

REVIEW

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The importance of medicinal herbs and plants for sports: an organic way to enhance athletic performance

Mohamad Hesam Shahrajabian^{1†} and Wenli Sun^{1*†}

Abstract

Background Natural components in plants can be used as a therapeutic adjuvant for different pathologies, improve physiological and biochemical changes which can enhance individuals who practice physical activities. Implementing and designing appropriate dietary interventions is integral to the function of sports nutrition professionals.

Objective This article aims to provide deep of knowledge of the influence of application of medicinal plants and herbs, as well as plant-based diets on athletes. It also seeks to provide valuable information and insights to simplify the nutritional strategies as well as principles with understanding the importance of natural products in an organic life, and focus on the appropriate way to use the natural advantages of plant-based nutrition.

Design Review. Online databases were used to retrieve data from 2003 to the present day.

Data sources Google Scholar, Scopus, and PubMed databases were used during the literature analysis.

Review methods Relevant identified studies were screened for final inclusion, and studies were included if they focused on athletes, sportsmen, medicinal plants, natural products, physical performance, and physical activity.

Results and discussion The supplementation of ginseng can increase lactate, cardio respiratory function, aerobic capacity, frequent redundancy (e.g., increase endurance capacity, endurance running time, and endurance performance), and muscle strength with positive effects on immune function, brain function and stabilizes blood pressure. Green tea and *Coffea arabica* supplementation can enhance endurance capacity, anaerobic performances, blood catecholamine, immune responses in cyclist and runner, serum catecholamine levels, muscle strength and improve endurance running performance. Ephedrine can increase alertness and reaction time and aerobic capacity and reduce fatigue. Ginger can increase fatigue resistance in athletes, and reduce inflammation biomarkers, aspartate aminotransferase (AST), and alanine aminotransferase (ALT). Application of *Tribulus terrestris* can increase production of luteinizing hormone (LH), testosterone production in healthy male, muscle growth, and reduce inflammation, oxidative damage in muscle and cardiovascular activity. *Rhodiola Rosea* can improve performance, muscle fatigue resistance and memory as well as concentration. *Cordyceps sinensis* may increase lactic acid production, heart rate

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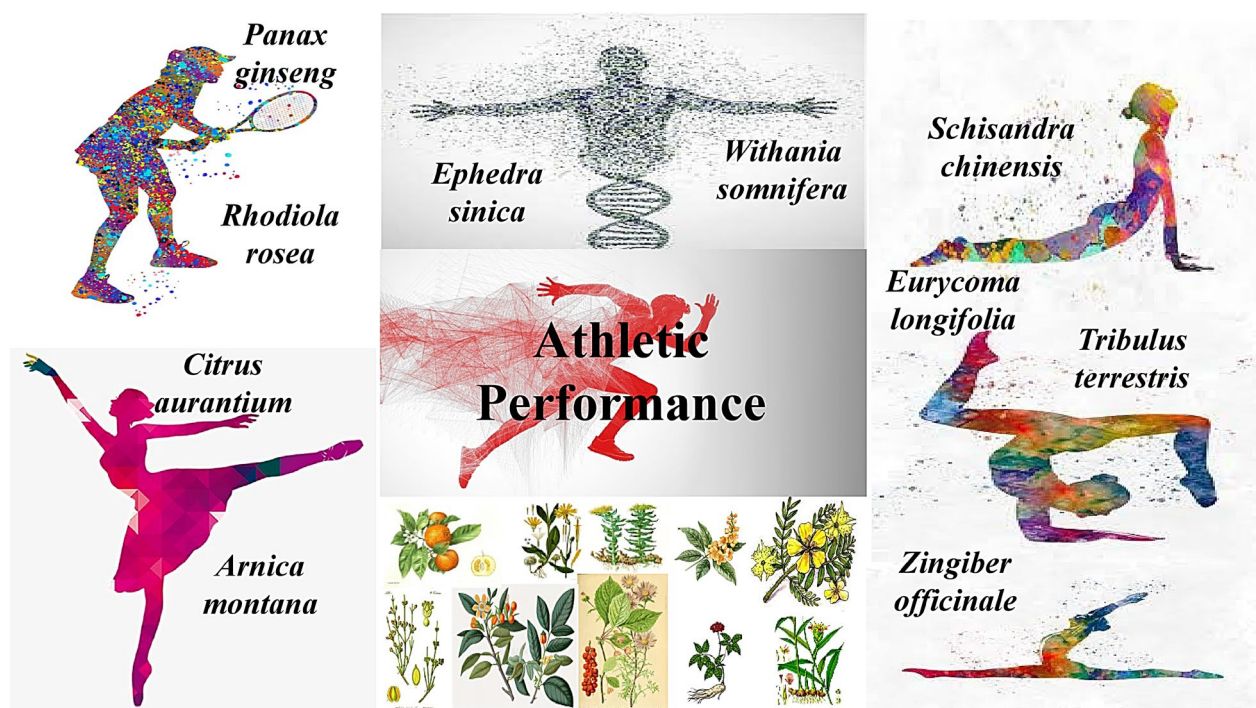
variability and blood, muscle fatigue resistance, aerobic capacity and cardiovascular responses in health runners. Application of *Ginkgo biloba* can increase the endurance performance and time to exhaustion in athletes and improve muscle tissue blood and exercise performance. Increase in muscle strength in patients with osteoarthritis of the knee, reduce pain and improve immune system can be increased after supplementation of Arnica. Application of Astragalus can increase aerobic performance in runner, immune system and reduce pain. High treatment of musculoskeletal and joint-related conditions, treatment of pain and aches can be used after application of *Salix alba*. Application of saffron can reduce tumor necrosis factor alpha, levels of lactate dehydrogenase, and improve catalase, superoxide dismutase and blood flow in retina and choroid. Supplementation of fenugreek can increase endurance capacity and fatty acids, free testosterone levels and reduce serum creatinine. *Myrtus communis* can increase anaerobic performances, serum proteins and decrease triglycerides.

