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Original Research Article

Nutraceuticals and functional foods

Recent Trends of Nutraceutical Advancements in Sports Induced Inflammation and Performance

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Abstract: Functional foods, which are medicinal, provide health benefits beyond its energy and essential nutrients. The proposed literature review highlights nutraceutical advancements in sports physiology and performance. The review focuses on recent innovations and applications of nutraceutical formulation in the sports industry. The scientific-based evidence and reports presented were elucidated from Advance Search, Elsevier, NCBI, and peer-reviewed journals. Literature documents have revealed the emerging effect of polyphenols and flavonoids in muscle performance, especially Quercetin, Resveratrol, and green tea catechins, which also protect muscle cardiovascular fibers against oxidative stress induced by ischemia. It is widely clear that athletes do extensive exercises and good nutrition to provide maximum results. 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 supplements. These nutritional supplements are usually claimed to improve strength, performance, and stamina, help build lean muscle, and burn excess fat. The current understanding of muscle damage and pain couples muscle damage and associated pain with generating reactive oxygen species (ROS), oxidative stress, and inflammation. Mounting bodies of evidence have substantiated the utility of several plants, plant extracts, and phytochemicals as Nutri-pharmacotherapeutic interventions to scavenge ROS and ameliorate inflammation. The medicinal herbs have shown promising therapeutic effects in supporting sports performance and helping manage sports injuries.

Keywords: Sports performance, Sports injuries, Muscle inflammation, Flavonoids, Nutraceuticals.

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1. INTRODUCTION

1.1. Overview On Nutraceuticals

The term nutraceutical was coined from "Nutrition" and "Pharmaceutical" in 1989 by Stephen Defelice, founder and chairman of the Foundation for Innovation in Medicine, Cranford, an American organization encouraging medical health. Nutraceutical combines 'nutrition' and 'pharmaceutical,' which refers to a food or product that provides health benefits. According to the Food Safety and Standards Authority of India (FSSAI), a nutraceutical is a food product that provides physiological benefits and helps maintain good health. Functional foods, or "nutraceuticals" or "designer foods," contain supplements intended to improve health. Many studies, including several European Commission (EC) funded projects, have led to understanding the potential mechanisms of biologically active components in food, which could improve health and reduce the risk of disease while enhancing our overall well-being[1]. Bioactive compounds (BCs) are nutritional agents with diverse potentials exhibiting anti-inflammation, anti-oxidative stress, and anti-metabolic syndrome. The ability of BCs to modulate biological and physiological conditions may derive from their chemical and biological structures for favourable bioavailability and biochemical function[2]. Bioactive compounds, including terpenoids, polyphenols, alkaloids, and other nitrogen-containing constituents, show various beneficial effects from their antioxidant and anti-inflammatory properties. These compounds can be found in vegetables, fruits, grains, spices, and their derived foods and beverages such as tea, olive oil, fruit juices, wine, and chocolates. This review highlights recent articles exerting the numerous potential uses of products and by-products of the agro-food supply chain, which can have various applications. Food bioactive compounds are extra nutritional constituents that typically occur in small quantities in foods. Much scientific research must be conducted before we can make science/nutrition-based dietary recommendations. Muscle injuries are very common in sports athletes. It often produces pain, dysfunction, and inability to move back to events or competitions. Proper diagnosis and management can improve recovery and minimize the time to return to play. Initial conventional management highlighted the RICE principles (Rest, Ice, Compression, and Elevation). Inflammation plays a key role in the pathophysiology of diseases linked to the failure of skeletal muscles. Chronic inflammation with elevated levels of inflammatory mediators has been observed in various diseases, such as inflammatory myopathies and muscle-related issues. Skeletal muscles comprise about 40% of a person's total weight and are essential for good health. Skeletal muscle aids in important biological functions, including nutrition sensing, energy metabolism, core temperature regulation, and organ bone protection[3]. The current understanding of muscle damage and pain couples muscle damage and associated pain with generating reactive oxygen species (ROS), oxidative stress, and inflammation. Mounting bodies of evidence have substantiated the utility of several plants, plant extracts, and phytochemicals as Nutri-pharmacotherapeutic interventions to scavenge ROS and ameliorate inflammation[3]. Interest in the relationship between supplementation, exercise, and stress has been drastically increased in recent years.

