D-mannitol and various antioxidants, further contribute to its diverse pharmacological profile.

O. sinensis extracts offer a diverse array of therapeutic benefits, particularly valuable in high-altitude environments. Recent research has explored its potential in alleviating adverse effects induced by high-altitude conditions like high-altitude pulmonary edema (HAPE), acute mountain sickness (AMS), high-altitude cerebral edema (HACE), pulmonary embolism, frostbite, chilblains,

hypothermia, etc experienced by soldiers stationed at high altitudes. These extracts possess potent anti-inflammatory and immunomodulatory properties. By influencing metabolic regulators in skeletal muscles, *O. sinensis* extracts enhance endurance and combat fatigue, making them beneficial for athletes, mountaineers, and military personnel. Moreover, the antioxidant activity of *O. sinensis* is notable, effectively reducing oxidative stress induced by hypoxia through the upregulation of key antioxidant genes like HO1, MT, and Nrf2. Rich in bioactive compounds such as nucleobases, nucleosides (e.g., adenine, adenosine, uracil), phenolics, and flavonoids, these extracts contribute significantly to cellular protection and overall health. Specific formulations like DIP-C-ft, derived from *O. sinensis*, act as performance enhancers, improving physical and cognitive abilities in challenging environments. Furthermore, *O. sinensis* exhibits antimicrobial properties, potentially aiding in the prevention of infections. Dietary supplementation with *O. sinensis* supports homeostasis and overall well-being, addressing specific health challenges encountered in extreme environments. Continued research is essential to fully understand the mechanisms underlying these therapeutic effects and to explore their broader applications across various health conditions and populations.

The term “mushroom nutraceuticals” coined by Chang and Buswell underscores the significance of medicinal mushrooms like *O. sinensis* in providing essential nutrients and potentially therapeutic benefits in supplement form. *O. sinensis* and other medicinal mushrooms are recognized as valuable sources of nutraceuticals, providing essential nutrients that contribute to overall health and well-being. Medicinal mushrooms like *O. sinensis* are subjected to refinement processes to produce high-quality products suitable for use as dietary supplements. These refined extracts are commonly formulated into capsules or tablets. The DIPC-ft product derived from *O. sinensis* can specifically be used as a nutraceutical supplement. This product can be used alone or combined with other rejuvenating ingredients for managing high-altitude-related health issues such as altitude sickness, hypoxia-related conditions, and other stress-induced ailments [10].

Spirogyra porticalis

Spirogyra porticalis is a freshwater green filamentous alga harvested from the Trans-Himalayan cold desert of India. *Spirogyra porticalis* is noted for its significant content of protein, lipids, carbohydrates, multivitamins, and minerals (especially calcium, magnesium, and iron), surpassing the levels found in other algae like *Spirulina* and *Chlorella*.

The analysis of amino acids in *Spirogyra porticalis* revealed the presence of 19 amino acids, including: Essential Amino Acids (Leucine, isoleucine, valine, lysine, histidine, phenylalanine, threonine, tryptophan, methionine), Conditionally Essential Amino Acids (Arginine, cysteine, glycine, proline, tyrosine) and Non-Essential Amino Acids (Alanine, aspartic acid, glutamic acid, serine). Among the amino acids detected, alanine, norleucine, and cysteine-HCl+cysteine was found to be dominant, with alanine being the most abundant. The accumulation of amino acids in response to environmental stressors suggests adaptive responses in *Spirogyra porticalis*,

potentially conferring health benefits against oxidative stress, hypoxia, and other physiological challenges. Norleucine enrichment in *Spirogyra porticalis* could potentially impact brain health and cognition, offering neuroprotective effects against brain injury and encephalopathy. The presence of cysteine-HCl in significant amounts may contribute to various therapeutic outcomes, including control of hypertension, vasoconstriction, and radiation sickness. Lysine and proline content in *Spirogyra porticalis* suggests potential benefits for collagen formation, arterial health, cognition improvement, and osteogenesis.