Conclusion Supplementation of medicinal plants in athletes' diets can increase athletic performance, and provide synergistic health benefits.

Clinical trial number Not applicable.

Keywords Athletes, Ginseng, Medicinal plant, Natural products, Organic life, Sport supplements

Graphical Abstract



Introduction

One of the most determinants of training and fitness of a sports person is nutritional status [1–4]. Appropriate nutrient uptake can improve physical performance, and nutrient deficiency consequences can cause poor athletic performance [5–7]. Organized healthy diet and proper nutrition is necessary for athletes' lives, although, concern about the importance of proper nutrition as an integral part of the training has been enhanced among most athletes [8–11]. Energy requirements of athletes are usually high because of their increased body growth and physical activity [12, 13], and inadequate nutrient uptake may lead to poor athletic performance as well as health

problems [14–17]. There is a positive correlation between nutrition knowledge and nutrition attitude [18–20], and natural products are mainly obtained from roots, berries, seed, and leaves extracts, and because of their natural constituents, most of them are considered as both food and medicine with specifies the protocol of use [21, 22]. Plant-based diets and consumption of medicinal plants and herbs have been a central focus in the constantly changing field of sports nutrition. Athletes are encouraged to use a new way of thinking which involves embracing the wide range of plant-based foods, such as seeds, nuts, legumes, whole grains, vegetables, and fruits [23–26]. It is reported that medicinal plants and herbs

appear to be an appropriate alternative to their conventional counterparts as they are a high source of antioxidant bioactive components, minerals and vitamins [27]. The interaction between nutrition and exercise is complex, and various sports nutrition products have blends of micro- and macro-nutrients and phytochemicals which have clinical backing for athletes, and both exercise and nutrition have important influence on both chronically and acutely, and the system of the body. It is also essential to focus on botanically fortified components through awareness of relation between plant products and health [28, 29]. Appropriate nutritional supplements consumed by athletes can maximize nutrient absorption, increase physical endurance, and reduce injuries induced in sports [30–32], enhance metabolism, increase muscle mass, and improve the recovery process [33–35]. The most important parameters which can influence the diet choices of athletes are economic factors such as income and cost; psychological parameters such as hedonic hunger, weight control, and body image; social parameters such as religion, culture, marketing, social facilitation, availability and meal patterns; lifestyle, beliefs and knowledge such as motives for participating in sport, nutrition knowledge, and health beliefs; physiological and biological factors such as allergic reaction, food intolerances, food allergies, gastrointestinal discomfort, food preferences, taste, hunger, resting metabolic rate, fat-free mass, macronutrient balance, hunger, and appetite [36–41]. This study aims to discover the role of plant-based micro- and macronutrients as well as natural components of medicinal plants and herbs and their importance in enhancing overall health and the energy of athletes.

Methods

The systematic review of documents and manuscripts from clinical trials, and scientific societies has been carried out. The surveys of interest were indexed in “PubMed”, “Web of Science”, “SciFinder”, and “Elsevier”. As a research strategy to carry out this review, two reviewers were responsible for searching the publications. Relevant literature has been obtained using the keywords “sportsmen”, “athletes”, “medicinal plants”, “traditional Chinese medicine”, “natural products”, “traditional Iranian medicine”, “sportspeople”, “sportswoman”, “physical fitness”, “physical performance”, and “physical activity”. The selection criterion was to include research papers on the most important topics, using in vitro or in vivo studies. Duplicate studies and those that do not fall with the scope of the search were excluded. The goal of this review article is a survey about research progress on rhizosphere microbial species and their impacts on increasing yield of various plants by considering sustainable agriculture.

Results and discussion

Sports nutrition

Natural products from plants and herbs have been used by many athletes instead of synthetic drugs. Functional parameters in sports foods have significant role in managing and regulating the physical characteristics of sportspeople [42], and nutritional ingredients of sports food consist of both functional factors and basic nutrients [43, 44], and sports food market includes semi-solid and solid sports food and sports drinks [45]. In sports nutrition, both understanding of genetic information, and personalized a nutritional regime are vital to be useful to maximize athletic performance, as nutrition metabolism, distribution, excretion, and absorption as well as tendon elasticity, lung and heart size, skeletal structure, and muscle strength are noticeable parameters [46–48]. In fact, it is believed that improvement and management of nutritional strategies can improve two parameters of athlete performance, namely cognitive endurance and resilience [49, 50]. It is also found that the nutritional components of foods of sportsmen can be usually categorized into two groups, namely functional factors and basic nutrients [51]. Important parameters in natural components should have some characteristics such as endurance, power and strength such as β -alanine, bicarbonate, caffeine, vitamin C, vitamin D, and vitamin B12, and creatine [52–57]. Both short- and long-term effects of herbal products, vitamins and minerals can cause digestive, cramps, muscular, headaches, inter alia, and lack of energy problems [58, 59]. Basic nutrients for the metabolites needed by the human body consist of lipid, carbohydrate, and protein [60–62]. For young athletes, providing enough nutrient and energy intake is essential for development and growth which should have balance with the increased nutrient and calorie demands of physical activity [63]. Main reasons for tiredness and fatigue and reduced performance are caused by micronutrient deficiency, elevated extracellular K^+ concentration, dehydration, phosphocreatine depletion in the muscle, glycogen depletion in the muscle, and muscle acidosis [64–70]. Nutrition plays an important role in the human lifecycle, which is why proper quantity and quality, and a healthy balanced diet can provide the athletes' body with the needed nutrients [71–73]. Herbal products are extract from leaves, roots, gums, seeds, berries, bark, and flowers which contain various types of phytochemicals such as polyphenols, carotenoids, lignans, saponins, glycosides, flavonoids, alkaloids, and phenolic acids [74–76]. The application of some of the natural supplements have positive effects on relief of muscular pain, improve heavy training, changes of the physical structure, recovery of exercise lesions, and enhance mood and energy [77–79]. Athletes need special nutrient needs on the basis of exercise frequency, duration, intensity, and environmental