1.2. Dietary Supplementation, Skeletal muscle functioning, and Oxidative stress.

Exercise is said to have many benefits, such as preventive and therapeutic effects. A food or dietary supplement is a product intended to supplement the normal diet. It consists of a concentrated source of a nutrient or other substances having a nutritional or physiological effect in a simple or combined form, commercialized in dosed formulae, capsules, tablets, pills, and other similar forms, bags of powder, vials of liquid, dropper bottles, and other similar forms of liquids and powders to be taken in small, quantified amounts [4]. Dietary supplements, also known as nutritional or food supplements are a special category of health and nutritional products and include over-the-counter (OTC) formulations. Dietary supplements can support muscular health and development, but their effectiveness often depends on the type of supplement, dietary pattern, and specific goals. The combination of three pillars, i.e. diet, it, supplementation, and exercise, helps maintain skeletal health. It is a comprehensive approach of holistic health. Vitamin D is produced by phytoplankton, which is oldest of all and helps protect ultraviolet-sensitive macromolecules including proteins, DNA and RNA and helps maintain calcium homeostasis, a major physiological problem seen in athletes. Vitamin D plays an important role in calcium and phosphorus metabolism and helps ensure adequate levels of these minerals for metabolic functions and bone mineralization. Although exercise training can enhance endogenous antioxidant resources, these protective mechanisms are typically insufficient to adequately deal with ROS resulting from high-intensity or prolonged intermittent aerobic or anaerobic exercise. Because of this, various antioxidant or anticatabolic supplements have been investigated to determine their potential use in the protection from oxidative stress, corresponding muscle damage, or resultant performance decrements [5]. Few compounds show the properties of ergogenic aids that mitigate oxidative stress due to exercise. Few vitamins have the potential antioxidants, such as vitamins A, C, and E. There is much evidence that proper diet and exercise help to manage muscle health and performance. Antioxidant-rich foods help decrease the inflammation caused by exercises and attenuate exercise-induced muscle damage, which results in a decrease in stress markers. Recent research evidence has also indicated that direct supplementation with antioxidant-rich supplements may effectively combat oxidative stress and enhance endogenous resources. Exercise-induced muscle damage is another key factor for the increase in inflammatory markers, which results in muscle damage or muscle soreness. Free radicals generated through oxidative stress or exercise-induced muscle damage can activate the redox signaling pathways.

1.3. Importance of Vitamins and Minerals

Minerals and vitamins are essential for many human functions that impact athletes' health and performance. Vitamins and minerals are necessary for several movements, but most of the time, the body cannot produce these vital nutrients on its own; as a result, individuals must rely on exogenous food sources to meet their body's vitamin and mineral requirements dependent processes, including energy metabolism, oxygen transport, red blood cell synthesis, immune system function, muscle growth and repair, and bone health. Micronutrient losses are often seen in athletes via urine, sweat, etc. The composition of sweat and the amount

of minerals that athletes lose through perspiration depend on factors such as the duration and intensity of physical exercise and environmental factors (sex, body typing, training status). For example, male cyclists were found to have no elevated excretion of magnesium, iron, zinc, or copper during high-intensity training [6]. The use of food supplements is associated with risks for athletes in terms of health, performance, and doping. Based on recent research, it is estimated that 8–12% of doping cases are attributable to food supplements.

1.4. Macronutrient recommendation for endurance athletes [7]

Table 1: Macronutrient recommendation for endurance athletes

Type of sport	Nutrient Recommendation
ENDURANCE ATHLETES	CHO: 6-8g/kg/day for exercise (1h/day) 6-10g/kg/day for exercise (1-3h/day) 8-12g/kg/day for exercise (>4 h/day)
	Protein: 1.2-1.4g/kg/BW
	Fat: Do not restrict < 20% of total energy requirement. Supplement on CLA, omega-3, and MCT. Limit of fat only during Carbohydrate loading.
	Water: Initial plan of hydration 400-800ml/hour