The fatty acid composition analysis of *Spirogyra porticalis* reveals a rich profile of various fatty acids, particularly emphasizing its potential benefits in addressing cardiovascular and cognitive health issues associated with hypoxic stress. Dominant Monounsaturated Fatty Acids (MUFAs) identified in *Spirogyra porticalis* include cis-10-pentadecenoic acid (34.76%), oleic acid (3.00%), and palmitoleic acid (1.29%). Major Poly Unsaturated Fatty Acids (PUFAs) detected in the alga include α -linolenic acid (34.33%), linoleic acid (3.00%), and cis-13,16-docosadienoic acid (2.58%). Significant Saturated Fatty Acids (SFAs) contributing to the total lipid content include palmitic acid (18.45%), heneicosanoic acid (2.15%), and lignoceric acid (0.43%). The dominance of α -linolenic acid (an ω -3 PUFA) in *Spirogyra porticalis* suggests potential benefits in maintaining lipid balance, blood sugar levels, and cardiovascular health, especially in high-altitude environments. Substituting saturated fats (SFAs) with MUFAs and PUFAs has been linked to reduced cardiovascular risks and improved lipid profiles. The MUFA: PUFA: SFA balance in *Spirogyra porticalis* (1:1:0.53 ratio) aligns with recommendations for cardiovascular health. The presence of specific fatty acids like cis-10-pentadecenoic acid and palmitic acid may support proper cognition and neuronal health, potentially impacting neurotransmitter levels like dopamine.

The vitamin profile of *Spirogyra porticalis* reveals a rich content of both fat-soluble and water-soluble vitamins, showcasing its potential as a valuable nutritional resource with significant health implications. In terms of fat-soluble vitamins, *Spirogyra porticalis* contains Retinol (Vitamin A) at 91.319 $\mu\text{g}/\text{kg}$, known for supporting eye health, immune function, and skin integrity, along with D- α -Tocopherol (Vitamin E) at 39.654 $\mu\text{g}/\text{kg}$, which acts as an antioxidant and promotes skin health. The water-soluble vitamin content of *Spirogyra porticalis* is particularly notable, with abundant levels of D-Pantothenic Acid (Vitamin B5) at 5468.184 $\mu\text{g}/\text{kg}$, essential for energy metabolism and hormone synthesis. Nicotinamide (Vitamin B3) is also present at 2107.164 $\mu\text{g}/\text{kg}$, alongside nicotinic acid (2076.450 $\mu\text{g}/\text{kg}$), both crucial for cellular respiration and metabolism. Additionally, Riboflavin (Vitamin B2) at 939.626 $\mu\text{g}/\text{kg}$ plays a role in energy production and antioxidant function, while Thiamine (Vitamin B1) at 148.304 $\mu\text{g}/\text{kg}$ is essential for nervous system function and carbohydrate metabolism. Pyridoxine (Vitamin B6) is detected at 69.311 $\mu\text{g}/\text{kg}$, important for protein metabolism and neurotransmitter synthesis. The presence of these water-soluble vitamins, especially the B-group vitamins (B2, B3, B5, B6), suggests potential benefits in supporting cognitive function, energy metabolism, and overall nutritional health. Moreover, given the challenges

posed by high-altitude environments, the vitamin B-rich supplementation from *Spirogyra porticalis* could help mitigate hypoxia-induced changes in cognition, hypophagia, and metabolic disruptions associated with altitude, providing valuable nutritional support in demanding conditions. This comprehensive vitamin profile underscores *Spirogyra porticalis* as a promising source of essential nutrients with potential therapeutic implications for addressing health issues, particularly in high-altitude regions.

The antioxidant capacities of *Spirogyra porticalis* against oxidative stress highlight its potential therapeutic implications. Under hypoxic conditions, catalase activity significantly increased, suggesting a compensatory response to combat oxidative stress. Treatment with *Spirogyra porticalis* extract further enhanced catalase activity, reinforcing antioxidant defenses. Superoxide dismutase (SOD) activity, responsible for neutralizing superoxide radicals, was reduced under hypoxic conditions but restored to near-normal levels with *Spirogyra porticalis* extract treatment. This restoration indicates the extract's ability to mitigate the impact of oxidative stress on cellular function. Additionally, Trolox equivalent antioxidant capacities and glutathione (GSH) levels were depleted under hypoxic conditions but significantly recovered following treatment with *Spirogyra porticalis* extract. This recovery demonstrates the extract's capacity to bolster cellular antioxidant defenses. The efficacy of *Spirogyra porticalis* extract against oxidative stress can be attributed to its rich composition of natural antioxidants, including polyphenols, flavonoids, and specific chemical constituents identified. These compounds possess potent free radical-scavenging properties and contribute to the extract's overall antioxidant activity.