and mode conditions, and providing adequate energy can maintain health, prevent injury and support exercise performance [80–83], so athletes encourage to consume medicinal plants and herbs to increase the extent of recovery between training sessions, and improve the effectiveness of the adaptations which may occur to improve the exercise performance [84–87].

Medicinal herbs and plants

Medicinal plants and herbs can increase fat metabolism, stimulate muscular growth, decrease oxidative stress, improve resistance and strength performance, maintain energy for a longer time, and improve muscular healing [88–90]. Gao et al. [91] found that application of lentils can offer low glycemic index (GI) carbohydrate options for endurance athletes, and both tart cherries and lentils have a very low GI. Medicinal plants such as *Ephedra sinica*, *Eurycoma longifolia* Jack, *Zingiber officinale*, *Arnica montana*, *Tribulus terrestris*, and *Panax ginseng* are found effective to improve physical performance [92–99]. In other researches, medicinal plants such as *Withania somnifera*, *Vitis vinifera*, *Tribulus terrestris*, *Schisandra chinensis*, *Rhodiola rosea*, and *Citrus aurantium* are recommended for sports nutrition and energy homeostasis [100–102]; the mentioned plants have been found appear to have mild impacts on exercise-related recovery and performance [103–106]. Top ten medicinal herbs which have been used by soccer athletes with distinguished function in modern sports nutrition in the West Bank of Palestine are mate, coffee, soy, fenugreek, green tea, chili pepper, date, olive, small nettle, and ginseng, and these medicinal herbs can provide testosterone-like effects, decrease joint and muscle pain and alleviate stress [107, 108]. Caffeine is an alkaloid which may be perceived to be ergogenic, which can present advantages on both anaerobic performance and endurance [109–113]. The application of caffeine can enhance performance at various exercise intensities levels, as well as humor and mental vigilance. It is reported that caffeine's ergogenic impact is because of its antioxidant characteristic with significant influence on free fatty acids. Various plants which contain caffeine are Mate (*Ilex paraguariensis*), green tea (*Camellia sinensis*), Kola nut (*Cola acuminata*), and coffee (*Coffea arabica*). Different species of ginseng are Korean ginseng, Asian ginseng, American ginseng, Chinese ginseng (*Panax ginseng*), and Siberian ginseng (*Eleutherococcus senticosus*) which contain different vitamins such as A, B, C, and E, fibers, minerals such as phosphorus, potassium, magnesium, and iron, saponins, proteins, etc., and its major active component is Ginsenosides, which can stabilize blood pressure, improve immune function, and decrease mental stress [114–118]. An important steroidal saponin component in Siberian ginseng is *Eleutherosides* [114], as well as

polysaccharides and phenolics [116]. It is reported that a small percentage of root extract or root powder with standardized *Ginsenoside* content induce higher improvement in anaerobic performance as well as cognitive activity in untrained older and young subjects [117, 118]. The extract of different parts of pomegranates can be used for menorrhagia, colic, colitis, headache, oxyuriasis, acne, diuretic, allergic dermatitis, piles, leprosy, oral diseases, diabetes and burns [119]. Bioactive components such as steroids, alkaloids, flavonoids, saponins, and terpenoids as well as curcumin, allicin, capsaicin and artemisinin have been found suitable for sportsmen [120–125]. Ginseng has been shown to cause headaches, insomnia, diarrhea, blood pressure fluctuations, rapid heartbeat, and can cause digestive disorders, as well as side effects in women such as breast tenderness, and vaginal bleeding [126–128]. Application of green tea extracts can improve the antioxidant defense system, enhance, endurance capacity, and improve muscle lipid oxidation in healthy or diabetic individuals [129], moreover, it can also improve epinephrine and plasma glycerol levels [130, 131]. It is also reported that Cocoa and Chocolate are main sources of alkaloid which have beneficial effects for athletes [133–134]. It is found that the influence of 150mg curcumin can significantly increase eccentric squat exercise in healthy young males [135]. The main ingredient of *Ginkgo biloba* are terpenoids and flavonoids, which can improve cerebral blood circulation in athletes [136, 137]. It can also increase endurance performance in patients with peripheral arterial diseases [138]. Short application of *Arnica* (*Arnica montana*) can increase muscle strength and reduce pain in patients with osteoarthritis of the knee [139], as well as decrease cell damage and muscle soreness after marathon in professional athletes [140, 141]. The 8-week application of *Astragalus* can increase aerobic performance in runners [142–144], and both *Astragalus* and ginseng can decrease cholesterol levels and enhance self-reported levels of energy [145, 146]. In another experiment, it is reported that short period of application of willow bark can reduce joint pain in patients with osteoarthritis [147], as white willow (*Salix alba*) contains salicin which can be used to treat aches, osteoarthritis, inflammation, pain, and decrease fever [148]. Oral application of 120 mg or 240 mg salicin for 4-week can decrease back pain in patient with low back pain [149], as in the sport, its chemical components can be used for treatment of joint-related conditions and musculoskeletal [150]. Medicinal plants such as *Citrus aurantium* and *Lignosus rhinocerotis* can be used alone or together to increase performance of young athletes [151, 152]. 4-week supplementation of saffron can decrease tumor necrosis factor alpha (TNF- α), lactate dehydrogenase (LDH), and creatine kinase (CK) in sedentary women [153, 154]. Fenugreek has