1.5. Micronutrient recommendation for endurance athletes

Table 2: Micronutrient recommendation for endurance athletes

Nutrients	Performance impact
Nitrates: 300–600 mg of nitrate/ 500 mL beetroot juice/ 3–6 whole beets within 90mins of onset exercise. 6 days of a high-nitrate diet before the event	Supplementation has been associated with 4–25% improvements in exercise time to exhaustion.
Caffeine: 3–6 mg/kg taken 30–90 min before exercise.	Caffeine consumption during activity should be considered concurrent with CHO intake for improved efficacy.
Probiotics: ***Lactobacillus and Bifidobacteria*** will help me resolve gut issues.	Helps in creating a neat and clean microbiome in the gut
Creatine: Loading-phase: ~ 20 g/day (divided into 4 equal daily doses) for 5–7 days **Maintenance phase:** 3–5 g/day (single dose) for the duration of the supplementation period	Enhanced maximum isometric strength and the acute performance of single and repeated high-intensity exercise, e, lean mass gains and improvements to muscular strength and power; potential anti-inflammatory and anti-oxidant effects are noted (Deminice et al., 2013**).**
Sodium Bicarbonate: NaHCO3 dose of 0.2–0.4 g/kg, consumed 60–150 min before exercise	Enhanced performance in high-intensity sprints
Beta Alanine: Daily consumption of ~ 65 mg/kg BM over an extended supplement time of 10–12 weeks.	variations in muscle carnosine synthesis have been reported (Nassis et al., 2016)
Vitamin D: Recommend 1,000 IU/day D3	effects of vitamin D supplementation on muscle function and recovery
Omega 3-fatty acids: (about 2 g/day)	increased muscle protein synthesis; reduced symptoms of or enhanced recovery from muscle-damaging exercise (e.g., DOMS).
Glutamine:	Some evidence of a reduction in URS after endurance events in competitors receiving glutamine supplementation (2 × 5 g).

2. OBJECTIVES

The proposed Systematic scientific review investigation addresses the nutraceutical advancements in sports-induced inflammation and performance.

2.1. Methodology

The proposed literature review highlights nutraceutical advancements in sports physiology and performance.

2.2. Research Design

The investigation focuses on recent innovations and applications of nutraceutical formulation in the sports industry. The scientific-based evidence and reports presented were elucidated from Advance Search, Elsevier, NCBI, and peer-reviewed journals. The investigation aims to draw scientific evidence and reports from Advance Search, Elsevier, NCBI, and peer-reviewed journals. The investigation criteria include scientific-based evidence in English and full-text from experimental, In vivo, and in-vitro studies.

2.3. Documentation

Citations used for the review study (Google Scholar, Research Gate, PubMed, Semantic Scholar, NCBI, and Science Direct).

2.4. *Criteria*

56 papers were pre-reviewed, of which 38 were included in the research relevant to establishing the findings.

2.5. *Data acquisition /analysis*

The 56 research papers included Review articles (29), experimental studies (18), and original articles (9).

2.6. *Review of literature*

Literature about the proposed research is highlighted in the following.

3. PATHOPHYSIOLOGY OF MUSCLE INFLAMMATION

Sports-related knee injuries occur commonly in athletes. However, there has yet to be a published epidemiological study from India to date [8]. 23% of India's population are into sports, out of which Cricket is the most played game and football is the game where injuries are mostly seen. By INDIAN ACADEMY OF ORTHOPAEDICS 50-62% of sports individuals are injured. Sports can be classified into individual, partner, team, and extreme sports. Most injuries occur in collision sports, individual sports, and recreational sports. Injuries to skeletal muscle account for over 40% of all injuries with the lower leg being the predominant site of injury. One of the main variables explored in sports is nutrition. This study investigates the evidence around various nutrition strategies, including macro- and micronutrients, as well as total energy intake, to reduce the risk of injury and improve recovery time, focusing on injuries to skeletal muscle and sports-induced inflammation(Close et al., 2019)The International Olympic Committee (IOC) in its manual on sports injuries defined MSK-Is as "new or recurring musculoskeletal complaints incurred during competition or training that require medical attention or nutritional attention, regardless of the potential absence from competition or training.