Hence, *Spirogyra porticalis* is a valuable nutraceutical resource suited for high-altitude environments. Its potential to combat oxidative stress, enhance antioxidant capacities, and contribute to overall health makes it particularly beneficial in regions like Ladakh. By harnessing this native alga, there's an opportunity to improve food security and promote well-being in remote, high-altitude areas where access to conventional agricultural produce is limited. This underscores the significance of exploring and utilizing *Spirogyra porticalis* as a locally cultivated nutraceutical to address unique challenges associated with high-altitude living [11].

Wild edible fruit plants of the Indian Himalayan region

The wild edible fruit plants of the Himalayan region, including *Berberis asiatica* (Kilmora), *Celtis australis* (Khareek), *Ficus palmata* (Bedu), *Fragaria indica* (Kiphalia), *Morus alba* (Sahtoot), *Myrica esculenta* (Kaphal), *Phyllanthus emblica* (Anwla), *Prunus armenica* (Khuwani), *Pyracantha crenulata* (Ghingaroo), and *Terminalia chebula* (Harad), offer a diverse range of nutritional benefits and antioxidant bioactive compounds. Research findings have revealed significant variations in the nutritional content among these species, underscoring their potential for nutraceutical development.

Terminalia chebula, known for its high total phenolic content (up to 76.67 mg GAE/g fw), is associated with potent antioxidant properties. These antioxidants can neutralize harmful free radicals,

reducing oxidative stress implicated in various diseases, including cancer and cardiovascular disorders. *Phyllanthus emblica*, rich in ascorbic acid (up to 33.15 mg/g fw), contributes to immune function and collagen synthesis, vital for wound healing and skin health. The flavonoid-rich *Myrica esculenta* (up to 4.73 QE mg/g fw) possesses anti-inflammatory properties, potentially beneficial for conditions like arthritis. *Berberis asiatica* stands out for its anthocyanin content (24.59 mg/100 g fw), which has been linked to improved microcirculation and anti-inflammatory effects, potentially supporting cardiovascular health. The nutritional profile of *Morus alba*, particularly its high ascorbic acid content (29.53 mg/g fw), contributes to antioxidant defense and may help combat oxidative stress-related diseases.

These bioactive compounds found in wild edible fruits have been associated with various health benefits. For example, antioxidants can mitigate cellular damage linked to aging and chronic diseases. Flavonoids and phenolics have anti-inflammatory properties, potentially beneficial for conditions like arthritis and inflammatory disorders. Ascorbic acid supports immune function and skin health, while anthocyanins contribute to cardiovascular health through their effects on microcirculation and inflammation. Furthermore, the diversity of these fruits provides an opportunity for dietary diversification and supplementation in high-altitude regions where access to nutritious foods may be limited. Encouraging the cultivation and utilization of these species could contribute significantly to addressing nutritional challenges and promoting health in mountainous ecosystems [12].

Nutraceuticals in Sports

Intense exercise can lead to increased production of Reactive Oxygen Species (ROS) or free radicals within muscles. ROS production is also influenced by aging and certain pathological conditions. During aerobic exercise, there is a significant increase in oxygen consumption, especially by contracting muscles, which can exceed the body's antioxidant capacity. Regular exercise promotes the up-regulation of antioxidant defense mechanisms in the body to counteract oxidative stress. However, during intense exercise, ROS production may outpace these defenses [13].

Nutraceuticals can play a role in supporting athletes by addressing typical ailments, enhancing recovery, and potentially improving performance. They are rich in antioxidants such as polyphenols, lutein, curcumin, isoflavones, resveratrol, carotenoids, folic acid, melatonin, carnitine, and omega-3 fatty acids. For instance, antioxidants can help mitigate exercise-induced oxidative stress. Nutraceuticals are often considered safer with fewer side effects compared to conventional drugs. They also tend to have better bioavailability, meaning they are more readily absorbed and utilized by the body [13].

Despite their benefits, caution should be exercised to avoid self-diagnosis or treatment ("do-it-yourself" approach). It's advisable to seek guidance from healthcare professionals or nutrition experts when incorporating nutraceuticals into a regimen. The incorporation of specific nutraceuticals like omega-3 fatty acids, pro-

biotics, policosanols, polyphenols, etc. into athletes' diets can play a pivotal role in enhancing performance, recovery, and overall health [13].