around 32 chemical components such as phenolic acid and flavonoid glycosides as well as saponins, vitamins, coumarins, and alkaloids, and its application may have beneficial impacts on serum creatinine, free testosterone, body fat, and other organs with minimum side effects [155, 156]. Myrtle fruits have high antioxidant activity with noticeable phenolic content as well as high levels of linoleic acid, and varied and low proportions of saturated acids [157, 158]. In one trial, 4 weeks application of myrtle fruit at 3.4 mg/kg/day can increase serum protein, anaerobic performances, and iron content, and decrease triglycerides in trained athletes [159–161]. The prevalence of athletes' application of supplements changes from 40 to 70% [162, 163] (Garthe and Maughan 2018; Garthe and Rambsbottom 2020). In sports, supplementation of American ginseng can reduce fatigue and improve the intensity of exercise [164–167]. Williams [168] (2006) reported that *Tribulus terrestris*, *Gamma oryzanol*, *St. Johns wort.*, Ginkgo biloba, Ginseng, and different species of Capsicum are marked as ergogenic aids for athletes, however, more studies are needed for careful attention to analyze product purity, experimental designs, subject compliance, standardized dosages, and statistical power. *Tribulus terrestris* L. which is an annual herb plant which has been used in traditional folk medicines as palliative, aphrodisiac, tonic, antihypertensive, stomachic, astringent, lithotriptic, and diuretic [169, 170], and it is very popular in sport in modern days which can significantly increase testosterone, improves higher gains in muscle mass and strength [171]. Chun et al. [172] found that the extract of *Phlomis umbrosa* and *Dipsacus asperoides* in the Korean medicine can be used for treatment of arthritis- and bone-related diseases, inhibited the production of serum cytokines, and reduced the histopathological characteristics of osteoarthritis knee tissue. Esmaili et al. [173] showed that supplementation of green tea and

8 weeks of aerobic training can increase LDL, HDL, and BMI of the athletes. Wang et al. [174] showed that secondary metabolites and substantial plant extracts show a positive impact in fighting knee osteoarthritis, and the main signaling pathway influenced by the isolated components and extracts are SIRT, AMPK, MAPKs, NLRP3, mTOR, PI3K/AKT, WNT/ β -catenin, NF- κ B, NRF2, and JAK/STAT3 as well as the cell death modes apoptosis, ferroptosis, pyroptosis, and autophagy. The most noticeable functions and benefits of application of ginseng in sports are presented in Table 1.

Iranian medicinal plants and herbs which commonly used in sports performance are jujube (*Ziziphus jujuba*), sage (*Salvia officinalis*), saffron (*Crocus sativus*), Chamomile (*Matricaria chamomilla*), and Ginkgo Biloba [182]. Jujube has capability to increase endurance and energy levels, supports muscle function, increases endurance and energy levels, improve bone health, enhance energy production and decreases inflammation; sage is famous because of its anti-inflammatory and antioxidant activities, decreases post-exercise soreness, increases muscle recovery, aids in wound healing, and boosts oxygen delivery to muscles and blood circulation; saffron contain adaptogenic properties and high antioxidant activity, helps athletes cope with stress, protects cells from damage, increases alertness, and enhances cognitive function; chamomile can aids in muscle recovery, increases relaxation and deep rest; increase overall performance and recovery, and decreases inflammation; Ginkgo biloba is also rich in antioxidants, increases blood flow to the brain, enhances cognitive focus and function, and improves overall performance [182–184]. Many scholars reported the beneficial effects of ginger and its sub-components in mechanical pain, spontaneous pain, and thermal pain due to containing [6]-shogaol and [6]-gingerol [185–189]. The ingestion of caffeine in the form of