3.1. *Exercise-induced muscle damage*

Exercise-induced muscle damage (EIMD) results in transient muscle inflammation, strength loss, and muscle soreness and may cause subsequent exercise avoidance. Omega-3 (n-3) supplementation may minimize EIMD via its anti-inflammatory properties; 4 weeks' supplementation of omega 3, 3g/day, was given to healthy male athletes. The study revealed that it successfully attenuated minor aspects of EIMD. While not improving performance, these findings may be relevant to soreness-associated exercise avoidance. (Kyriakidou et al., 2021) Nutri kinetics extends the classical pharmacokinetics concept. It summarizes ADME characteristics in the human superorganism. Nutri kinetics: What the body does to the food product /drug. It includes bioavailability and bioaccessibility. Responses to dietary supplements can vary substantially between individuals, and therefore, ingesting any supplement must be assessed in training before being used in competition. It is recommended that dietary supplements are only used based on the advice of a qualified sports nutrition professional. Muscle Inflammation during Injuries in Exercises Physiological responses depend on the extent of EIMD[9].

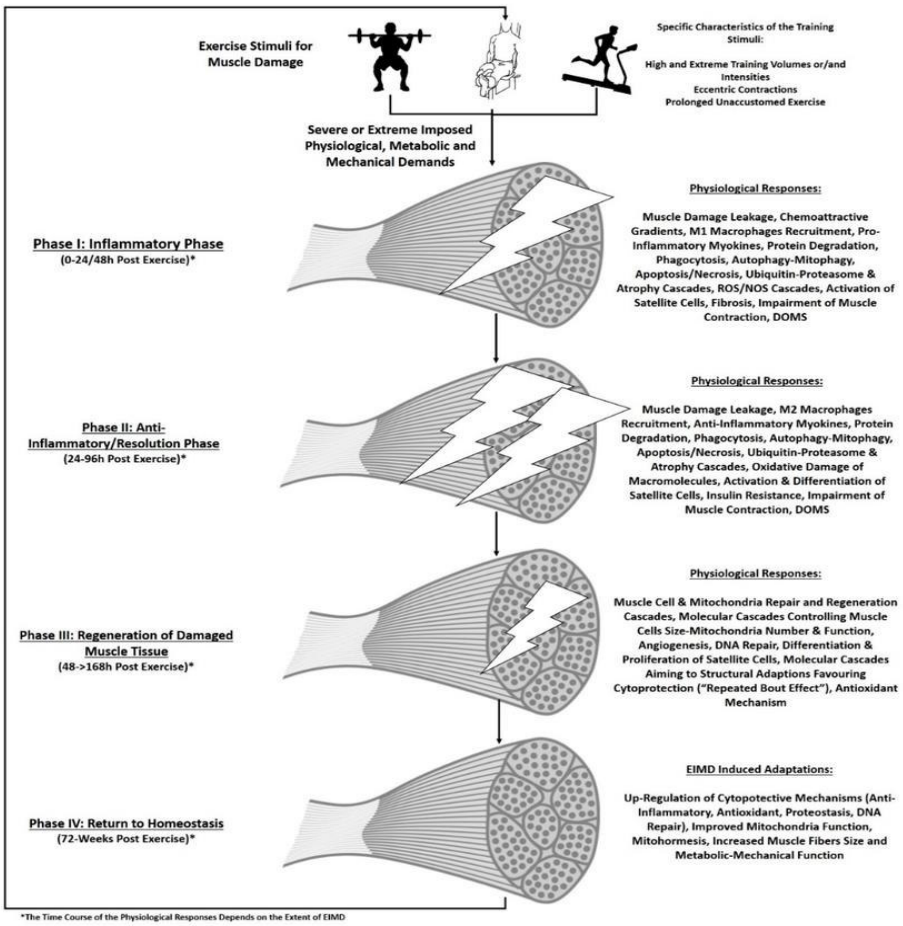

Fig 1: Physiological responses depend on the extent of EIMD[10]

A skeletal muscle's structural and functional unit is a motor unit composed of a motor neuron and a group of muscle fibres or *myocytes*. The motor neuron's axon contacts each muscle fiber in a single junction called a neuromuscular junction.

3.2. Characteristics of Muscle Tissue

Muscle tissue has a property of *excitability* as the muscle cell releases specific chemicals called neurotransmitters like acetylcholine (Ach). Ach stimulates the muscle cell, generatingrates a change in membrane potential (action potential,), i.e., response to stimulus. The developed action potential can be propagated along the muscle membrane and eventually triggers the muscle cell to contract forcibly due to the frequent and adequate amount of stimulation, termed *contractility*. It can also stretch appropriately beyond its resting link, known as *extensibility*. It has the special property of maintaining *elasticity*.