Omega-3 fatty acids

Omega-3 fatty acids, sourced from fish and plant oils, have shown remarkable benefits in muscle development and strength gains when supplemented at appropriate doses over time. Studies indicate that omega-3 intake can reduce post-exercise muscle damage and soreness, attributed to its anti-inflammatory properties that support muscle recovery and overall exercise performance [14]. Furthermore, omega-3's ability to enhance cell membrane permeability and insulin sensitivity may improve nutrient uptake by muscle cells, contributing to optimal athletic performance [13].

Probiotics

Probiotics, commonly found in yogurt and fermented foods, offer distinct advantages for athletes, particularly in immune function and gastrointestinal health [13]. By promoting a healthy gut microbiota, probiotics help mitigate the risk of infections and digestive disturbances often associated with intense training [15]. Improved nutrient absorption facilitated by probiotics can lead to enhanced energy production and utilization, potentially translating into improved athletic performance. Moreover, probiotics exhibit anti-inflammatory effects that contribute to faster recovery and reduced muscle soreness post-exercise, highlighting their importance in supporting athletes' overall well-being [16].

Policosanols

Policosanols, natural substances derived from plant sources like sugar cane wax and beeswax, have historically been promoted for their cholesterol-lowering effects. While scientific evidence supporting their direct impact on athletic performance is limited, early studies suggest potential benefits in improving grip strength and reducing body fat in athletes. Further research is needed to better understand the role of policosanols in optimizing sports performance [13].

Polyphenols

Polyphenols, abundant in fruits, vegetables, tea, and other plant-based sources, possess potent antioxidant and anti-inflammatory properties that are highly beneficial for athletes. Anthocyanin-rich fruits such as tart cherries have been shown to attenuate inflammatory and oxidative responses post-exercise, leading to faster recovery and improved performance [13]. Curcumin, a bioactive compound in turmeric, relieves delayed onset muscle soreness (DOMS), promotes muscle regeneration, and exhibits antioxidant and anti-inflammatory effects when supplemented at specific doses (e.g., 2.5 g/day Green tea extract, containing catechins and caffeine, supports recovery by reducing oxidative stress and enhancing fat utilization in active individuals [17].

Creatine

Creatine is a naturally occurring compound synthesized in the

body, primarily in the kidneys and liver. It plays a fundamental role in cellular energy production by replenishing ATP (adenosine triphosphate) stores, which are crucial for muscle contractions during exercise. By supplementing with creatine, athletes can increase their muscle's ability to perform high-intensity workouts, leading to improvements in muscle mass and strength. Combining creatine with sugars can enhance its uptake by muscles, further supporting athletic performance and recovery [18].

Glutamine

Glutamine is the most abundant amino acid in muscle tissue and plays a critical role in muscle protein synthesis and recovery. During intense exercise or periods of stress, glutamine levels can become depleted, making supplementation beneficial for athletes. Glutamine supports muscle building, immune function, and neurological health. Additionally, it helps maintain proper blood sugar levels and can reduce cravings for sugar and alcohol. For athletes, glutamine supplementation can aid in muscle recovery, immune support, and overall performance optimization [18].

Arginine

L-Arginine is a semi-essential amino acid known for its role in nitric oxide production, which helps dilate blood vessels and improve blood flow. While arginine supplements are popular among athletes for potentially enhancing exercise performance, research results are mixed. Some studies suggest arginine may not significantly improve exercise capacity in healthy individuals. However, arginine remains widely used in sports nutrition for its potential to enhance blood flow, nutrient delivery to muscles, and overall vascular health [19].

Tribulus Terrestris

Tribulus Terrestris is a plant extract believed to boost testosterone levels and promote muscle growth. It works by increasing luteinizing hormone levels, which stimulates testosterone production. Athletes may use Tribulus Terrestris to support protein synthesis, enhance endurance, and accelerate recovery from workouts. However, caution is advised with dosage, as excessive intake may lead to adverse effects on organ health [18].

Beta-hydroxy Beta-methyl butyrate (HMB)

HMB is a metabolite of the amino acid leucine, known for its potential to reduce muscle protein breakdown and promote protein synthesis. While HMB supplementation has shown promise in supporting muscle growth and exercise performance, results can vary among individuals. HMB may be particularly beneficial for populations prone to muscle loss, such as the elderly or individuals with chronic diseases. Athletes interested in optimizing muscle recovery and growth may consider incorporating HMB into their supplementation regimen, especially during periods of intense training [20].