Table 1 The importance of application of ginseng in sports

Dose and Period	Key-points	References
Application of 1 g/day Siberian ginseng, Chinese ginseng and placebo for 6 weeks	It can enhance quadriceps strength and maximal oxygen uptake	[175]
Usage of 200 mg/day of standardized ginseng extract (4% or 7% ginsenoside content) for 9 weeks	It can increase aerobic capacity and reduce heart rate and lactate production	[176]
Application of 400 mg/day ginseng extract for 20 weeks	It can enhance running time	[177]
Application of 6 g extract of ginseng for 8 weeks	It can increase physical performance and cardio respiratory function, and decrease lactate	[178]
Application of 1.35 mg/day ginseng	It can increase endurance running time	[179]
Utilization of 0.1 mg of Eurycoma per 100 ml of drink or placebo drink during exercise	It can improve cycling endurance performance	[180]
Application of 150 mg of Eurycoma for 5 weeks	It can improve muscle strength	[181]
2 capsules per day which contain 75 mg of Eurycoma for 7 days before exercise trial	It can increase running distance, and physiological responses	[181]
Application of 200 mg of ginseng one hour before the exercise test	It can increase endurance running time	[117]
Application of 200 and 400 mg/day ginseng for 8 weeks	It can increase maximal and submaximal exercise performance	[115]

coffee or anhydrous caffeine has commonly been shown to increase performance in time to exhaustion exercises performed at submaximal intensities, although, caffeine-containing energy drinks can improve muscular strength, endurance exercise, endurance activities, and sport-specific actions [190–192], and the factors which may influence its effectiveness are dosage, abstinence period, administration and training status of athletes [193–196]. Stankiewicz et al. [197] found that application of a lyophilized black chokeberry extract which contains high antioxidant activity, can increase the serum TAC and IL-10 levels and reduce IL-6 levels during the recovery period after maximal aerobic testing, which proved its high value to enrich the dietary patterns for athletes. It can also reduce post-exercise inflammation because of its high antioxidant activity [198–202]. Although variation in economic status, religion, race, culture, and type of sport can lead to changes in nutritional practices, inadequate nutrients may lead to additional health problems and poor athletic performance [203–205]. One technique to enhance the dietary practices of athletes is to increase their sports nutritional knowledge as the key factor [206], and a well-chosen diet of medicinal plants and herbs is important for increasing sport performance and increasing the beneficial training adaptations [207]. Although, many researches have shown the importance of nitrates on various aspects of physical performance [208], some researches have shown that nitrate supplementation is less effectual in well-trained individuals, as athletes have a maximal oxygen uptake (VO₂max) less than 65 mL/kg/min [209–211]. In fruits such as blueberries, raspberries and strawberries, in citrus fruits such as lemons, grapefruits and oranges, and cherries, pears, and apples, it is possible to find different antioxidants such as flavonoid, quercetin, vitamin C, and anthocyanins; in vegetables such as carrots, tomatoes, bell peppers, cauliflower, broccoli, Swiss chard, kale and spinach, there are plenty of Beta-carotene, lycopene, vitamin A, vitamin C, Indoles, sulforaphane, glucosinolates, vitamin E, zeaxanthin, lutein, polyphenols, and quercetin; there are also vitamin E, selenium, polyphenols, omega-3 fatty acids, and vitamin E in pumpkin seeds, sunflower seeds, flaxseeds, chia seeds, walnuts, and almonds [212, 213]; isoflavones, coenzyme Q10, resveratrol, and flavonoids are available in kidney beans, pinto beans, black beans, lentils, and chickpeas [214, 215]; Beta-glucans, ferulic acid, polyphenols, selenium, and vitamin E can be found in whole wheat, barley, oats, brown rice, and quinoa [216, 217]. It is possible to provide protein from legumes [218, 219], omega-3 fatty acids from walnuts, chia seeds, and flaxseeds [220, 221], iron from pumpkin seeds, spinach, chickpeas, and lentils [222, 223], calcium from bok choy and kale [224, 225], zinc from cashews, pumpkin seeds, chickpeas, and lentils [226], vitamin D

from fortified orange juice [227, 228], fiber from legumes, seeds, nuts, whole grains, vegetables, and fruits [229, 230], antioxidants from seeds, nuts, and berries [231, 232], and carbohydrates from fruits, sweet potatoes, and whole grains [233, 234]. It is reported that supplements such as beetroot juice, β -hydroxy- β -methylbutyric acid (HMB), caffeine, and β -alanine are the best nutritional strategies to optimize recovery and performance in rowing athletes [235]. Pedro et al. [236] reported high levels of antioxidant, vitamin C, and total polyphenols in goji berries from organic production. It is reported that coffee beans have high total phenolic acids, flavonoids, and quercetin-3-O-glucoside [237], raspberries are rich in total polyphenols, anthocyanins and flavonoids [238], butternut squash contain high β -carotene, folic acid and tocopherol [239], apples contain high flavonols and phenolic acids [240] sweet bell pepper has high carotenoids, polyphenols and vitamin C [241] which have positive influence on performance of athletes. Some of the most important phytochemicals which are suitable for athletes are anthocyanin in *Aristotelia chilensis*, ascorbic acid in *Rosa pendulina* L., caffeine in *Ilex guayusa* Loes., Niazirin in *Moringa oleifera* Lam., proanthocyanidins in *Vitis vinifera* L., Phenolic acids and saponins in *Androsace umbellata*, 1,8-Cineole in *Salvia officinalis* L., Bacoside A in *Bacopa monniera* L., Bethulic acid in *Centella asiatica* L., Borneol in *Salvia officinalis* L., Camphor in *Salvia officinalis* L., Caryophyllene in *Salvia officinalis* L., Madecassic acid in *Centella asiatica* L., and Picroside II in *Picrorhiza scrophulariiflora* Pennell. [242–244]. It is also reported that Kiwifruit and protein interventions can increase both sleep quantity and quality, and tart cherry juice can improve sleep quantity which shows the importance of medicinal plants and natural components to improve both sleep quantity and quality [245]. Jan et al. [246] also reported that quinoa and amaranth are small-seeded grain with notable phytochemical and nutritional components which can offer protection against cardiovascular, cancer, diabetes, and hypertension disorders, which also possess considerable nutritional benefits due to their abundance of fiber, proteins, minerals, and vitamins with positive effects on health and activities of athletes. It is also reported that diets on the basis of medicinal plants have roles in cardiovascular health with high importance in increase of endurance of athletes though improve blood pressure, lipid concentration, blood glucose, and body weight, and the medicinal plants have also been found essential to decrease indicators of inflammation [247]. One of the most important medicinal plants in traditional Chinese and Indian medicine is *Tribulus terrestris* L. which has been proved to modulate and counteract specific physiological biomarkers out of the normal range by stressful and intense physical exercise [248]. Practical applications of medicinal