Functions of Muscle Tissue

- Produces Locomotion/movement for the skeletal system
- To maintain posture and stabilization
- Helps stabilize the joints
- Aids in generating heat

Skeleton muscle has the largest mass in the human body, accounting for 45% of total body weight. Muscle injuries can be caused by bruising or stretching. The classification of injuries is mild, moderate, and severe. The Orthopaedic classification of muscle injury is Grade I (Oedema and discomfort), Grade II (Loss of function), and Grade III (Complete rupture, severe pain, and extensive hematoma).

3.3. Occurrence of inflammation

When an inflammation occurs in your body, many different immune system cells may be involved. The Inflammatory response occurs when tissues are injured by trauma, heat or any other cause. The damaged cells release chemicals called histamines and prostaglandins. These chemicals leak out fluid into the tissue, causing swelling. The chemicals also attract white blood cells called phagocytes, and the process is called phagocytosis. When a wound swells up, turns red, and hurts, it may indicate inflammation. The five cardinal signs of inflammation are redness, heat, swelling, pain, and loss of function.

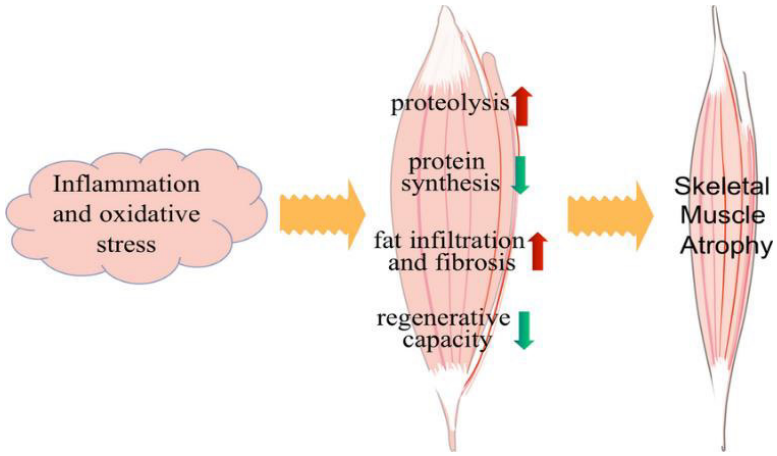

Fig 2: Occurrence of Inflammation[11]

4. EPIDEMIOLOGICAL EVIDENCES -Applications of phytochemicals in sports-induced muscle inflammation

Epidemiological and intervention studies have been conducted to discover dietary patterns, foods, and bioactive compounds with protective anti-inflammatory actions. Thus, a way to prevent inflammation that can lead to carcinogenesis or cardiovascular diseases is by using bioactive food compounds of spices and herbs that show both antioxidant and anti-inflammatory properties. For this reason, anti-inflammatory phytochemicals represent an exogenous aid crucial for preventing chronic diseases mediated by inflammatory processes. Literature documents have revealed the emerging effect of polyphenols and flavonoids in muscle performance, especially Quercetin, Resveratrol, and green tea catechins, which also protect muscle cardiovascular fibers against oxidative stress induced by ischemia. Furthermore, recent work has shown that a green tea extract enriched in catechins increases muscle performance while increasing lipid oxidation.

4.1. *CURCUMIN*

Curcumin, chemically known as 1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione or diferuloylmethane, is isolated from the plant *Curcuma longa.* Curcumin is the yellowish polyphenol plant found in the turmeric plant, traditionally used for most pathological conditions such as infection, reducing inflammation, stress, and depression. Studies have also reported that curcumin possesses potent activity as an antioxidant and anti-inflammatory agent and exerts beneficial therapeutic effects on wound healing [12]. Curcumin effectively reduces inflammation through the NF-κB and IκB kinase signalling pathways [13]. Inflammation and oxidative stress may affect exercise performance and heath, which can cause an imbalance between ROS, RNS, and endogenous antioxidants. Several clinical trials have investigated the efficacy of curcumin in reducing muscle damage and soreness induced by exercise via a reduction in oxidative stress and inflammation [14]. Curcumin supplementation has been shown to improve sports performance, providing less EIMD and reducing fatigue. EIMD affects all individuals depending upon