Cordyceps Sinensis (Caterpillar Fungus)

Cordyceps Sinensis is a traditional Chinese medicinal fungus believed to enhance athletic performance by improving oxygen uti-

lization and energy production. Athletes may use Cordyceps to support endurance, cardiovascular health, and overall vitality. Cordyceps acts similarly to caffeine but without typical side effects like jitters or insomnia. Research suggests that Cordyceps supplementation may benefit athletes looking to improve stamina and recover more efficiently from workouts [18].

Ornithine- α -ketoglutarate (OKG)

OKG supplementation has shown potential benefits in improving nitrogen balance, which is essential for muscle maintenance and recovery in athletes. Studies suggest that OKG may promote greater gains in muscle strength during resistance training. However, further research is needed to fully understand its effects on muscle mass and athletic performance. Athletes engaged in intense training may consider OKG supplementation to optimize recovery and support muscle growth, although individual responses may vary [18].

Methoxy Isolavone

Methoxy Isolavone belongs to the isoflavone family and is known for its potential anabolic effects, particularly in increasing protein synthesis without androgenic side effects. This compound is favored by athletes seeking to gain lean muscle mass. Methoxy Isolavone may partially suppress cortisol, a catabolic hormone, while enhancing nitrogen retention, which can contribute to muscle growth and recovery. While Methoxy Isolavone shows promise as a non-hormonal anabolic agent, further research is needed to elucidate its long-term effects and optimal usage for athletes looking to optimize muscle growth and recovery [18].

Nutraceutical Types for Athletes

Organic Fat burners

Nutraceuticals designed for athletes encompass various categories aimed at enhancing performance and supporting bodily functions. Among these, organic fat burners are widely used to boost metabolic rates, increase energy levels, suppress appetite, and reduce water retention. Common ingredients in these fat burners include natural sources of caffeine like guarana and kola nut, Citrus aurantium (bitter orange), cayenne pepper, chromium, and Garcinia cambogia. While fat burners offer benefits when used correctly, they are also prone to abuse, with individuals often exceeding recommended doses for quicker results, leading to health risks. Notably, substances like ephedra, once popular, have faced bans due to serious side effects associated with misuse.

Natural fat burners like Garcinia cambogia, green coffee bean, and raspberry ketone are gaining popularity for their metabolism-regulating properties. Raspberry ketone, a compound found in red raspberries, aids in fat breakdown by regulating the release of the metabolism-regulating protein adiponectin. Garcinia cambogia, derived from a small pumpkin-shaped fruit, curbs fat storage and appetite. Green coffee beans, rich in chlorogenic acid, support weight loss by regulating blood sugar and metabolism. These natural alternatives are preferred for their minimal side effects compared to synthetic fat burners and are best complemented by a bal-

anced diet and regular exercise [18].

Muscle Building Supplements

In the realm of muscle building, protein supplements like whey proteins (WP) play a crucial role in facilitating muscle repair and growth. Whey proteins are esteemed for their high nutritional value, containing all essential amino acids necessary for human health in optimal proportions. They are rich in branched-chain amino acids (BCAAs) that provide energy during intense exercise, aiding in muscle preservation and recovery. Whey protein's complete amino acid profile supports muscle growth and recovery post-workout, making it an effective supplement for athletes seeking performance enhancement.

Whey protein is available in various forms such as whey powder, concentrate, and isolate, each differing in protein content and bioactive components due to distinct processing methods. Whey protein isolate, containing 90% or more protein, is produced through processes like microfiltration and ion exchange, preserving essential bioactive components critical for muscle recovery and growth [18].

Nutraceuticals in Sports-Related Gastrointestinal Disorders

Physical exercise is widely recognized as a key tool for managing physical fitness and overall health, both for prevention and treatment purposes, particularly in relation to metabolic and immune health. However, these intense exercise regimens can also lead to gastrointestinal symptoms (GIS) like bloating, cramps, nausea, flatulence, abdominal pain, and changes in bowel movements. This is due to the redistribution of blood flow away from the gastrointestinal tract towards skeletal muscles during exercise, potentially causing splanchnic ischemia. Additionally, elevated catecholamine levels can disrupt gastrointestinal motility, affecting nutrient transit and absorption.

These exercise-induced gastrointestinal issues can lead to inflammatory conditions in the digestive tract, possibly affecting permeability and causing microbial translocation, leading to systemic inflammation and mild endotoxemia. Such conditions can impact an athlete's training and competition performance and have broader implications for intestinal microbiota and immune system function. Various substances with nutraceutical properties have potential applications in supporting intestinal health and modulating gut microbiota. These substances offer targeted approaches beyond traditional fiber-based prebiotics, aiming to address specific gut-related issues [21].