Table 2 Practical applications of medicinal plants and herbs for athletes

Practical points	Key-points	Reference
Incorporating medicinal plants into athletes' diets	It is important to develop a strategy to use plant-based foods into their meals.	[249–252]
	It should be focused on high nutritional content and apply protein sources from natural components to the diets.	
	Protein sources such as tofu, beans, and lentils are strongly recommended to the diets of athletes.	[251]
Developing antioxidant-rich natural components for recovery and training	Natural components which are rich in carbohydrate should be used to increase endurance athletes.	[79, 253]
	The balanced consumption of proteins and carbs with components high in antioxidant activities are recommended.	[254–256]
	Fruits which are rich in vitamin C like kiwi and citrus fruits can reduce oxidative stress.	
Fruits	Consumption of vegetables such as tomatoes and bell peppers which are high in antioxidant activity are recommended.	[257, 258]
Vegetables	Berries, citrus fruits, pears, apples, mangoes, pineapple, and pomegranate are rich in vitamin C, anthocyanins, flavonoids which can be used to protect against muscle damage, enhance immunity and decrease inflammation.	[259]
Legumes	Leafy greens, cruciferous vegetables, tomatoes, onions, carrots, sweet potatoes, and bell peppers are rich in vitamin C, carotenoids, and several phytonutrients which can enhance antioxidant defenses, improve cell health, and support recovery.	[260–265]
Seeds and nuts	Soybeans, kidney beans, chickpeas, black beans, and lentils which have high fiber and protein which can enhance muscle building.	[266]
Spices and herbs	Hemp seeds, flaxseeds, chia seeds, almonds, and walnuts which are high in vitamin E, fats, and minerals which can enhance cell health, and provide sustained energy.	[267, 268]
	Oregano, rosemary, parsley, cinnamon, garlic, ginger, and turmeric which contain noticeable anti-inflammatory and antioxidants activities which can boost digestion, increase flavor, and provide additional health advantages.	[269–271]

herbs and plants for athletes are shown in Table 2. List of phytochemical classes along with representative molecules in medicinal herbs and plants are shown in Table 3. The most noticeable characteristics of different medicinal plants and herbs for sportsmen are presented in Table 4.

Conclusion

Like all other populations, athletes can get much benefits from herbal products and natural supplements in an organic life from amateurs to elite groups to increase fat burning and improve muscle growth, and proper nutrition is appropriate for the health and well-being of athletes with important effects on performance, muscle repair, recovery and provide enough energy for physical

exertion. Dietary supplements with medicinal plants and natural components have significant ability to cover the specific nutritional necessities of physically active populations which may change according to the time of the season, age, external environment, physical condition, duration and intensity of exercise. Although, supplementation of medicinal plants and herbs have many positive benefits, their usage should be with precaution due to possible harmful side impacts on different organs such as stomach and kidney. This article can help athletes to understand the importance of integration of medicinal plants, and natural products into their sports nutrition to prevent injury, rehabilitation, and improve athletic performance.

Table 3 List of phytochemical classes together with representative molecules in medicinal plants and herbs