the type, intensity, and duration of the exercise they undertake and the training status of the individual. Curcumin has been shown to attenuate muscle soreness, improve performance, reduce blood levels of inflammatory markers, and enhance endogenous oxidative capacity post-exercise [15]. Muscle damage is prominent post-exercise due to the release of prostaglandins under the influence of cyclooxygenase (COX-1 and COX-2), contributing to redness, swelling, and pain at the site of damage. Curcumin downregulates the expression of COX-2 and thus decreases the release of prostaglandins, reducing muscle damage. Curcumin downregulates the expression of COX-2 and thus decreases the release of prostaglandins, reducing muscle damage. Therefore, this review was undertaken to summarize the effect of curcumin supplementation on exercise and muscle performance and to define its therapeutic benefits better.

Table 3: Preclinical studies that evaluated the effect of Curcumin supplementation on exercise performance

Dosage	Model /study design	Results /exercise test
180 mg/day	Randomized single-blind, parallel clinical trial	Resistance exercise: eccentric isokinetic contractions
500mg/day curcumin	Double-blind crossover clinical trial	1 hour of aerobic exercise (treadmill running) at 65% VO2 max.
1.5 g/day curcumin	Randomized double-blind crossover clinical trial	35 min of steady-state aerobic exercise (cycling) at 60% VO2 max with mental stress challenges
6 g of curcumin + 60 mg of piperine/day	Randomized singleblind crossover clinical trial	Improved Aerobic exercise
400 mg/day	Randomized doubleblind clinical trial	Resistance exercise
Mediterranean diet þ 50 mg Phytome RV turmeric (10 mg of curcumin) þ 140 mg of Boswellia extract (105 mg of boswellic acid.) 3 months	Controlled randomized parallel clinical trial	Aerobic exercise (cycling), around 200 km weekly
12.3, 24.6, and 61.5 ml/kg curcumin daily; 28 days before trial	Male mice model	Increased Muscle glycogen, decreased Serum lactate, ammonia, glucose, BUN, CK, AST, and ALT

4.2. RESVERATROL

Resveratrol (3,5, 40-trihydroxystilbene) is a polyphenol compound in grapes, nuts, and red wine. Resveratrol, a natural polyphenolic flavonoid antioxidant, has numerous health benefits and acts as a potent anti-inflammatory substance. It helps increase the amount of mitochondria in cells through their biogenesis induction. Many studies have shown that resveratrol possesses antiaging, anticancer, anti-atherosclerosis, and anti-inflammatory effects, increases insulin sensitivity, and reduces ROS levels. When consumed orally, trans-resveratrol is rapidly converted to the more biologically active form of dihydro resveratrol [16]. This resveratrol form has been reported to regulate AMPK and TNF-α, which enforces cell mitochondrial function, increases insulin sensitivity, and inhibits inflammation and low-density lipoprotein oxidation. Resveratrol activates molecular pathways during exercise and produces a performance-enhancing effect. It also helps boost performance in exercise and has contributed to maintaining health in aging and quality of life. Studies show that it helps boost endurance and other motor abilities, helps skeletal muscle strength to a greater extent, and increases exercise capabilities and skeletal muscular endurance. Resveratrol enables mitochondrial biogenesis in the skeletal muscle and helps in ATP production (mitochondria) through oxidative phosphorylation.

Table 4: Preclinical studies that evaluated the effect of Resveratrol supplementation on exercise performance

Dosage	Model/study design	Results/ exercise test	Author	DOI
4g /kg for 12 weeks	Mice model (rodents)	Increases stamina	Wicinski etal. (2018)	https://doi.org/10.1016/j.scispo.2018.02.010
150mg R Given in 2 doses	Mouse model-Humans	Increased exercise	Yu su etal., (2023)	https://doi.org/10.3390/nu15010249
(100 mg/day) for 90 days	Military fighters (human study)	reduced IL-6 and TNF-a level	Macedo etal., (2015)	http://dx.doi.org/10.1016/j.cbi.2014.12.033
480mg/day	Cyclists (human study)	Reduced IL-6 levels	Tsao etal., (2021)	10.7150/ijms.55633