Berberine

Berberine (BBR), derived from various medicinal plants, has gained attention for its wide-ranging health benefits, including insulin regulation, lipid metabolism, and immune modulation. Berberine influences gut microbiota by reducing diversity and shifting bacterial balance. Notably, it can increase levels of beneficial bacteria like Akkermansia muciniphila while suppressing other species. Berberine also modulates immune response by reducing inflamma-

tory factors and promoting butyrate synthesis, beneficial for gut health. Clinical studies suggest effectiveness in managing diarrhea and improving gut barrier function [21].

Curcumin

Curcumin, the primary curcuminoid isolated from *Curcuma longa* L., is renowned for antioxidant, anti-inflammatory, and anti-cancer properties. Its metabolism by gut bacteria generates bioactive metabolites with therapeutic potential. Curcumin influences gut microbiota composition, favoring beneficial bacteria like *Lactobacillus* and *Bifidobacterium* while reducing pathogenic species. Animal studies demonstrate positive effects against diabetes-associated microbial changes and colorectal cancer-related species. Curcumin also inhibits inflammatory pathways, potentially protecting the intestinal mucosa [21].

Green Tea

Green tea polyphenols, particularly epigallocatechin gallate (EGCG), modulate gut microbiota composition and promote the growth of beneficial bacteria like *Akkermansia* and short-chain fatty acid producers. Human studies show increased prevalence of specific bacterial families with green tea consumption, contributing to anti-inflammatory and antioxidative effects in the gut. Green tea may offer potential against obesity through its interactions with the gut microbiome [22].

Boswellia

Boswellia serrata (frankincense) exhibits anti-inflammatory and immunomodulatory properties. Its bioactive component, 3-O-acetyl-11-keto- β -boswellic acid (AKBA), influences gut microbiota composition, particularly increasing *Akkermansia muciniphila* levels. *Boswellia* supplementation during a low FODMAP regimen shows promise in reducing abdominal bloating in individuals with gastrointestinal issues [21].

Cranberry

Cranberry polyphenols influence intestinal microbiota by promoting beneficial bacteria like *Lactobacillus*, *Bifidobacterium*, and *Akkermansia muciniphila*. Studies indicate that cranberry consumption can modulate gut microbiota composition, reduce inflammation, and improve metabolic health. This fruit's impact on microbiota diversity may contribute to its protective effects against obesity and metabolic disorders [21].

The demand for sports nutraceuticals is rapidly increasing due to heightened consumer awareness and growing acceptance of nutraceutical supplements in the market. This surge in consumer interest is expected to drive strong sales in the sports nutrition industry. According to BCC Research, the global market for sports nutrition products is growing at an impressive growth rate of 24.1%.

The explosive growth of sports performance supplements can be attributed to shifting market focus. Traditionally, sports endurance supplements targeted bodybuilders and professional athletes. However, sports nutrition products are now classified into multiple fitness categories, appealing to a broader audience that includes in-

dividuals engaged in recreational workouts and physical activities. Furthermore, there is a notable increase in the use of sports performance nutritional supplements among both genders and within the youth segment, as indicated by surveys such as the National Health Interview Survey (NHIS) [18].

Conclusion

This study concludes by highlighting the important role that nutraceuticals play in treating complicated medical problems, especially in high-altitude settings where physiological difficulties are common. Examining certain sources, including *Spirogyra porticalis* and *Ophiocordyceps sinensis*, exposes their extensive profiles of bioactive chemicals that may have medicinal uses. The significance of traditional dietary resources is further highlighted by the discovery that the wild edible fruit plants of the Indian Himalayan area are important providers of key minerals and antioxidants. Nutraceuticals are useful tools for athletes to maximize their health since they can improve athletic performance and recuperation, as the review also demonstrates. It is clear from classifying different sports nutraceuticals—from organic fat burners to supplements for muscular growth—that these substances can help with certain performance-related problems, such as digestive disorders. Furthermore, the advantages of nutraceuticals such as green tea, curcumin, and berberine in enhancing gut health and regulating gut microbiota highlight their many uses. Overall, the results indicate that there is a lot of potential for improving health outcomes and quality of life in a variety of groups by incorporating nutraceuticals into traditional healthcare and sports nutrition practices.

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Conflict of Interest

No Conflict of Interest.

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