Phytochemical class	Sub-Class	Representative compounds	Chemical formulae
Carotenoids	Carotenes	Phytofluene	C ₄₀ H ₆₂
		Phytoene	C ₄₀ H ₆₄
		Lycopene	C ₄₀ H ₅₆
		Beta-carotene	C ₄₀ H ₅₆
		Alpha-carotene	C ₄₀ H ₅₆
	Xanthophylls	Violaxanthin	C ₄₀ H ₅₆ O ₄
		Rubixanthin	C ₄₀ H ₅₆ O
		Fucoxanthin	C ₄₂ H ₅₈ O ₆
		Astaxanthin	C ₄₀ H ₅₂ O ₄
		β-cryptoxanthin	C ₄₀ H ₅₆ O
		Zeaxanthin	C ₄₀ H ₅₆ O ₂
		Antheraxanthin	C ₄₀ H ₅₆ O ₃
		Canthaxanthin	C ₄₀ H ₅₂ O ₂
		Lutein	C ₄₀ H ₅₆ O ₂
Vitamins	Tocopherols	Alpha-tocopherol	C ₂₉ H ₅₀ O ₂
		Beta-tocopherol	C ₂₈ H ₄₈ O ₂
		Gama-tocopherol	C ₂₈ H ₄₈ O ₂
		Delta-tocopherol	C ₂₇ H ₄₆ O ₂
	Ascorbic acid		C ₆ H ₈ O ₆
Polyphenols	Tocotrienols	Alpha-tocotrienol	C ₂₉ H ₄₄ O ₂
	Flavonoids	Malvidin	C ₁₇ H ₁₅ O ₇ +
		Petunidin	C ₁₆ H ₁₃ O ₇ +
		Peonidin	C ₁₆ H ₁₃ O ₆ +
		Delphinidin	C ₁₅ H ₁₁ ClO ₇
		Cyanidin	C ₁₅ H ₁₁ O ₆ +
		Pelargonidin	C ₁₅ H ₁₁ O ₅ +
		Eriodicytol	C ₁₅ H ₁₂ O ₆
		Hesperetin	C ₁₆ H ₁₄ O ₆
		Hesperidin	C ₂₈ H ₃₄ O ₁₅
		Naringin	C ₁₅ H ₁₀ O ₅
		Naringenin	C ₂₁ H ₂₀ O ₉
		Daidzin	C ₁₅ H ₁₂ O ₅
		Genistein	C ₂₇ H ₃₂ O ₁₄
		Daidzein	C ₁₅ H ₁₀ O ₄
		Epigallocatechin gallate	C ₂₂ H ₁₈ O ₁₁
		Epigallocatechin	C ₁₅ H ₁₄ O ₇
		Gallocatechin	C ₁₅ H ₁₄ O ₇
		Epicatechin gallate	C ₂₂ H ₁₈ O ₁₀
		Epicatechin	C ₁₅ H ₁₄ O ₆
		Catechin	C ₁₅ H ₁₄ O ₆
		Baicalin	C ₂₁ H ₁₈ O ₁₁
		Chrysin	C ₁₅ H ₁₀ O ₄
		Galangin	C ₁₅ H ₁₀ O ₅
		Tangeretin	C ₂₀ H ₂₀ O ₇
		Nobiletin	C ₂₁ H ₂₂ O ₈
		Isosinensetin	C ₂₀ H ₂₀ O ₇
		Sinensetin	C ₂₀ H ₂₀ O ₇
		Apigenin	C ₁₅ H ₁₀ O ₅
		Luteolin	C ₁₅ H ₁₀ O ₆
		Myricetin	C ₁₅ H ₁₀ O ₈
		Isorhamnetin	C ₁₆ H ₁₂ O ₇
		Quercetin	C ₁₅ H ₁₀ O ₇
		Kaempferol	C ₁₅ H ₁₀ O ₆

Table 3 (continued)

Phytochemical class	Sub-Class	Representative compounds	Chemical formulae
Polyphenols	Stilbenes	Fisetin	C ₁₅ H ₁₀ O ₆
		Isorhapontigenin	C ₁₅ H ₁₄ O ₄
		Rhapontigenin	C ₁₅ H ₁₄ O ₄
		Pterostilbene	C ₁₆ H ₁₆ O ₃
		Piceatannol	C ₁₄ H ₁₂ O ₄
		Pinosylvin	C ₁₄ H ₁₂ O ₂
		Resveratrol	C ₁₄ H ₁₂ O ₃
		Phenolic acid	C ₇ H ₆ O ₃
		Protocatechuic acid	C ₇ H ₆ O ₄
		Hydroxybenzoic acid	C ₇ H ₆ O ₃
		Coumaric acid	C ₉ H ₆ O ₂
		Gentisic acid	C ₇ H ₆ O ₄
		Vanillic acid	C ₈ H ₈ O ₄
		Syringic acid	C ₉ H ₁₀ O ₅
		Gallic acid	C ₇ H ₆ O ₅
Phytosterols		Stigmastanol	C ₂₈ H ₅₀ O
		Campestanol	C ₂₈ H ₅₀ O
		Stigmasterol	C ₂₉ H ₄₈ O
		Sitosterol	C ₂₉ H ₅₀ O
		Campesterol	C ₂₈ H ₄₈ O

Table 4 The important of different medicinal herbs and plants for athletes

Plants	Plant Family	Key points	Reference
Bitter orange (<i>Citrus aurantium</i> L.)	Rutaceae	Its fruits contain coumarins such as bergapten and umbelliferone, and flavonoids such as naringenin and hesperidin. It has antioxidant, antimicrobial, anti-cancer, anti-diabetic, anti-obesity, and anxiolytic activity. It has been considered as the recognized anti-obese agent which can manage thermogenesis and adipogenesis via AMP-activated protein kinase alpha (AMPKα).	[272–277] [278, 279] [280]
Bittu bark, Malaysian ginseng (<i>Eurycoma longifolia</i> Jack)	Simaroubaceae	The most important pharmacological benefits of <i>Eurycoma longifolia</i> are anticancer, antimalarial, anti-inflammation, anti-hyperglycaemic, anti-osteoporosis, aphrodisiac, and antiadipogenic activities. It can act as a testosterone booster in males, enhance the libido, and consider as energy boosting and aphrodisiac properties.	[281–284] [285–290]
Ginger (<i>Zingiber officinale</i> Roscoe)	Zingiberaceae	It can be used as a potential alternative treatment to enhance the serum values of testosterone. Consumption of ginger can cause weight loss, and active anorexic hormones in females.	[291–293] [294–296]
		Ginger application can decrease symptoms of menstruation and pain. It is reported that application of 4 g of ginger can increase muscle strength and recovery as well as positively improve intense exercise on muscle damage.	[297] [298]
Ginseng (<i>Panax ginseng</i>)	Araliaceae	It can help to increase energy both emotionally and physically. It can induce catabolic process in the different organisms and help muscle renewal and regeneration. Ginseng can noticeably enhance physical work capacity due to its ginsenosides content. It is found that anti-fatigue characteristic of mountain cultivated ginseng is very high because of its acidic polysaccharides which can reduce the accumulation of malondialdehyde, blood urea nitrogen, blood lactate, and increase creatine kinase, blood urea nitrogen, and catalase, as well as prolonged fatigue tolerance time.	[299, 300] [301–303] [304] [305]
		The positive impact of ginseng application on diastolic and systolic blood pressure as well as heart rate is reported.	[306–308]
Golden root (<i>Rhodiola rosea</i>)	Crassulaceae	Its rhizomes and roots are essential part of folk medicines of China, Mongolia, Scandinavia, and Russia.	[309, 310]