4.3. QUERCETIN

Quercetin is a unique bioflavonoid found in fruits and vegetables and has unique biological properties that are likely to improve mental/physical performance and reduce infection risk during intense exercise. These properties include anti-inflammatory, antioxidant, and psychostimulant activity, as well as the ability to stimulate mitochondrial biogenesis, and they form the basis for potential benefits to overall health and diseases. Good evidence supports the hypothesis that quercetin may increase endurance exercise capacity. The evidence comes primarily from *in vitro* and *in vivo* studies in rodents that show that quercetin has a combination of biological properties known to affect both physical and

mental performance, including antioxidant, and anti-inflammatory activity [17]. Concerning anti-inflammatory properties, quercetin has been shown to modulate intracellular signaling pathways, including the inflammatory signaling cascade, by inhibiting activation of the important proinflammatory transcription factor nuclear factor-kappa (NF-κB), among others. The estimated flavonoid intake ranges from 50 to 800 mg/day (quercetin accounts for 75%). Quercetin intake was reported to be 4.37 mg/day, where the main food sources of flavanol were apples (7.4%), followed by potatoes (3.9%), lettuce (3.8%), and oranges (3.8%). At the same time, the average quercetin intake was 4.43 mg/day, with apple (3.7%), potato (2.5%), celery (2.2%), eggplant (2.2%), and Actinidia (1.6%) being the main food sources of quercetin [18].

Table 5: Preclinical studies that evaluated the effect of Quercetin supplementation on exercise performance

Dosage	Model /study design/ cell lines	Author	Results	DOI
3 µmol/L	Guinea pig epithelial cells	Kim Hp etal.,	Inhibition of both cyclooxygenase and lipoxygenase: Anti Inflammatory effect	https://doi.org/10.1016/S0952-3278(98)90125-9
1000mg/day	Human studies	Bigelman et al.,	Vo2 max	10.1249/MSS.0b013e31822495a7
500mg quercetin + 250mg vitamin C	Human studies	Askari etal.,	CRP and IL 6 have shown low levels	17(7): 637–641.

Table 6: Application of Medicinal herbs – Anti-inflammatory / Antioxidants.

Source	Dosage	Model /study design/ cell lines	Author	Results	DOI / References
Ginger (Zingiber officinale)	30mg/day Oral administration	Oral administration (mice model)	Mona Ghasemian etal.,	TNF-α and high-sensitivity C-reactive protein have significantly decreased	doi.org/10.1155/2016/9130979
Ginseng	3female triathletes aged 24 to 36 years old	Human trial	Van Schedule	↑↑ Running time, increased endurance activity s	doi.org/10.1186/s12970-018-0218-y
Eurycoma Longifolia	150mg	Human trial (healthy men)	Yusof etal.,	↑ muscular strength	Br J Sport Med. 2003; 37:465–6.
Ginseng extract	400 mg/day ginseng extract	Female athletes	Maha sellami etal.,	↑↑ Increased endurance time	1993; 19:337–47.
Caffeine	2-9 mg/kg body mass 1hour prior to exercise	Runners and cyclist		Increases strength	Senchina DS, Hallam JE, Kohut ML, Nguyen NA, Perera MA. 2014 Jan 1;20

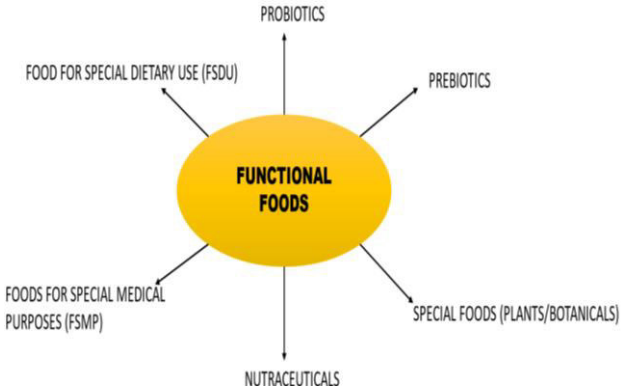

Fig 3: Application of functional foods in Nutraceutical innovations.

There are various medicines for controlling and suppressing inflammatory crisis; steroids, nonsteroid anti-inflammatory drugs, and immunosuppressants are the practical examples of these medications that are associated with adverse effects while in practice, our goal is to apply minimum effective dose by the highest efficacy with the least adverse effects. Thus, we need to apply natural anti-inflammatory factors within medication therapy to achieve increased pharmacological response and the lowest degree of unwanted side effects. Herbal medicines are promoting subjects in medicine, and, of course, we must increase our knowledge about them. Complementary, alternative, and traditional medicines are

pivotal sources of guidance for herbal medication, but modern medicine must prove these guidelines through scientific methods before using them in practice.

5. FUTURE TRENDS

Future therapeutic advancements will benefit greatly from nutraceuticals, but their success will depend on maintaining strict efficacy, safety, and purity standards. The convenience of nutraceuticals for today's lifestyle will ensure their continued popularity. Certain products have undergone thorough investigation and contain innovative additives that have the potential to accelerate the advantages of consuming conventionally healthy foods. Curcumin is the best example of sports nutrition knowledge, and it has evolved globally for better results. A few tropical fruits that can be used for sports nutrition are bananas, cherries, grapes, pomegranates, and watermelons. Those fruits may be developed as a sports supplement in the form of nanoparticles, which have several training and competitive benefits for athletes. Scientists can find clear clarity between food, genetics, and phenotype mapping. Only a few companies or healthcare platforms give plans based on their metabolism. As a result, personalized diet plans could be successfully applied to combat players, as tools tailored to a particular individual's requirements could be developed, advising an athlete to consume more or less of certain food groups. On the other hand, several food and nutrition companies work on nutraceuticals and bioactive that are enhanced with specific nutrients or plant-based polyphenols, which can incorporate a wide range of bioactive compounds into foods and beverages.

6. SAFETY AND EFFICACY

No relevant safety information was provided, and none of the trials considered had any documented negative effects. Therefore, this review study is unable to make any remarks on it. WADA has approved all drugs covered in this assessment as safe for use in humans when taken at recommended dosages. Even though some products are considered safe and approved by WADA athletes, they should be cautious about using them in quantity and concerning nutrient periodization. Furthermore, based on this review, sports performance and recovery among athletes have been measured but should be particularized with age, sex, body typing, and exercise duration.

7. NUTRACEUTICALS AND ITS RATIONALE

The sports nutrition and nutraceutical industry is largely witnessing plant-based nutraceuticals in different forms of supplementation gels, bars, effervescent gummies, ready-to-drink products, and powders. The trend for supplements has shifted to natural-based foods like extracts and plant-based products to enhance performance, reduce exercise-induced inflammation, and improve motor abilities. Herbal extracts are becoming increasingly popular due to the consumer's reliance in traditional remedies. The demand for plant-based nutritional supplements is growing on the increasing graph. Nutri vigilance and Phyto vigilance are relatively new concepts in our country; however, regulatory authorities must proactively observe the adverse effects and issues related to substandard and counterfeit nutraceutical products. Healthcare professionals, including pharmaceutical physicians, can play an important role in safeguarding the population by advocating the rational use of nutraceuticals, food supplements, and consumer health products. Increased demand for herbal and herbal extracts was on the rise due to the population's growing preference for natural and herbal foods and traditional remedies. The market showed growth in functional foods and beverages incorporating added nutrients or functional ingredients targeting specific health benefits such as probiotics, prebiotics, antioxidants, and nutraceuticals.

8. CONCLUSION

Nutraceuticals offer a preventive and therapeutic approach with fewer long-term complications than pharmaceuticals, such as gut issues and skin reactions. They provide nourishment and health benefits, playing a growing role in healthcare, disease prevention, and performance enhancement, especially in sports. Athletes increasingly use nutraceuticals for improved performance and muscle mass, although doping risks exist with certain supplements. Plant-based, natural products in sports nutrition are gaining popularity, requiring more clinical trials to understand their efficacy, dosages, and potential side effects. Nutraceuticals may serve as natural alternatives to conventional pain medications.

9. AUTHORS CONTRIBUTIONS STATEMENT

Bhargavi M Data collection, Data tabulation; Sushma BV Data designing, Reporting, and interpretation. Ms. Bhargavi M conceptualized and gathered the data about this work. Dr. Sushma BV analyzed the data and gave input on designing the manuscript. All the authors discussed the final methodology and results and contributed to the final Manuscript.

10. CONFLICT OF INTEREST

Conflict of interest declared none.

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