Table 4 (continued)

Plants	Plant Family	Key points	Reference
Indian ginseng (<i>Withania somnifera</i>)	Solanaceae	Its phenylpropanoids components are rosarin, rosin, and rosavin; the phenylethanoid derivatives are tyrosol and salidroside; its flavonoids are tricetin, rhodalin, rhodiosin, rhodionin, rhodionidin, and rhodiol; monoterpene derivatives such as rhodiolsides A-E, rosiridin, and rosiridol; Triterpenes such as beta-sitosterol and daucosterol; Phenolic acids such as gallic acid, hydroxycinnamic acid, and chlorogenic acid.	[311–319]
		It can reduce stress, help with fatigue, decrease the symptoms of depression, improve brain function, increase exercise performance, manage diabetes, with anti-cancer activities.	[320–323]
		Its extract can enhance the tolerance and threshold of mechanical pain in young.	[324–326]
		It can significantly improve inflammation and intestinal barrier of <i>Lateolabrax maculatus</i> juveniles.	[327]
		Its extract can improve sleep quality, enhance sleep efficiency, and reduce fatigue severity scale.	[328]
		Its caffeine can ameliorate the physical performance safely and effectively.	[329]
		Its extract has shown high anti-fatigue effects which can also reduce cortisol response, with high ability to increase concentrate.	[330–332]
		It can enhance the permeability of the blood-brain barrier to precursors of serotonin and dopamine which can lead to increase the impacts of neurotransmitters on the brain.	[333, 334]
		Its herbal preparations can treat mild-to-moderate depression and anxiety, and reduce the signs of depression, fatigue, and daily stress.	[335, 336]
		Many studies report that its application and increase resistance and endurance in rapid muscle recovery.	[337–339]
Ma Huang, Yellow Horse, Sea Grape (<i>Ephedra sinica</i>)	Ephedraceae	It can also activate the synthesis of ATP in mitochondria and promoted energy processes after intense exercise.	[340–342]
		Its rhizome contains rosavin which can decrease interleukin, pro-osteoporotic matrix metalloproteinase 3, tumor necrosis factor α , and enhanced anti-osteoporotic interleukin 10, and tissue inhibitor of metalloproteinase 3.	[343, 344]
		Its application can decrease the parameters and lactate levels of skeletal muscle damage as well as increase the adaptogen ability to physical exercise.	[345]
Puncture vine (<i>Tribulus terrestris</i>)	Zygophyllaceae	It contains alkaloids and steroidal lactones, which is traditionally applied for general recovery and strengthening.	[346–348]
		Its supplementation can noticeably enhance muscle strength and mass, and it can be useful in conjunction with a resistance training program.	[349]
		Not just for females, but also for males, its application can improve recovery, and enhance strength.	[350]
		In traditional medicine, it always uses to treat fever, coughs, and asthma with high anti-obesity, anti-inflammatory, and antioxidant activity.	[351–357]
Schisandra (<i>Schisandra chinensis</i>)	Schisandraceae	It is effective in losing weight, increase the resting metabolic rate, and inhibit lipid accumulation. The impacts of combining caffeine and ephedrine are synergistic.	[358–361]
		Ephedrine has considerable role in reducing weight.	[361]
		Its main chemical components are carbohydrates, protein, vitamins, tribuloside, kaempferol-3-rutinoside, kaempferol-3-glucoside, kaempferol, alkaloids, flavonoids, and saponins.	[362–366]
		It has special ergogenic impacts of sports performance.	[367, 368]
		It can increase skeletal muscle hypertrophy.	[369, 370]
		It can promote muscle anabolism, and important testosterone booster.	[371]
		It is also effective in post-exercise recovery, attenuate oxidative and muscle damage.	[372, 373]
		It has effective roles in muscle growth.	[374–377]
		As a unique aroma, it contains high tannin with antioxidant and anti-inflammatory activities.	[378]
		Its application can improve muscle strength in adult females.	[379]
		It is important to treat and prevent obesity-induced muscle atrophy.	[380]
		Its application can increase skeletal muscle strength, and improve exercise time.	[381–384]

Table 4 (continued)

Plants	Plant Family	Key points	Reference
Wolfs Bane, Mountain To- bacco, Moun- tain Arnica (<i>Arnica montana</i>)	Asteraceae	It has shown anti-inflammatory and antioxidant activity. It has different pharmacological benefits such as muscle aches, bruises sprains, superficial phlebitis, wound healing, joint pain, and appropriate for swelling from broken bones. It is appropriate for both arthritis and muscle pain, and it displayed high effectiveness in decrease of pain scores.	[385, 386] [387–396] [397–401]

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